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Modernization of Agricultural Statistics in Support of the Sustainable Development Agenda

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FOREWORD

The adoption of the Global Indicator Framework for assessing progress towards the 169 targets of the 2030 Agenda for Sustainable Development has been a watershed for the global statistical system. Monitoring the SDG indicators will be a very demanding task for all countries in the world. Not only they are about four times more numerous than the MDG indicators, but data will also have to be made available for various vulnerable population groups to reflect the guiding principle of "leaving no one behind".

Agriculture is at the heart of the 2030 Agenda. Modernizing agricultural statistics is thus crucial for enabling countries to rise to the challenge of monitoring the SDGs with timely, relevant and accurate data. In response to this need, the Italian National Institute of Statistics (Istat), in close collaboration with the Food and Agriculture Organization of the United Nations (FAO), organized the Seventh International Conference on Agricultural Statistics – ICAS VII, under the overarching theme "Modernization of Agriculture Statistics in Support of the Sustainable Development Agenda".

The Conference, held in Rome on 26-28 October 2016, convened 428 experts from around the world to discuss cutting-edge methodologies and best practices in the field of agricultural statistics for monitoring the 2030 Agenda. A significant part of the programme has been dedicated to the utilization of new data sources and innovative methods to support the production of cost-effective and high-quality agricultural statistics. At the same time, the interaction between analytical research and agricultural statistics has been one of the highlights of the Conference, together with a strong focus on the use of data for evidence-based decision making. The papers presented at the 48 parallel sessions and the four plenaries, as well as the posters, collected in this online editorial format, are meant to foster the methodological and analytical debate on the critical issues and opportunities that agricultural statistics face in the 21st century.

We are grateful to all session organisers and authors for the contribution they provided to the success of the Conference. Our sincere esteem also goes to all the members of the Scientific Programme Committee who have helped develop such a thought-provoking Conference agenda, and to all the sponsoring agencies who generously supported a large number of participants from developing countries.

The joint organization of ICAS VII has to be seen as yet another testimony of the long-standing and strong collaboration between FAO and Istat, which has allowed over the years a fruitful exchange of knowledge and expertise in support of the advancement of agricultural statistics at the international level.

G. Alleva | President | Istat | Rome | Italy

P. Gennari | Chief Statistician | Food and Agriculture Organization of the United Nations (FAO) | Rome | Italy

MODERNIZATION OF AGRICULTURAL STATISTICS TO RESPOND TO NEW MULTIDIMENSIONAL DEMANDS

Session Organizer and Presenter
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ABSTRACT

Institutes of Statistics, National Institutions and International Organizations are committed to modernizing statistics worldwide. This commitment should include also agricultural statistics, which plays a key role in the analysis of human development, as widely acknowledged, for example in the Millennium Development Goals.

Modernization means changing, renewing, in order to better achievequality and relevance of statistical informationas well as efficiency in the production of such information. Modernizing implies lower costs, with a great opportunity, especially for developing countries.New technologies and statistical methods can enable to gain of efficiency, reducing time needed to improve and to fill the gaps.

Primarily, the exploitation of administrative sources provides a tremendous opportunity to reduce data collection costs, and therefore helping the modernization ofdeveloping countries and facilitating reducing differences between countries. The use of new technologies, new methods and the exploitation of existing databases can be favored by the action of international organizations.

Thus, the main areas of intervention of modernization processes are: joint exploitation and integration of data from different sources (e.g. administrative data vs survey data, master sampling frames, big data etc.), new data collection techniques, new technological improvements (e.g. GPS and remote sensing) and the production of new indicators in response to the growing demand by policy-makers and decision makers for statistics based oninformation that is interlinked in economic, social, and environmental aspects (e.g. indicatorsfor gender/youth-related data, rural statistics,agro-environment data, better integration of geographic information and statistics).

In addition to the above areas, organizational and human resource management issues are equally important. In particular , investing in the development of human capital will be crucial for the modernization of agricultural statistics as well as for the development in general .

To show the main and most challenging opportunities and advantages of the modernization of agricultural and rural statistics, discussing the key success factors of this process are the objectives of the session.

PAPER

Mr Gennari, distinguished guests, colleagues, good morning. It is indeed a great pleasure to welcome every one of you to the ICAS VII International Conference on Agricultural Statistics.

This seventh edition -- that we, as Istat, the Italian National Institute of Statistics, have had the honour to organise in collaboration with the Food and Agriculture Organization -- is intended to offer you the ideal forum to share views and ideas on the changing needs and new opportunities for agricultural statistics, both in terms of needs for information and methodological tools.

The next three days provide a very full agenda with a rich programme of sessions and side events. The conference has as its foundation 4 Plenary sessions, with 48 Parallel sessions focusing on: 5 sets of themes, 3 multi-disciplinary themes and one poster session. More than 200 presentations are scheduled, with over 600 contributors and almost 500 registered participants from some 80 countries around the world.

Today, I wish to discuss the modernisation of statistical systems, and of agricultural statistics in particular, which I believe is essential in order to be able to address the increasing complexities of the compelling need for information.

Of course, we are no longer at the starting gate of this race for information. A significant wealth of information at the global level has already been made available. Moving forward from this as a baseline, I would like to showcase just a few relevant and multidimensional milestones which also indicate directions for the future of world agriculture.

PL01

The need for information is still growing very quickly. World statistical capacity is growing too, and with the agreement that has been reached on the Sustainable Development Goals (SDGs), data producers are being asked to accelerate their production to new levels. The SDGs represent a challenging opportunity to strengthen the institutional statistical framework, to support governments' decisions, to enhance capacity, foster co-operation, share experiences and reduce inequalities. Actually, as we will see, agriculture statistics play a central role in the 2030 Agenda for Sustainable Development.

I will briefly review the coordinated efforts of agricultural statisticians in the building and achievement of a coherent global system of agriculture statistics based on high quality data.

Finally, starting from the existing toolbox that countries may use to produce high quality data, I will stress some key elements in the process of modernization of statistical systems as a strategy for the integration of sources, technologies, methodologies and competencies, a strategy which, I believe, is also highly relevant for agricultural statistics.

Agriculture lies at the very centre of a number of interconnections between humanity, its odds of survival, living conditions and the planet. It is no wonder, then, that the demand for statistical data related to the primary sector is increasing.

As it has been for thousands of years in the past, agriculture today is the basis of human food production. The perspectives for world population represent a huge challenge: the population of the world is expected to surpass 9 billion people by 2050, and feeding 2 more billion people represents the major goal for world agriculture. We need to address this challenge, which is all the more serious because the increase in population will occur entirely within urban areas.

Today, one person out of nine still experiences chronic hunger. The percentage of the undernourished population has gone from a level of 19 to 11 percent, nearly fulfilling the Millennium Development Goal target to "halve, between 1990 and 2015, the proportion of people who suffer from hunger". However, this situation is still far from satisfactory, particularly in those 30 countries where hunger affects over 20% of the population.

At the dawn of the third millennium, almost 2.6 billion people still base their subsistence on the pursuit of agriculture, forestry, fishery or hunting activities. The economic weight of the agricultural sector has experienced a long term decline, even if it recovered part of its original share of global GDP in the last decade, and today it represents about 4.3% of total GDP. One fifth of the employed population in the world is engaged in the agriculture sector.

Meanwhile, thanks mainly to a continuous rise in productivity, agricultural production has progressively increased, supplying more and more food to the world population (sessions B7 and B8 will be dedicated to agriculture productivity). At the same time, food deficit (a basic measure of access to food) has decreased considerably since the Nineties all over the world. Of course, food availability does not always guarantee high food security, which is also determined by income, food prices, infrastructures and social support. Many African countries still register a daily per capita food deficit index well over 100 kilocalories.

As for what concerns environmental issues, agriculture plays a positive role in capturing carbon, managing watersheds, preserving biodiversity and landscapes, and providing feed stock for biofuel production. At the same time, in most countries, agriculture is the largest user of water, a big producer of chemical pollution and soil degradation and a contributor to climate change. The Intergovernmental Panel on Climate Change estimated that agriculture accounted for one fourth of global greenhouse gas emissions in 2010, mostly with crop cultivation, the raising of livestock and deforestation. The trend is not encouraging. Agriculture greenhouse gas emissions have grown by 15% since 1990, even if they rose less than emissions from other human activities. In the same period, the production of livestock grew by 72% and 3% of forests disappeared. According to FAO's 2016 SOFIA Report, the status of fish stock is also of great concern, despite certain improvements in the recent past.

Well, some of these key facts and figures in agriculture I just presented are probably well-known to most of you, and this is only a minor portion of the data you can find on FAOStat and in other international data-warehouses. However, let me say that if we are able to draw accurate pictures of world agriculture, it is thanks to producers of agricultural statistics, to FAO, to National Statistical Offices, researchers, it is thanks to you.

Nevertheless we cannot consider ourselves satisfied, ever: very basic information. such as, for example, the exact number of farmers, is still unknown. A long road is still ahead of us and important challenges need to be met.

First of all, a huge new need for information is represented by the Sustainable Development Goals and the set of indicators associated with them. Agriculture is by nature a crucial determinant of any sustainable development strategy. Each one of the 17 Sustainable Development Goals somehow relates to agriculture, and agriculture can be considered as a common thread that binds all of the 17 SDGs together.

For some of the goals, the relationship is direct and self-evident, such as for the 'zero hunger goal (2)', 'life on land (15)' and 'fishery (14)'. We have to consider that the rural population represents the largest majority of the world's poor (1) and agriculture is a massive (substantial) source of employment and a fundamental economic sector (8). Infrastructures (9) will definitely alleviate poverty, facilitate access to food and water, but also generate employment and reduce poverty in rural areas, thus reducing overall inequalities (10) and limiting the creation of slum dwelling (11). The enhancement of a sustainable consumption and production model (12) forecasts a sharp decrease in food wasted.

Food systems consume about a third of the world's available energy and agriculture contributes to the production of energy crops (7), effects healthy environments and produces emissions (13). Crops and livestock account for about 70 percent of all water withdrawal, and agriculture is also a significant water polluter, therefore playing a central role in the clean water goal (6).

In some cases, the relationship between agriculture and SDGs is less immediate, but still strong and persistent. Since the demand of water and wetlands is at the heart of many conflicts, an increase of efficiency and sustainability in agriculture might be considered as a tool to promote peaceful and inclusive societies (16). Over half of the food in the world is produced by women, but difficulties in access to resources makes them less productive than their male counterparts, feeding gender inequality (5). Moreover, child agriculture workers represent nearly 60 percent of child labour that has limited access to a quality education (4). Finally, all these processes need a strengthening of international aid and technical cooperation for agriculture (17).

On overall, statistics has been given a prominent role in the implementation of the 2030 Agenda for Sustainable Development and, in particular, in the monitoring of the 169 targets associated with the 17 goals.

This new common framework could bring about important results in terms of statistical capacity. Indeed, data availability has significantly improved thanks to the adoption of the Millennium Development Goals framework. Yet, with 304 proposed indicators, some of which are difficult to monitor or have very little data coverage and availability, monitoring the SDGs will be even more challenging as time goes on, and it will entail significant costs. The latest Statistical Capacity Indicator dashboards show that during the past 10 years nearly 30% of the 146 selected countries never conducted an agriculture census, the fundamental source of information for this field.

Substantial work is still needed to strengthen statistical systems at the national level and improve methodologies. According to the Sustainable Development Solutions Network (SDSN, a global UN initiative), about 1 billion dollars a year may be needed in 77 low income countries to strengthen statistical systems in order to support and track the SDGs. (*The issue of financing the modernization and resource mobilization will be addressed on Friday in Plenary PL 4*).

The increase in statistical capacity must be confronted with a view to building a consistent and homogenous global system of agricultural statistics, which will necessarily be based on the interdependence of national and international statistical activity.

This comprehensive and detailed framework is represented by the Global Strategy to Improve Agricultural and Rural Statistics, which was approved by the UN Statistical Commission in 2010 and aimed at improving the availability and use of reliable agricultural and rural data.

These goals are to be achieved with the production of a minimum set of core economic, social, environmental and geographical data, which each country in the world should collect; through a more complete integration of agricultural statistics into national statistical systems and by achieving substantial advances in governance and statistical capacity building.

The challenge represented by the new emerging demands for information and processes has to be tackled keeping in mind the ultimate goal of statistics: producing high quality data.

Data quality basically refers to compliance with agreed upon international standards: the professional independence of statistical authorities, the adoption of sound methodologies, the accuracy and precision of estimates, their timeliness and punctuality, their coherence, comparability, accessibility and clarity.

In addition to what has been said, official statistics is encountering human and budget constraints all over the world. Thus, efficiency also becomes a necessary condition for meeting our responsibilities.

However burdensome, quality standards should be applied to each step in the data chain, from the statement of objectives to data collection and processing to dissemination.

Indeed, there are many challenges National Statistical Offices need to face:

- The measurement of new complex cross-cutting issues (such as, for example, globalization, sustainable development, climate change)

- Sampling surveys are expensive, response rates are decreasing, and it is necessary to limit response burden. Nonetheless, the conduct of surveys will remain essential in order to satisfy the multidimensional demand for good quality statistics
- Agriculture, forestry and fisheries statistics normally draw on several different sources and are often collected by statistical offices, ministries and other research authorities, therefore consistency checks are important
- Data collection should not be redundant. Close cooperation should be established between all institutions involved for the purpose of increasing efficiency
- New technologies, administrative data and big data may reduce the number and the sample size of statistical surveys; we shall see several examples of this during the conference. Re-thinking data capturing systems represents a milestone in re-engineering the work of statistical offices
- Finally, human capital skills must be improved and adapted to changing roles and responsibilities

All these factors contribute towards the enlargement of the methodological toolbox and a re-thinking of the organization traditionally implemented by statistical offices. New methodological and technological instruments and international best practices should drive change; new possibilities for collecting, processing, integrating and disseminating high quality statistical data in a more efficient way should be explored.

We refer to all these different improvements using the term "modernisation".

The modernisation of agriculture statistics needs to be addressed through the analysis of the strengths and weaknesses of available techniques.

Traditional statistical surveys tend to respond to local or national conditions, cultures and goals, even if, over the past few years, increased efforts have been made to establish methods to allow comparison and evaluation across national and cultural boundaries.

Aside from their solid methodological background, dependence on traditional surveys is associated with a difficulty in identifying other coherent and timely data sources.

Administrative data are more and more important in the framework of official statistics (*sessions F32 and F33 are specifically dedicated to this issue*). The acquisition of administrative data may have lower costs for the statistical offices, and timeliness is normally not an issue but may vary widely among sources. A lot of capacity is required for setting up the infrastructures for storing and computing this type of data and the methodologies for exploiting them in official statistics production. The measurement of accuracy is also a complex issue to be managed; stability and efficiency of national statistical systems are key requirements to ensure the usefulness of these data for statistical purposes.

Experts' estimations are very often used for hard-to-measure phenomena, such as rare or illicit cultivations, even though the quality of expert's estimates may be poor (*Session B9 tackles this issue*). These estimates should be periodically benchmarked with more robust measurement tools.

Statistical models (which will be discussed during sessions G43 and G45) and Small Area Estimations are also needed when very detailed or rare phenomena are to be measured (for example, to estimate crop production for particular small areas or the degree of humidity of some cereals). They enhance overall quality, leveraging spatial and time correlations of data.

Finally, the use of Big Data in the agriculture statistics framework is still developing, but some best practices are rapidly growing, and examples of application are going to be discussed during various sessions of this conference.

Among Big Data techniques, the ones deriving from the use of remote sensing are very often used in agriculture; they may achieve high quality standards, especially in estimating coverage and detail. This is one of the latest measurement tools, however it usually requires additional field surveys to validate the preliminary estimations from satellite images (*Session F30 is specifically dedicated to these techniques*). Recently, the availability of free of charge maps has reduced the costs of implementation, although a relevant capability of the statistical office is still needed.

Other Big Data sources are used in agriculture to a lesser extent. Potentially, the implementation of more robust methodologies and best practices will improve quality and timeliness of agriculture statistics.

Nevertheless, the use of Big Data introduces new areas of concern related to data access and privacy issues, real costs, a shift in IT requirements, the impact on consolidated methods and data processing.

All these techniques may be combined with each other, as often happens in many statistical offices. As stressed by Constance Citro "we can and must move from a paradigm of producing the best estimates possible from a survey to that of producing the best possible estimates to meet user needs from multiple data sources". In order to achieve this goal, we need to build capacity in different directions, by integrating knowledge and methods and experimenting and co-operating with many national and international partners.

Increased effort must be dedicated to the full integration of administrative data with existing surveys. Statistical institutes in Northern European countries have shown that a "register-based statistical system" can be a powerful approach for fully exploiting all statistical information in an integrated manner. Data sources integration in agricultural statistics along with observation of the associated populations allow for measurement and evaluation of various issues related to the agricultural sector: for example, the educational level of a farm holder and the size of the farm can affect the productivity of land parcels and the risk of malnutrition of rural households (*Plenary session 2 and sessions F33, F34, F35 are dedicated to these topics*).

Techniques should be "sustainable" for statistical offices. Sustainability depends on human skills, technical development, financial support and specific strategies.

The answer to these strategic, thematic and methodological challenges lies in the modernisation of statistical systems.

Key elements of the modernisation process could be summarised as follows:

- Assessing user needs as the first stage for tailoring products and services

- Giving incentives for the development and exploitation of methodological, technological and organizational innovation

- Integrating and linking sources to boost coherence

- Guaranteeing a sound legal framework to manage the existing trade-offs among confidentiality, open access to microdata and IT security

- Enhancing and reorienting staff skills (*session H48 addresses this issue*)

- Moving away from the traditional 'silo' approach of statistical agencies towards the setup of horizontal services (for management, methodology and IT services that would serve to impel the integration process)

- Reducing the response burden with the reuse of available data and information

- Increasing the use of technology, resulting in significant efficiencies and reducing time lags

The adoption of a "register-based statistical system" represents a milestone in a modernization strategy for official statistics. It is a structure based on the integration of administrative and survey data which are organized into a system of statistical registers linked together on the basis of defined keys. Such a system may succeed in terms of reducing costs and response burden while continuing to maintain data quality.

A register-based system represents a long-term goal to be progressively implemented in accordance with country-specific characteristics, whereas its adoption should be based on best practices and institutional support from statistical offices already involved in such a process.

I would also like to stress the crucial role that the Census of agriculture plays for agricultural statistics. As we have seen before, a significant number of countries are still not carrying it out. Since the 1980s, the FAO World Program for the Census of Agriculture has been setting definitions, concepts, standards and guidelines, in order to ensure data comparability and address emerging information needs.

The 2020 edition of WCA calls attention to emerging themes in the digital era, giving emphasis to the use of information technology in data collection, processing and dissemination. Technology also serves to support data dissemination with the use of interactive maps, charts and graphs; aggregate data and microdata can be disseminated on-line to empower wide public access. The use of these accessible technologies inevitably represents the immediate future for agriculture censuses all over the world.

It is clear that modernization initiatives need to be shaped in accordance with the maturity of the particular national statistical system and with awareness of the institutional setting. Countries are at different stages in terms of their use of administrative records and innovation methodologies, and, in addition, statistics production in diverse thematic areas may be at different stages within the same country.

To summarize, five key drivers may characterize a successful process of modernisation: trust, quality, competencies, research and innovation, partnership.

These drivers are strongly related and they feed on each other. Quality, transparency and the independence of the statistical authorities are crucial to engender trust in an NSI's work; quality is based on the competencies of the researchers and analysts who are responsible for the day to day data production. Research in the development of new techniques and methodologies is crucial in fostering improvements, defining new processes and procedures, creating new products. Finally, modernization calls for strong partnerships among the public and private sectors and the scientific community in order to enrich the information and improve data quality.

I would like to close with an invitation to all the stakeholders in the agriculture statistics system: the national statistical systems, national and international agencies, the scientific community, private data producers and data owners, governments. There is an increasing need for stimulating a coordinated effort to fulfil international goals set at the global level, be those relative to the production of new information, or relative to the adoption of methodological standards.

Of course, everyone needs to take part in this process, according to his or her own abilities and responsibilities.

Donor countries have recovered only in 2013 the absolute value of Official Development Assistance, yet without raising its share of GDP. Even if agriculture is increasing its share of total ODA, thanks to a steep increase in bilateral and multilateral aid flows to agriculture, there is a need for additional resources. Sharing experiences among NSIs and taking advantage of globalisation can disseminate innovative solutions for every country.

Let me conclude by stating that modernisation is a priority on the statistical agenda today and in the future. Efforts to modernise agricultural statistics are crucial for providing those tools that are essential in order to be able to address particular issues and monitor advancements in the sustainable development agenda.

Keeping this in mind, we should all be engaged and forward looking. I wish for all of you a very fruitful work throughout the next three days. Thank you.

PLENARY SESSION

02

INTEGRATION OF DATA SOURCES IN AGRICULTURAL STATISTICS

Session Organizer
P. Lavallée | Statistics Canada | Ottawa | Canada

ABSTRACT

Agricultural surveys are often targeting specific topics: crops, livestock, finance, etc. To get a global picture of the agriculture behaviour of a country, it is often necessary to measure such information in an integrated way. The addition of social and household data to information agricultural can also help in refining such studies. For example, studies such as agricultural practices and productivity, poverty reduction and social well-being, are generally benefiting from such integration. Now, simply adding the results of independent surveys or data sources together is generally not enough to get data that will lead the required studies, and thus, a planned integration of surveys and data sources needs to be done. This session will present different methodological approaches to integrate data sources and surveys, with the emphasis on agricultural and social topics. These approaches will be presented in relation with integration projects performed by statistical agencies

LIST OF PAPERS

Potential uses of tax data in the Canadian census of agriculture
P. Hunsberger | Statistics Canada | Ottawa | Canada
L. O'Neill | Statistics Canada | Ottawa | Canada
DOI: 10.1481/icasVII.2016.pl2

Optimal sampling for integrated observation of different populations
P. D. Falorsi | Istat | Rome | Italy
P. Righi | Istat | Rome | Italy
DOI: 10.1481/icasVII.2016.pl2b

PL02

Potential uses of tax data in the Canadian census of agriculture

P. Hunsberger Statistics Canada | Ottawa | Canada
L. O'Neill Statistics Canada | Ottawa | Canada

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ABSTRACT

As in many statistical organizations, Statistics Canada is examining ways to reduce the amount of survey response burden placed on its respondents while maintaining a high level of quality for its statistics. Statistics Canada's Agriculture Statistics Program has placed a high importance in recent years on exploring the expanded and improved use of farming revenue and expense data reported by farm operators to Canada's tax agency when filing their tax returns.

The Canadian Census of Agriculture is no exception to this initiative. In addition to questions on agricultural characteristics such as livestock inventories, crop acreages and agricultural practices, the Canadian Census of Agriculture has traditionally collected information from farm operators related to revenue and detailed expenses. The possibility of removing these detailed, high response- burden financial questions from the Census and replacing them with income tax data was explored following the 2011 census occasion as part of a feasibility study. The study concluded that such a replacement would work well for the vast majority of farms, but there were certain sub-populations in which it would not perform well.

Agricultural tax data can also be used in the processing of other variables collected by the Census of Agriculture. Tax data will be used in the data validation stage of the 2016 Census of Agriculture, to corroborate the responses provided to census questions such as agricultural commodities. They will also be used to improve the nearest neighbour donor imputation of total non-response.

A further use of tax data has been to help define the frame of farm operations to be used for the mail out of the Census. Detailed agricultural tax data are used to add and remove units from the agricultural population.

The paper will describe the studies undertaken after the 2011 Census of Agriculture to assess the feasibility of using tax data for the replacement of respondent-provided information and frame generation. It will also describe the new agricultural tax data environment developed at Statistics Canada which can be used by both the Census of Agriculture and other agricultural programs, including the Agriculture Taxation Data Program. Finally it will discuss the manner in which tax data will be used for the Census of Agriculture in 2016.

Keywords: Data replacement, agricultural frame, data validation, feasibility study

PAPER

1. Introduction

Statistics Canada's Agriculture Statistics Program has a long history of using administrative data. These data are obtained from other federal and provincial government departments as well as non-government organizations, and are incorporated into the Agriculture Taxation Data Program (ATDP), the quinquennial Canadian Census of Agriculture (CEAG), the Remote Sensing and Geospatial Analysis project and ongoing and special agricultural surveys. This paper will discuss recent initiatives undertaken by Statistics Canada to increase the use of agricultural tax data obtained from Canada's tax agency, the Canada Revenue Agency, in the construction of the agricultural survey frame, the redesign of the agricultural tax data environment, the processing of the 2016 Census of Agriculture and the potential replacement of existing variables in a future Census of Agriculture. Adding to the challenge of achieving these goals is the fact that multiple agricultural projects have been historically using tax data in different ways, and the new standardized processing and frame methodology must now meet their various needs at the same time.

2. Building the Agricultural Survey Frame

Prior to 2012, Statistics Canada maintained a list of agricultural operations solely for the purposes of the Agriculture Statistics Program called the Farm Register (FR). The CEAG and agricultural surveys derived their survey frames from the FR, which included baseline information necessary for survey design. The FR in turn was largely updated in terms of additions and deletions of operations and contact information primarily by conducting the CEAG once every five years, and to a lesser extent throughout each year based on feedback from agricultural surveys.

That changed in 2012 when Statistics Canada made the decision to use the Business Register (BR) to maintain its frame of agricultural operations for its Agriculture Statistics Program, similar to most other business survey programs at the Agency, in an effort to reduce redundancy. The BR is a complete list of Canadian businesses primarily maintained by reported tax data and other associated administrative signals, such as indications of cessation of business activity, structural changes, and shifts in primary business activity type. A key field on the BR is the Business Number, a nine-digit code that facilitates interaction with some government departments and that has been incorporated into the CEAG. The post-2011 CEAG reconciliation of the FR with the BR involved major challenges; for more information see Dongmo Jiongo et al (2013). Tax data are typically received for existing farm businesses every year and in some cases every month. The direct connection between the BR and tax data allows the BR, and hence the agriculture survey frame, to be updated more fully and more frequently.

A key annual use of tax data is in the selection of which businesses should be added into (birthed), or removed from (deathed), the agricultural survey frame. Initially, the BR identifies a unit as a birth or a death based on the appearance or long-term disappearance of tax data. The agricultural survey frame, as a subset of units on the BR, will then reflect these additions or removals. New units added to the BR are included in the agricultural survey frame based on tax indications of agricultural activity. However, it is not prudent to include all new businesses that have reported agricultural activity. Filtering has proved necessary for a variety of reasons. For example, some BR units that file agricultural tax information are out of scope to the Agriculture Statistics Program. Out of scope agricultural tax units may include landlords who rent out farmland to others, but do not actively operate a farm themselves, yet still identify themselves when filing taxes as being an operator of a business of an agricultural nature and with agriculture-related revenue. Conversely, there are other businesses that report agricultural tax activity that are suspected, but not yet confirmed, to be in a partnership of some sort with an existing unit on the agricultural survey frame. Their automatic addition would generate duplication. A filter is therefore applied to only incorporate tax births that exhibit significant, unique, detailed and commodity-specific agricultural revenue and/or expenses to the agricultural survey frame.

Finally, tax information, in the form of commodity-specific agricultural revenue and expense information supplied by the tax filer, is used to derive measures of commodity-specific agricultural production that allow agricultural surveys to better identify their survey populations and develop efficient survey designs. Currently these production measures are generated for previously unknown (birthed) frame units on an annual basis, and so overall the agricultural survey frame now has a better, more recent picture of the agricultural activities of Canadian farm operations during the inter-censual period.

3. The Redesigned Agricultural Tax Data Environment

For over 25 years the ATDP has tabulated statistics based on agricultural revenue and expense information reported on farm operators' Canada Revenue Agency tax returns. Prior to 2016, the ATDP received a sample of tax records from the Canada Revenue Agency that contained some indication of agricultural revenue. The ATDP processed the tax fields obtained from this sample using custom rules and methodology. Starting in 2016, the ATDP will be defining their population of interest using the BR in a similar manner to that used by the CEAG and agricultural survey programs. Tax data will be obtained for all units resulting in a census of in-scope agricultural tax filers rather than a sample. This transition faces some challenges. Statistics Canada has a system in place for the processing of tax data for businesses in all industries including those outside of the agriculture sector, but this system does not include some specialized rules and variables necessary for both the ATDP and other uses within the agriculture program. It was therefore necessary to build a new hybrid system, consisting of the general Statistics Canada tax processing rules plus some extra agriculture-specific requirements. Furthermore, the standardized tax data processing does not uniformly produce the highly specific commodity-level revenue and expense details required by ATDP, and so a new imputation system for agricultural tax data was implemented.

This updating of the agricultural tax data processing environment was undertaken collaboratively, with ATDP contributing their tax data processing techniques and CEAG their agricultural frame expertise. The ultimate goal of these efforts is to produce one high-quality Agricultural Tax (Ag-Tax) database that will be capable of supplying all agricultural statistics programs in Statistics Canada with highly detailed, processed financial information on a sub-annual basis. The Ag-Tax database resulting from this initiative will be made available to a variety of agricultural statistics programs, including the CEAG, for the first time in 2016 for the 2015 tax year.

With both the ATDP and the CEAG now defining their populations based on the BR and using the same set of processed agricultural tax data, the potential benefits are great. ATDP can now produce financial statistics based on a census of agricultural operations rather than a sample. The resulting Ag-Tax database from the redesigned tax system reduces the need for the CEAG to collect this data from respondents directly, and makes it feasible to directly replace detailed expenses in a future Census or other agricultural surveys which require financial information. In addition to the reduction in survey response burden, it results in more coherence between the financial statistics from different products within the Agriculture Statistics Program.

4. Use of Agricultural Tax data in the 2016 Census of Agriculture

Drawing directly from the newly created Ag-Tax database described above, the 2016 CEAG will for the first time have a high-quality comparative dataset of agricultural tax revenues and expenses available at a commodity-specific level of detail. The most extensive use of this database will be made by CEAG data validation, although it will also be applied to total non-response imputation.

Ag-Tax data, as well as other sources of administrative data, will play an important role in the validation of CEAG data. They will be used to confront and validate both the data provided by respondents, as well as data which has been imputed. For tax data in particular, CEAG will use total farm revenue and total operating expenses tax fields to validate the gross farm receipts and total operating expenses questions on the CEAG questionnaire (Statistics Canada, 2015). CEAG will also make use of other tax variables in the Ag-Tax database to improve the data quality in other sections of the CEAG questionnaire. For example, the detailed revenue Ag-Tax variables will be used to validate the presence of corresponding commodities as reported by the respondent on the Census questionnaire. CEAG validators will also use tax data to validate the value of land and buildings and machinery values provided by respondents on their census form. Another important use of tax data in validation will be to ensure that the values reported by the respondent do not include components that are considered to be out of scope for the Census such as capital sales and goods purchased only for resale. Goods purchased for resale can be a difficult concept to identify in the gross farm receipts value provided by the CEAG respondent, so CEAG validators employ ratios using detailed expense items and other relevant questions on the questionnaire. For example, seed purchases in relation to greenhouse area under glass to remove resales in greenhouse operations; and livestock purchases in relation to feed purchases to eliminate sales from livestock dealing activities. Finally, using detailed revenues from tax data will also allow analysts to identify non- agricultural receipts, such as revenue from trucking, rental income or oil leases.

Another application of the Ag-Tax database in the 2016 CEAG will be to use variables from this database as matching variables to assist in the identification of nearest neighbours in the CEAG total non-response imputation stage. Ag-Tax variables used in this manner are total revenue, total expenses and a field describing the main agricultural activity of the farm. As has traditionally been the case, the CEAG uses a nearest-neighbour hot-deck imputation system, imputing missing information from a valid CEAG donor record using Statistics Canada's BANFF generalized imputation system (Statistics Canada, 2014). It is expected that the application of tax data here will lead to improved total non-response imputation results, with recent Ag-Tax data now being used instead of five-year old CEAG data.

Finally, tax data will be used to maximize coverage of CEAG farms. While the initial 2016 CEAG frame is derived from the agricultural survey frame, and hence the Business Register, as close to Census day as possible, there is still at that time a volume of new tax units that will not be added to the BR until later in the year. Since the goal of the CEAG is to achieve 100% coverage of all Canadian farms as of Census day, an attempt is made to match this set of new tax units to the Canadian Census of Population, which is carried out concurrently with the CEAG and contains a question asking if anyone in the household is a farm operator. At defined points throughout census collection, a list of Census of Population households with an agricultural operator is generated.

Households from the list that link successfully to a tax unit on the waiting list that has reported agricultural tax data are eligible to be sent a CEAG questionnaire.

5. Potential for Detailed Financial Data Replacement in a Future Census of Agriculture

The 2011 CEAG questionnaire (Statistics Canada, 2010) featured two questions on financial totals (Total Sales and Total Expenses) and seventeen questions on detailed financial expenses, such as fertilizer expenses, livestock purchases, wage expenses and machinery rental. In many (but not all) cases these census questionnaire variables sought the same information as that which was already available on the agricultural tax forms submitted to the Canada Revenue Agency. With the goal of assessing whether a direct replacement of CEAG questionnaire variables with tax data from the proposed Ag-Tax program would be feasible in the future, a comparative analysis was undertaken in conjunction with the 2011 CEAG collection period.

The 2011 CEAG Tax Data Replacement Initiative was a strategic investment of Statistics Canada and was part of the 2011 CEAG program. The tax data replacement feasibility study (TAX) (Statistics Canada, 2013) replaced 2011 CEAG financial data with corresponding tax data from the Canada Revenue Agency.

The purpose of the study was to evaluate the robustness of tax data as a replacement for detailed operating expenses provided by respondents. It has been estimated that the use of administrative data to replace all of the detailed CEAG financial questions would reduce the response burden for CEAG respondents by as much as 13.5% in terms of time spent completing the questionnaire. In addition, their removal would address requests to do so by respondents in previous censuses. Tax data were processed through the existing 2011 CEAG production edit and imputation system to produce a set of financial data for all of the approximately 200,000 Census in- scope records. In this manner CEAG-TAX financial data were fully edited, imputed and consequently validated using the same processing methodology as in 2011 CEAG production, allowing for a fair comparison between 2011 CEAG and CEAG-TAX replacement data.

The results of this comparison, showing the percent relative difference between TAX and CEAG financial data, are shown below in Table 1. Results are grouped into "Standard" and "Non- Standard" farm types. "Non-Standard" here defines the less than 1% of Canadian farms that are either extremely large and/or complex in terms of production and therefore have a critically high impact on the Agricultural sector in Canada, or that are highly unique in terms of their reporting arrangements.

Table 1: Percent Relative Difference between TAX and CEAG: Gross Farm Receipts and Total Operating Expenses, by Farm Type

CANADA	FARM TYPE	% RELATIVE DIFFERENCE (TAX vs. CEAG)
Gross Farm Receipts	**All**	**-2.00%**
Gross Farm Receipts	Standard	-0.70%
Gross Farm Receipts	Non-Standard	-8.65%
CANADA	**FARM TYPE**	
Total Expenses	**All**	**0.60%**
Total Expenses	Standard	2.60%
Total Expenses	Non-Standard	-8.63%

Overall, the comparison for all farms between TAX and CEAG for gross farm receipts and total operating expenses at the Canada level was good. However, there were significant differences in the comparability between TAX and CEAG for "Non-standard" CEAG farms. This analysis was also extended to detailed expense items, and a similar pattern of results was found, with most detailed expense categories comparing well for "Standard" farms and the largest differences occurring for "Non-standard" CEAG farms.

The study arrived at several key conclusions. For "Standard" farms, which make up 99% of the farm population in Canada, the total replacement of CEAG detailed expense items was deemed feasible by the study; however, it was considered essential to keep gross farm receipts, value of forest products sold and total operating expenses fields on future CEAG questionnaires. Gross farm receipts and total operating expenses are considered critical fields for reconciliation between CEAG questionnaires and tax data, and also for imputation for the small number of CEAG units for which linkage to tax data is not possible. Value of forest products sold is not obtainable from tax data with any degree of quality and so it should continue to be asked on the questionnaire.

While it was deemed feasible to use tax data for total wages and salary expenses, it was recommended not to provide the split between family and non-family wages directly through tax replacement. It was recommended that future CEAG questionnaires collect the proportion of family or non-family wages and salaries.

The study concluded that due to their complex structures and importance to the agriculture sector, extremely large agricultural operations should continue to provide their detailed finances via the CEAG questionnaire rather than through tax data. Similarly, due to their unique nature and the poor reconciliation between CEAG questionnaires and tax forms, it was recommended to continue to require direct collection of detailed finances for community pastures, institutional farms and northern farms. To allow for the replacement of financial data with tax data for collective farm operations, it was recommended that research be undertaken to better understand their organization and reporting tendencies. It is worth noting, however, that the more recently developed harmonized Ag-Tax processing environment may provide significant and necessary methodological improvements regarding the processing of raw tax data for the above-mentioned "Non-standard" farms. If this proves to be the case, this recommendation would need to be revisited.

In general, the feasibility study showed shifts in financial variables, with some shifts more unique and impactful than others. Having used the same processing methodology to treat tax data and CEAG financial data alike, the feasibility study recognized that some of these shifts may be due to systematic differences in the way that certain financial information is reported to the Canada Revenue Agency as compared to CEAG. Consequently it was recommended that CEAG should consult with agricultural accountants and other knowledgeable parties to understand reporting tendencies relating to tax filing and to help provide explanations for these data shifts.

Overall, the results of the feasibility study were encouraging. They align well with Statistics Canada's commitment to increase the use of administrative data to reduce the burden on survey respondents (Statistics Canada, 2016) and the recognition that harmonization of the processing of raw agricultural tax data within the agricultural statistics program would reduce duplication of efforts and also improve the overall quality of financial data. However, while the Ag-Tax database was successfully developed as described above in Section 3, fiscal constraints resulted in the 2016 CEAG cycle being unable to implement the replacement of detailed expenses with tax data. Plans are ongoing to consider having the 2021 CEAG ask only total agricultural sales, total expenses and value of forestry product information as in the 2016 CEAG questionnaire, and use the Ag-Tax database of processed micro-level tax data to fully replace the detailed financial expense questions. At this time, a final decision has not been made. If the decision is made to proceed with tax data replacement in 2021, these financial expense fields would be processed and validated alongside other 2021 CEAG questionnaire fields such as questions on commodity, machinery and land management practices to ensure consistency, and released as part of 2021 CEAG dissemination.

CONCLUSION

Statistics Canada has successfully undertaken the major recent initiative to adopt the Business Register as its agricultural survey frame, which directly enabled linkage to administrative data including tax data. The CEAG and the ATDP are therefore now both running off a similar frame, and the ATDP will for the first time produce a census file of tax records, as opposed to a sample.

The resulting availability of up-to-date, processed tax and administrative data will support the ongoing maintenance of the agricultural survey frame. It will also make it easier to use tax data for the validation and imputation of the 2016 CEAG. Building on the results of a feasibility study, continuing investigations are being made to consider using tax data to replace detailed financial questions on future censuses and agricultural surveys. The resulting efficiencies gained in population coverage and contact success rates as well as the reduction in response burden on Canadian farm operators with regard to the reduced direct collection of financial information should be significant.

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PL02

Optimal Sampling for the Integrated Observation of Different Populations

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ABSTRACT

This work deepens the problem of defining an optimal sampling in the multivariate case where the variables of interest are related to different target populations. In order to get insight to the underlying phenomena, the observation has to be carried out in an integrated way, implying that units of a given population have to be observed jointly with the related units of the other population. Indirect sampling provides a natural framework for this setting since the units belonging to a population that is the object of a given survey can become carriers of information on another statistical population. This problem is studied with respect to the different contexts which characterize the available information in the sampling design phase, ranging from very well organized situations in which the links among the different units are known in the design phase to a situation in which the available information is very poor. Empirical studies on agricultural data of two developing countries are developed. These show that controlling in the design phaseis effective since by not doing so, the errors of the indirectly observed population can become very high. Furthermore, the need of having good models for predicting the unknown variables or the links is stressed.

Keywords: integrated surveys, sample allocation, indirect sampling

PAPER

1. Introduction

The need of observing in an integrated way different statistical populations related to each other is often encountered in survey sampling. The underlying relationships among the populations are regulated by formal rules, contingent dependencies or relationships created for the pursuit of common purposes. For instance, agricultural surveys often refer to statistical units such as rural households, farms and land parcels that are related to each other. The integrated observation of such populations allows to measure global phenomena of the agricultural sector: for example, the education level of a farm holder and the farm size can affect the productivity of land parcels and thus the risk of malnutrition of rural households. The observation of such units in an integrated way can be recommended to get insights into the agricultural system of a country.

Indirect sampling (Lavallée, 2007) provides a natural framework for the estimation of the parameters of two target populations that are related to each other since the units belonging to a population that is the object of a given survey can become carriers of information on another statistical population, through the type of relationship between the entities. Furthermore, indirect sampling is suitable for producing statistics of populations for which there is no sampling frame. In such context, the sampling procedure assumes a population U^A related with the population of interest U^B, and for whichthe sampling frame of U^A is available. Then, a sample is selected from U^A, and using the existing links between the two populations the units of U^B are observed.

This work deepens the problem of sampling allocation when an indirect sampling design is implemented. The allocation problem for the direct sampling setting has been dealt with in several papers. When one target parameter is to be estimated for the overall population, the optimal allocation in stratified sampling can be performed (Cochran, 1977). When more than one target parameter is to be estimated the problem aleads to a compromise allocation method (Khan et al., 2010), with a loss of precision compared to the individual optimal allocations. Several authors have discussed various criteria for obtaining a feasible compromise allocation: see, for example, Kokan and Khan (1967), Chromy (1987), Bethel (1989) and Choudhry et al. (2012).

Falorsi and Righi (2015) provide a general framework for multivariate and multi-domain surveys. This paper offers a further generalization of the framework proposed by Falorsi and Righi (2015) to the case of integrated observation of two or more populations. Different scenarios related to the level of knowledge of the existing links are examined. Section 2 introduces the background and symbols. Sections 3 and 4 illustrate the basic allocation problem and how it is declined in the different informative scenarios.

PL02

2. Background

Let s^A, M^A, m^A be a selected sample from U^A without replacement and with fixed sample size, thenumber of units in U^A and the number of units in s^A, respectively. We use π_j^A to represent the inclusion probability of the *j*th unit in U^A with $\pi_j^A > 0$ and $\sum_{j\in U^A} \pi_j^A = m^A$. We denote with $y_{j,v}$ the value of the *v*th (*v*=1,…,*V*) characteristic on unit *j* and the total of all $y_{j,v}$'sby Y_v^A.We estimate the total Y_v^A according to the Horvitz-Thompson (HT) estimator, $\hat{Y}_v^A = \sum_{j\in s^A} w_j^A \, y_{j,v}$, where $w_j^A = (1/\pi_j^A)$.Many practical sampling designs define planned domains that are sub-populations in which the sample sizes are fixed before selecting the sample. Denote by U_h^A (*h*=1,…,*H*) the planned domain of size $M_h^A = \sum_{j\in U_h^A} d_{j(h)}$ where $d_{j(h)} = 1$ if $j \in U_h^A$ and $d_{j(h)} = 0$ otherwise. Let us suppose that the $d_{j(h)}$ values are known, and available in the sampling frame, for all population units. Fixed sizes sampling designs are those satisfying $\sum_{j\in s^A} \mathbf{d}_j = \mathbf{m}^A$,where $\mathbf{d}_j = (d_{j(1)},\ldots,d_{j(h)},\ldots,d_{j(H)})'$ and $\mathbf{m}^A = (m_1^A,\ldots,m_h^A,\ldots,m_H^A)'$ isthe vector of integer numbers defining the sample sizes fixed at the design stage, with $\sum_{j\in U^A} d_{j(h)}\,\pi_j^A = m_h^A$. In our setting, the planned domains can overlap; therefore, the unit *j* may have more than one value $d_{j(h)} = 1$ (for $h = 1,\ldots, H$).Several customary fixed size sampling designs may be considered as special cases. A well-known example is the stratified sampling design where strata are the planned domains and the $\mathbf{d}_j$ vector has *H*-1 elements equal to zero, and one element equal to 1.We suppose that the $M^A \times H$ matrix $\mathbf{D} = (\mathbf{d}_1,..,\mathbf{d}_j,\ldots,\mathbf{d}_{M^A})'$ is non-singular. According to this general sampling design framework, Deville and Tillé (2005) proposed an approximated expression of the variancebased on the Poisson sampling theory for $\hat{Y}_v^A$ given by $V(\hat{Y}_v^A \mid \mathbf{m}^A) \cong \sum_{j\in U^A} [(1/\pi_j^A) - 1]\eta_{j,v}^2$,where

$$\eta_{j,v} = y_{j,v} - \pi_j^A \, \mathbf{d}'_j \, \boldsymbol{\beta}_v \text{ and } \boldsymbol{\beta}_v = \boldsymbol{\Delta}^{-1} \sum_{l\in U^A} \pi_l^A \,(1/\pi_l^A - 1)\,\mathbf{d}_l \, y_{l,v} \text{ ,with}$$

$$\boldsymbol{\Delta} = \sum_{j\in U^A} \mathbf{d}_j \, \mathbf{d}'_j \, \pi_j^A (1 - \pi_j^A).$$

We also make use of the notation: M^B, N^B, U_i^B and M_i^B to be the number of units in U^B, thenumber of clusters in U^B, the *i*th cluster of U^B with $\bigcup_{i=1}^{N} U_i^B = U^B$ and the number of units in the*i*th cluster U_i^B. We indicate by $y_{ik,r}$ the value of the *r*th (*r* =1,…,*R*) characteristic for the *k*th unit of the *i*th cluster of U^B and the total of all $y_{ik,r}$'s by $Y_r^B = \sum_{i=1}^{N^B} \sum_{k=1}^{M_i^B} y_{ik,r}$.

We define $l_{j,ik}$ as an indicator variable of link existence: $l_{j,ik} = 1$ indicates that there is a link between *j*th unit in U^A and *k*th unit in U_i^B, while $l_{j,ik} = 0$ indicates otherwise.

Let us suppose that we carry out an indirect sampling process in which if the unit $j \in U^A$ is included in $j \in s^A$, then all the clusters U_i^B, for which $L_{j,i}^B = \sum_{k=1}^{M_i^B} l_{j,ik} > 0$, are observed in the indirect sample of population U^B. Let n^B be the cluster sample size of population U^B obtained after the indirect sampling process. We estimate Y_r^B according to the Horvitz-Thompson estimator based onthe theory of the Generalized Weight Share Method (GWSM):

$$\hat{Y}_r^B = \sum_{i=1}^{n^B} w_i^B \, y_{i,r} \qquad (2.1)$$

where $y_{i,r} = \sum_{k=1}^{M_i^B} y_{ik,r}$ and $w_i^B = \sum_{j\in s^A} w_j^A \, \tilde{L}_{j,i}^B$, with $\tilde{L}_{j,i}^B = L_{j,i}^B / L_i^B$ and $L_i^B = \sum_{j=1}^{M^A} L_{j,i}^B$.

Theorem in Section 3 of Lavallée (2007) states that (2.1) offers an unbiased estimator for Y_r^B provided all links $l_{j,ik}$ can be correctly identified and $L_i^B > 0$ for all $i \in U^B$.By defining $z_{j,r} = \sum_{i=1}^{N^B} \tilde{L}_{j,i}^B \, y_{i,r}$, the estimator (2.1) can be expressed as an usual Horvitz-Thompson (HT) estimator on the z values referring to the U^A population, $\hat{Y}_r^B = \sum_{j \in s^A} w_j^A z_{j,r}$ .Therefore, the variance, $V(\hat{Y}_r^B)$, of $\hat{Y}_r^B$ maybe expressed as the variance of the HT estimator on the U^A population.The approximate variance of $\hat{Y}_r^B$ implementing fixed sizes sampling designs isgiven by $V(\hat{Y}_r^B \mid \mathbf{m}^A) \cong \sum_{j \in U^A} [(1/\pi_j^A) - 1] \eta_{j,r}^2$, where $\eta_{j,r} = z_{j,r} - \pi_j^A \mathbf{d}'_j \boldsymbol{\beta}_r$ with $\boldsymbol{\beta}_r = \Delta^{-1} \sum_{l \in U^A} \pi_l^A (1/\pi_l^A - 1) \mathbf{d}_j z_{l,r}$.

3. Problem

Given the above framework, we are interested in finding the vector $\boldsymbol{\pi}^A = (\pi_1^A, \ldots, \pi_j^A, \ldots, \pi_{M^A}^A)$ of inclusion probabilities that minimizes the expected survey cost bounding the sampling variances, $V(\hat{Y}_v^A)$ (v=1, ... ,V) and $V(\hat{Y}_r^B)$ (r=1,... ,R) under given variance thresholds:

$$\begin{cases} \min \sum_{j \in U^A} c_j \pi_j^A \\ V(\hat{Y}_v^A \mid \mathbf{m}^A) \le V_v^* \quad \forall v = 1, \ldots, V \\ V(\hat{Y}_r^B \mid \mathbf{m}^A) \le V_r^* \quad \forall r = 1, \ldots, R \\ 0 < \pi_j^A \le 1 \end{cases}, \tag{3.1}$$

where V_v^* ($v = 1, \ldots, V$) and V_r^* ($r = 1, \ldots, R$) are the variance thresholds fixed by the sampling designer and c_j is the variable cost for observing the unit j in the population U^A and the linked $L_j^A = \sum_{i=1}^{N^B} L_{j,i}^B$ units in the population U^B. A reasonable expression of c_j is $c_j = f_c(L_j^A; C^B)$,where f_c is a known monotone non-decreasing function and C^B is the per unit cost for observing a cluster in the population U^B .Brewer and Gregoire (2009) propose an extensive analysis of different forms of costs functions. The minimization problem (3.1) is a generalization of the univariate precision constrained optimization approach (Cochran, 1977).The problem (3.1) assumes that all the values $y_{j,v}, y_{i,r}, y_{ik,r}, L_j^A$, $L_{j,i}^B$ and L_i^B are known as alsothe vectors $\boldsymbol{\beta}_v$ and $\boldsymbol{\beta}_r$, although they depend on the vector $\boldsymbol{\pi}^A$. In this case, problem (3.1) becomes a classical Linear Convex Separate Problem (LCSP; Boyd and Vanderberg, 2004) and can be solved by the algorithm proposed in Falorsi and Righi (2015). The algorithm represents a slight modification of the algorithm of Chromy (1987), originally developed for multivariate optimal allocation in Stratified Simple Random Sampling Without Replacement (SSRSWOR) designs and implemented in standard software tools[1]. Alternatively, the LCSP can be dealt with by the SAS procedure NLP as suggested by Choudhry *et al.*(2012).

4. Informative contexts and optimization problem

Optimization problem as presented in (3.1) is quite theoretical since one needs to know the values of the variables of interest in both populations and the values of actual links among the unitsof the two populations. From now on, we introduce three more concrete informative contexts in successive steps. We start from two contexts in which the information is very rich, whereas the third context considers a casein which the information is very poor. Thelatter context is the most common, altough the incresing availability of administrative registers and statistical software tools for data integration increase the plausibility of the first two contexts.

Context 1. The sampling frames for U^A and U^B are available. All the values L_j^A $L_{j,i}^B$ and L_i^B are known and the values of $y_{j,v}, y_{i,r}$ are unknownbut can be predicted by suitable superpopulation models.

This context may be realistic in countries, like the Nordic ones, having well established register based systems (Wallgren and Wallgren, 2014) in which the units ofagiven statistical register have unique identifiers of good quality, which allow to identify the same unit in the whole systems of registers.The*working*models that we studycan be expressed under the following forms:

[1] See for example the Mauss-Rsoftware available at: http://www3.istat.it/strumenti/metodi/software/campione/mauss_r/.

$$\begin{cases} y_{j,v} = \tilde{y}_{j,v} + u_{j,v} = f_v(\mathbf{x}_j;\boldsymbol{\varphi}_v) + u_{j,v} \\ E_{M_v}(u_{j,v}) = 0 \quad \forall j \\ E_{M_v}(u_{j,v}^2) = \sigma_{j,v}^2 \\ E_{M_v}(u_{j,v}, u_{l,v}) = 0 \ \forall j \neq l \end{cases}, \begin{cases} y_{i,r} = \tilde{y}_{i,r} + u_{i,r} = f_r(\mathbf{x}_i;\boldsymbol{\varphi}_r) + u_{i,r} \\ E_{M_r}(u_{i,r}) = 0, \\ E_{M_r}(u_{i,r}^2) = \sigma_{i,r}^2 \\ E_{M_r}(u_{i,r}, u_{i',r}) = 0 \ \forall i \neq i' \end{cases} \tag{4.1}$$

where, omitting the subscripts for the sake of brevity, $\mathbf{x}$are vectors of predictors (available in the two sampling frames), $\boldsymbol{\varphi}$ are the vectors of regression coefficients and $f(\mathbf{x};\boldsymbol{\varphi})$are known functions, u are the error terms, $\tilde{y}$ are the predicted values and $E_M(\cdot)$ denote the expectations under the models. We assume that the parameters of the models to be known, although in practice they are usually estimated. The right-hand side superpopulation model of (4.1) can be defined starting from an elementary unit level model. We do not dealt with this second modelin this paper. The model expectations at cluster level on the right hand side of (4.1) can be easily derived as:

$E_{M_r}(y_{i,r}) = \tilde{y}_{i,r} = \sum_{k=1}^{M_i^B} \tilde{y}_{ik,r}$; $V_{M_r}(y_{i,r}) = \sigma_{i,r}^2 = M_i^B \sigma_r^2 [1 + (M_i^B - 1)\rho_r]$; $Cov_{M_r}(y_{i,r}, y_{i',r}) = 0$ for $i \neq i'$,

where V_{M_r} and Cov_{M_r} denote respectively the model variance and covariance.

Note that the *working* models (4.1) are variable specific. They are introduced as useful tools for defining the sampling design but they are not necessarily representing exactly the real models generating the data.

According to (4.1),the model predictions and the variancesof the z variables are given by

$E_{M_r}(z_{j,r}) = \tilde{z}_{j,r} = \sum_{i=1}^{N^B} \tilde{L}_{j,i}^B \tilde{y}_{i,r}$ and $V_{M_r}(z_{j,r}) = \sigma_{j,zr}^2 = \sum_{i=1}^{N^B} (\tilde{L}_{j,i}^B)^2 \sigma_{i,r}^2$.

Thus, in the optimization problem,the variance terms $V(\hat{Y}_v^A \mid \mathbf{m}^A)$ and $V(\hat{Y}_r^B \mid \mathbf{m}^A)$ are replaced by the Anticipated Variances. Denoting with E the expectation under the sampling design, the anticipated variance of the HT estimator $\hat{Y}_v^A$ is $E_{M_v}E(\hat{Y}_v^A - Y_v^A)^2 = E_{M_v}V(\hat{Y}_v^A - Y_v^A)$., with $V(\hat{Y}_v^A - Y_v^A) = V(\hat{Y}_v^A \mid \mathbf{m}^A) \cong \sum_{j \in U^A}[(1/\pi_j^A) - 1]\, \eta_{j,v}^2$ The same result may be derived for the estimate $\hat{Y}_r^B$. Thus,we obtain the following expressions: $E_{M_v}[V(\hat{Y}_v^A \mid \mathbf{m}^A)] = \sum_{j \in U^A}[(1/\pi_j^A) - 1]\, E_{M_v}(\eta_{j,v}^2)$,

$E_{M_r}[V(\hat{Y}_r^B \mid \mathbf{m}^A)] = \sum_{j \in U^A}[(1/\pi_j^A) - 1]\, E_{M_r}(\eta_{j,r}^2)$,where $E_{M_v}(\eta_{j,v}^2)$ and $E_{M_v}(\eta_{j,r}^2)$ arenot given here for the sake of brevity.The problem (3.1) is then reformulatedusing $E_{M_v}V(\hat{Y}_v^A \mid \mathbf{m}^A)$and $E_{M_r}V(\hat{Y}_r^B \mid \mathbf{m}^A)$.

Remark 4.1: Falorsi and Righi (2015) propose an upward approximation of the anticipated variances that simplified the optimization problem. This conservative approximationis a safe choice in this setting, since they prevent from the risk of defining an insufficient sample size for the expected accuracies.

Remark 4.2: Lavallée and Labelle-Blanchet (2013) deal with the problem of indirect sampling applied to skewed populations by suggesting eight alternative methods for modifying the links, $l_{j,ik}$, to reduce the variance of the estimates.

Context 2.Suppose that in the sample design phase, the links $l_{j,ik}$ are not known with certainty but the probabilities of existing links, $Pr(l_{j,ik} = 1) = \lambda_{j,ik}$, are available.

To include the linkage uncertainty in the optimal allocation, we assume the links follow a Bernoulli model $M_l, l_{j,ik} \sim \mathrm{B}(\lambda_{j,ik})$, where $E_{M_l}(l_{j,ik}) = \lambda_{j,ik}$ and $V_{M_l}(l_{j,ik}) = \lambda_{j,ik}(1 - \lambda_{j,ik})$.We assume the parameters $\lambda_{j,ik}$ to be known, although in practice they are usually estimated with probabilistic record linkage procedures(Lavallée and Caron, 2001).

In this framework, the anticipated variance has to take into account both the models M_l and M_r .Since $E_{M_l}E_{M_r}E(\hat{Y}_r^A - Y_r^A)^2 = E_{M_l}E_{M_r}V(\hat{Y}_r^A - Y_r^A) + E_{M_l}V_{M_r}E(\hat{Y}_r^A - Y_r^A) + V_{M_l}V_{M_r}E(\hat{Y}_r^A - Y_r^A)$ and $E(\hat{Y}_v^A - Y_v^A) = 0$, the problem (3.1) can be reformulated replacing the function to be minimized by $\min \sum_{j \in U^A} E_{M_l}(c_j)\pi_j^A$ and the two set of variances respectively with $E_{M_v}V(\hat{Y}_v^A \mid \mathbf{m}^A)$ and $E_{M_l}E_{M_r}V(\hat{Y}_r^B \mid \mathbf{m}^A)$ where $E_{M_l}E_{M_r}[V(\hat{Y}_r^B \mid \mathbf{m}^A)] = \sum_{j \in U^A}[(1/\pi_j^A) - 1]\, E_{M_l}E_{M_r}(\eta_{j,r}^2)$. The main results for the derivation of the expression of $E_{M_l}E_{M_r}V(\hat{Y}_r^B \mid \mathbf{m}^A)$are not given in the paper. They are based on the Taylor' series approximation and making some reasonable assumption on the links. The predicted $\tilde{z}_{j,r}$ values are obtained as $\tilde{z}_{j,r} = \sum_{i=1}^{N^{\smile}} \tilde{\Lambda}_{j,i}^{B} \tilde{y}_{i,r}$,where $\tilde{\Lambda}_{j,i}^{B} = (\Lambda_{j,i}^{B} / \Lambda_{i}^{B})$,with $\Lambda_{j,i}^{B} = \sum_{k=1}^{M_i^B} \lambda_{j,ik}$ and $\Lambda_{i}^{B} = \sum_{j=1}^{M^A} \Lambda_{j,i}^{B}$.

Remark4.3:the uncertainty on total survey costs, which depends both on the selected sample and the model uncertainty on costs, obliges to consider in the optimization problem the *expected costs* $E_{M_1}(c_j) = f_c(\Lambda_j^A; C^B)$ where $\Lambda_j^A = \sum_{i=1}^{M^B} \sum_{k=1}^{M_i^B} \lambda_{j,ik}$.

Context 3.Data integration is not possible because the record linkage process does not provide good linkages, or simply because the frame of population U^B does not exist.

This is the most usualcontext in developing countries. However, it may also characterize specific survey contexts in developed countries, for instance in case of hard-to-reach populations.

In this case, the optimizazion problem can be dealt byusing all the available information, even if of poor quality. For instance, if a size variables x related to the variable y_r is known from the frame for the unitsof population U^A, and totals or estimated totals $\tilde{Y}_{r(q)}^{B}$ of U^B are available at certain domain level q (q=1,…,Q),then the predicted z variables can be determined as:

$$\tilde{z}_{j,r} = \frac{x_j}{\sum_{l \in U_q^A} x_l} \tilde{Y}_{r(q)}^{B} \quad \text{for } j \in U_q^A . \tag{4.2}$$

Examples of building the z values are illustrated in Section 5.3.2 of *Guidelines on Integrated Survey Framework* (FAO, 2015). Here, an example is reported. Population U^A is given by the farm register of a country. From the register, we known the region q where agiven farm belongs. The population U^B is defined by the rural households. Suppose furthermore that we know (from the Census data or from a previous survey) the total $\tilde{Y}_{r(q)}^{B}$ for a given variable of interest, e.g., "revenue", for the domain q. In particular, consider the farm j of region q with 50 workers living in the region q. In this region, the total number of workers of the farms (estimated or known) is 330,000, and we havethe total $\tilde{Y}_{r(q)}^{B} = 100,000$. The predicted revenue $\tilde{z}_{j,r}$ for the farm is given by $\tilde{z}_{j,r} = (50/330,000)100,000 = 15.15$.Note that this kind of prediction corresponds to the hypothesisof uniformity of the links in the qth domain. In absence of unit level information for U^B , this hypothesisseems tobe reasonable.In this context, it is necessary to try to model directly the z-value with a model of the type:

$$\begin{cases} z_{j,r} = \tilde{z}_{j,r} + u_{j,zr} = f_{zr}(\mathbf{x}_j; \varphi_{zr}) + u_{j,zr} \\ E_{M_{zr}}(u_{j,zr}) = 0 \quad \forall j; \\ E_{M_{zr}}(u_{j,zr}^2) = \sigma_{j,zr}^2 ; \\ E_{M_{zr}}(u_{j,zr}, u_{l,zr}) = 0 \quad \forall j \neq l \end{cases} \tag{4.3}$$

where $\mathbf{x}_j$ is a vector of variables related to the size of unit j. For building plausible predictions on the variance $\sigma_{j,zr}^2$,it may be necessary to carry out a pilot survey. However, in some cases, it may be very difficult to implement such an effort. Making reasonable assumption on the relationship of the squared predictions $\tilde{z}_{j,r}^2$ with the variances $\sigma_{j,zr}^2$,the optimization problem could be carried out with considering the variances of the predictions.

It is also necessary to build a model for assessing the survey costs on the total links L_j^A :

$$\begin{cases} L_j^A = \Lambda_j^A + u_{j,\Lambda} = f_{\Lambda}(\mathbf{x}_j; \boldsymbol{\varphi}_{\Lambda}) + u_{j,\Lambda} \\ E_{M_\Lambda}(u_{j,\Lambda}) = 0 \quad \forall u_{j,\Lambda}; \\ E_{M_\Lambda}(u_{j,\Lambda}^2) = \sigma_{j,\Lambda}^2 ; \\ E_{M_\Lambda}(u_{j,\Lambda}, u_{l,\Lambda}) = 0 \quad \forall j \neq l \end{cases} \tag{4.4}$$

The predictions Λ_j^A needto be positive. A useful model is the logaritmic one: $\log(\Lambda_j^A) = \mathbf{x}'_j \boldsymbol{\varphi}_{\Lambda}$. The model (4.4) allowsthe prediction of the total number of links Λ_j^A of the unit j, thus defining the expected cost survey cost attached to it.

Accordingly to the models (4.3) and (4.4), the problem (3.1) can be reformulated as follows:

$$\begin{cases} \min \sum_{j \in U^A} E_{M_A}(c_j)\pi_j^A \\ E_{M_v} V(\hat{Y}_v^A \mid \mathbf{m}^A) \le V_v^* \quad \forall v = 1,\dots,V \\ E_{M_{zr}} V(\hat{Y}_r^B \mid \mathbf{m}^A) \le V_r^* \quad \forall r = 1,\dots,R \\ 0 < \pi_j^A \le 1 \end{cases} ,0 \qquad (4.5)$$

where $E_{M_A}(c_j) = f(\Lambda_j^A; C^B)$. The solution algorithm is identical to the one that solves the problem defined in context 2 except that the models for predicting the z-values and the expected costs are less specific, which results in a higher model uncertainty.

Remark 4.4:In some situations, the model variances $\sigma_{j,zr}^2$ are not known, and it is not feasible (for organizational or cost constraints) to carry out a pilot study for assessing them, while the predictions $\tilde{z}_{j,r}$ can be assessed with a super-simplified model as in (4.2). In order to find a realistic sampling solution, it may be reasonable to assume that the following relations hold: $\tilde{z}_{j,r}^2 + \sigma_{j,zr}^2 \cong \kappa \tilde{z}_{j,r}^2$,where $\kappa > 1$.The sample designer may find a *quasi-optimal* sampling solution by running the problem with alternative reasonable choices of the κ value (e.g., κ =2, 3 or 4), and studying the sensitivity of the different solutions.

Remark 4.5: a good strategy which allows to be robust against model failure is to select a balanced sample with respect to the auxiliary variables $\mathbf{x}_j$. In this case, the auxiliary variables $\mathbf{d}_j$ of the balancing equations are replaced by the augmented variables $\mathbf{d}_j^* = (\mathbf{d}'_j, \mathbf{x}'_j / \pi_j^A)'$. For the calculation of the variances, the residuals $\eta_{j,v}$ are substituted by the modified residuals $\eta_{j,v}^* = y_{j,v} - \pi_j^A (\mathbf{d}_j^*)' \boldsymbol{\beta}_v^*$, where $\boldsymbol{\beta}_v^* = (\boldsymbol{\Delta}^*)^{-1} \sum_{l \in U^A} \pi_l^A (1/\pi_l^A - 1)\, \mathbf{d}_j^* y_{l,v}$ with $\boldsymbol{\Delta}^* = \sum_{j \in U^A} \mathbf{d}_j^* (\mathbf{d}_j^*)' \pi_j^A (1 - \pi_j^A)$. For the modified residuals $\eta_{j,r}^*$, similar expressions are used.

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MEASURING THE STRUCTURAL TRANSFORMATION OF THE AGRICULTURAL SECTOR

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ABSTRACT

Background: Global agriculture is undergoing important structural transformations, which are creating challenges for national statistical agencies.

In many countries, large commercial enterprises, sometimes encompassing multiple farms and complex organizational designs, account for growing shares of agricultural production. Even where production is shifting to larger farms, there remain many small farming operations, such that production is highly skewed, with a relatively small number of larger farms accounting for high shares of production. In a related development, large organizations are investing in farmland — sometimes to farm themselves, and sometimes as an investment vehicle while leasing the land to farm operators. The nature of farm tasks is also being transformed. Farm may specialize in a single stage of production of a production process: for example, farms may specialize in livestock production, while other farms produce feed; they may specialize in a single stage of livestock production, such as breeding or feeding. They may contract with another farmer to manage feed crop production on their farm, while focusing their energies on livestock. Structural transformations carry challenge for statistical agencies. They may have to organize and apply surveys in different ways to capture the key elements of transformations. Even if existing surveys are adequate to the task, agencies may need to rethink the measures and reporting that they use to summarize survey results. Papers should address the methodological challenges posed for statistical systems by structural transformation in agriculture. What statistics need to be collected, and with what frequency? Does structural transformation change the universe of entities that ought to be surveyed, and how should statisticians respond to that challenge? How should samples be designed? How can we best measure the key elements of structural transformation? How have those measures changed over time?

Structural change in Dutch agriculture, impact on farm level statistics
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Structural change in Dutch agriculture, impact on farm level statistics

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ABSTRACT

Structural change has been a constant factor in agriculture, the Netherlands included. For decades the number of farms has decreased and the size of farms has increased. Agricultural statistics help to analyse and understand structural change, but at the same time structural change affects and to some extend complicates the compilation and use of agricultural statistics. Developments in the size of farms and the number of farms, although often used as indicators of structural change, have a limited impact on agricultural statistics. Other factors such as the increase in complexity of agricultural holdings have a potential large impact.

Keywords: structural change, farm level statistics, complexity

PAPER

1. Introduction

In this paper the structural change in agriculture in the Netherlands will be described. Section 2 describes the driving forces of agricultural change as described in literature. Subsequently section 3 describes how structural change has had an impact on agricultural statistics and what kind of strategies are implemented to solve these problems (section 4). In this paper we focus on the impact on farm level statistics such as the Farm structure survey (FSS) and the Farm accountancy data network (FADN).

2. Driving forces of structural change

Structural change has been of large interest to policy makers and agricultural researchers. Several studies on structural change have provided a list of factors that determine structural change. Zimmermann et al. (2009) derive 8 factors from these studies. The factors identified are technology, off farm employment, policy, human capital, demographics, market structure, social setting and economic environment.

We will highlight some of these factors. With respect to technology Zimmerman et al. refer to Cochrane's treadmill. Technological innovation reduces the per unit costs. When adoption spreads, competition increases and prices will go down. This forces the others to adopt this technology or leave the business which leads to structural change. Another effect of technology not described by them is the increase in labor productivity. In the Netherlands still many farms are run as family farms. Investment in new labor saving technologies allows the farmer or the farming family to run a larger farm with the available family labour or allows for off farm employment.

In this way, off farm employment can sustain small farms or even subsidize the farm from other income sources. Off farm employment can also be considered as the first step out of agriculture. If wages outside the agricultural sector increase it becomes more attractive to allocate more labour to off farm activities. Increase in wages can also lead to a pressure to increase the scale of the farm to achieve similar income levels as outside of agriculture.

Policies affect structural change. Measures from agricultural policies such as subsidy payments, price support, and production quota have an impact on the structural development of the sector. Peerlings et al. (2010) and Zimmerman and Heckelei (2012) for example describe the impact of the EU dairy policy on the structural change in the dairy sector in different regions in Europe. Besides agricultural policies, also other policies on taxes, social security, inheritance, credit programs can affect the structural development. In the Netherlands also environmental policies influence the development of farms by setting restrictions on the environmental pressure of farms (for example the policy that the growth of dairy farms depends on its mineral surplus and the possibilities to process these surplus minerals (de Koeier et al. 2014).

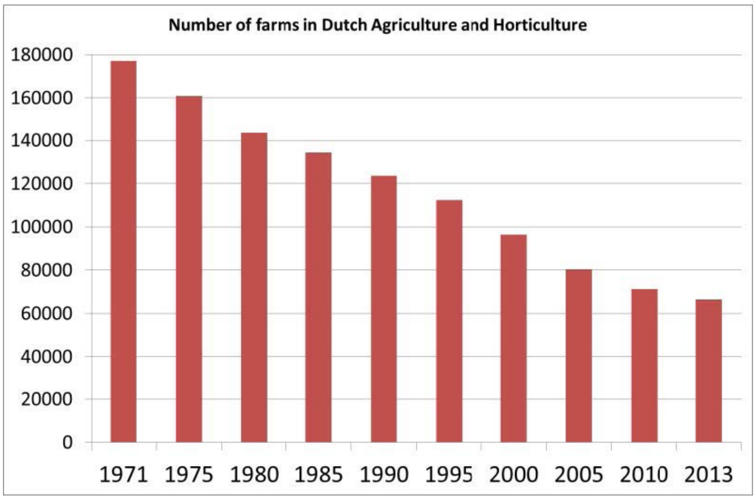
Human capital refers to schooling and management skills. Demographics refer to the age structure of farming and the availability of successors. Market structure determines the market power and therefore the setting of prices, but also the local opportunities for short supply chains (like on-farm sales). Besides market structure, also organisational structure should be mentioned. Vertical and horizontal integration has had a major impact on the agricultural sector, although the impact on structural change of agriculture is less clear. Social setting is mainly linked to the societal and individual motivations of family farming. The economic environment as a driving force for structural change refers to macro-economic developments such as price developments (especially also of labour income outside farming), exchange rates and interest rates.

This is a wide set of factors affecting structural change. Most of these factors are not directly captured by agricultural statistics. Some information is available on off-farm labour and income. Analysing these factors therefore asks to include information from other sources, apply a more case based approach or to infer proxi variables (productivity as a proxi for technology). In the next section we will describe the structural change in Dutch agriculture.

3. Structural change in Dutch Agriculture

Dutch agriculture has shown a continuous decrease in number of farms (see figure 1) and a continuous increase in the scale of production. Since the seventies the number of farms has decreased 2 to 3 percent every year. After 2000, this decrease has even accelerated. The explanation of this decrease is a combination of economic, technological and policy related factors as described in the previous section. Increased labour costs in combination with technical innovations enabled the reduction of labour input and the increase of the size of the farm that could be managed by one farmer. The increased labour costs also reflect attractive incomes in the booming economy outside agriculture. New juridical and financial structures further increased the scale of production.

Figure 1 - Decrease in number of farms



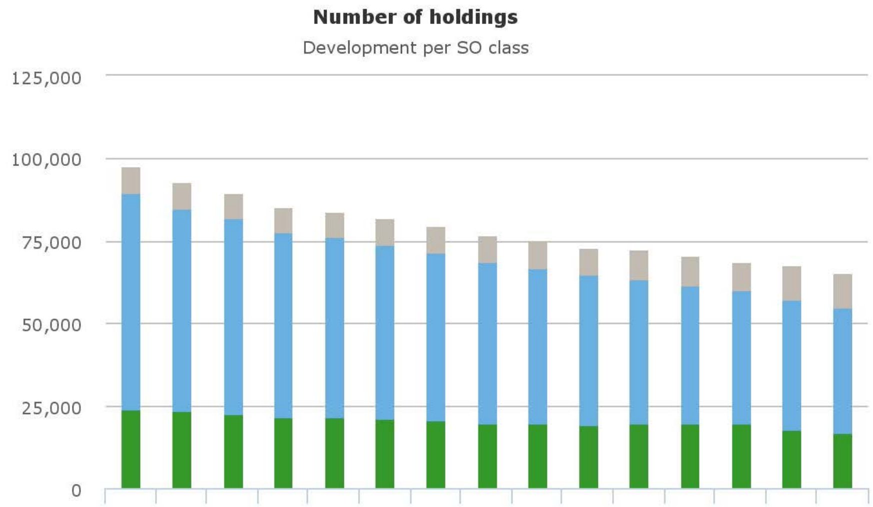
The continues increase in the average size of farms does not mean that all farms follow a similar growth path. The farming population is and always has been a heterogeneous group. Besides farm characteristics and the environment in which a farm is operating, it is also strongly influenced by different farm strategies. Some farms have chosen for a strategy of growth to grasp the benefits of economies of scale. Others have chosen a strategy of diversification of income sources by developing other off and on farm income activities. For still others the farming activity is just a hobby activity, which is not run (or only partially) to provide a source of income.

This is illustrated with figure 2. This figure shows that especially the mid-size group has declined over time (period 2000-2014). The group of small farms has remained stable at a percentage of around 25 percentage of the total farm population. The largest size group has shown a substantial increase (in number of farms and especially in the share of the production value). The mid-size group is declining because it is too small to remain competitive and too big to be run as a part-time or hobby farm.

Given these different farm strategies and differences in the developments of farms, the average size of the farm is more and more difficult to interpret. Therefor Lund (2004), later adopted by the OECD, have introduced the mid acreage or mid livestock indicator, meaning that 50% of the acres or 50% of the livestock can be found at farms larger than this mid-point and 50% on farms smaller than this mid-point. We will illustrate this indicator based on the developments in the dairy sector over a long time period.

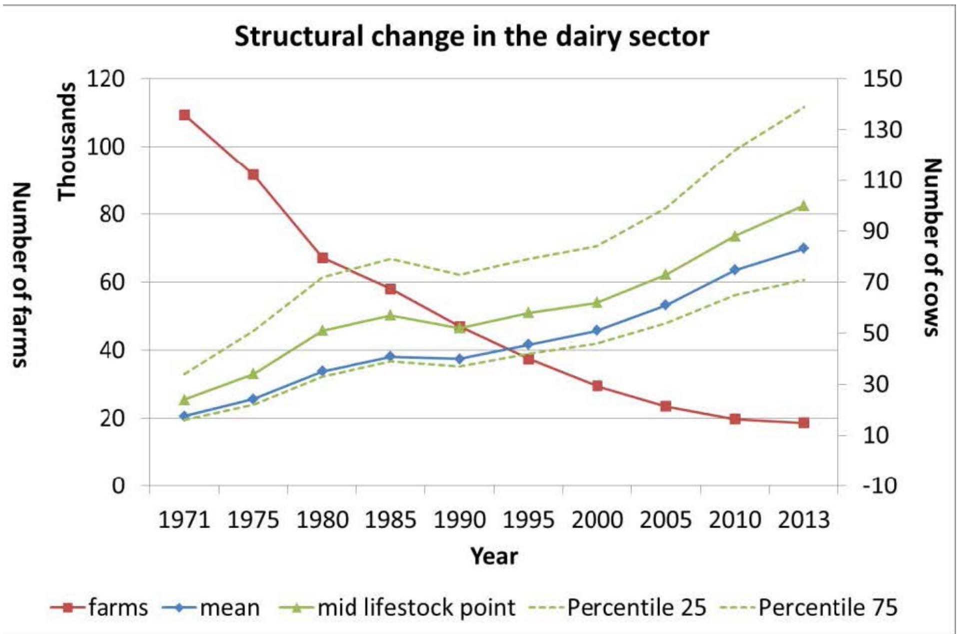
The dairy sector has always been an important sector in Dutch agriculture and structural change is clearly reflected in the developments of the dairy sector. In 1970 there were still more than 110 thousand farms with dairy cows in the Netherlands (see figure 3). The average number of dairy cows

Figure 2 - Development in the size distribution of farms



was about 25. In 2014 the number of dairy farms decreased till about 18 thousand and the average herd size increased till 84. Although still limited compared to the development in some other countries, also the Netherlands shows rapidly increasing herd sizes. The mid livestock point in 2013 was above 100 dairy cows (50% of the cows are in herd sizes of more than 100 cows) and the 75 percentile of this indicator increased till above 140 cows (25% of the cows are in herd sizes above 140). Despite this strong growth in size of dairy farms, the dairy sector still consists to a large extent of family farms.

Figure 3 - Structural change in the dairy sector



Compared to the dairy sector, the development of the landless sectors (intensive livestock and glasshouses) have even shown a much more rapid development. The average vegetables glasshouse increased from 1 hectare in 2000 till more than 3 hectares in 2013.The mid acreage point increased during that same period from 2 till more than 7 and the 75th percentile increased from 3,5 till 14 hectares.

This increase in farm size has been accompanied by large changes in the organisational and financial structure of farms e.g. to handle business risks (and separate family savings or spouse's income from the business, or to manage production in different locations. The traditional family farm (although still dominant in some of the sectors) has been replaced by limited companies and other juridical structures involving the cooperation of several farm holders.

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4. Impact on agricultural statistics

Structural change has often been studied based on the developments in number of farms and size of farms in different sectors (Goddard et al, 1993; EU, 2011; Offerman and Margarian, 2014). These factors are relatively easy analysed and well described by agricultural statistics. Also in the Netherlands the agricultural census provides meaningful data to describe these developments (as reported in section 3 above). Size and number of farms have however a limited impact on agricultural statistics. Other factors reflecting structural change (Jaklic et al., 2009; Goddard et al, 1993) have a much bigger impact on agricultural statistics. Table 1 gives an overview of the factors of structural change and its impact on the compilation and use of agricultural statistics. These impacts will be further elaborated in this section.

Table 1 Characteristics of structural change and impact on agricultural statistics

Factors of structural change	Impact on agricultural statistics
Increase in size of farms	Limited, small farms often cause the largest problems;
	Increase in record keeping facilitates data collection
	Impact on sampling plans
Larger dispersion in size	Need for other indicators (average has limited value)
	Increased risk of disclosure
	Choice of allocation mechanism in sampling becomes more relevant: e.g optimal vs proportional
Decrease in number of farms	Cheaper census, less elements
	More difficult to include sample elements of small strata;
	Impact on sampling plan
Increased specialisation	Easier data collection, less relevant data items Could improve or complicate benchmarking
Increased complexity (vertical and horizontal integration)	Definition of a farm becomes more unclear
	Increased risk of different definitions in different administrative / statistical / commercial systems
	More difficult data collection (in case different intertwined activities in bookkeeping)
	More difficult recruitment in voluntary sample
	Difficult separation of agricultural and nonagricultural activities and agricultural outputs can be hard to observe and value if they are input to another product (e.g. maize for energy production)
	Complicates use of data for benchmarking
Financial structure	Other indicators needed
Increase in Multi household farms	
	Decreased feasibility of collecting off-farm income
	Increased complexity of collecting farm demography
	Multi dm's increase complexity of farm recruitment in voluntary samples
Age structure	Young farmers better educated, more used to recording
Farm entry / exit	Difficult to capture with current statistics, especially in voluntary systems

Increase in size of farms

An increase in size does not necessary complicate agricultural statistics, in practise often the small farms cause problems (Pedersen, 2013). If the increase in size continues it could lead to changes in the structure and management of the farm that do have a strong impact. The increasing organizational complexity of farming establishments can affect data collection, accuracy of estimates, and the use of data, e.g., in multivariate and policy analysis, disclosure, and dissemination of estimates (Ahearn, 2013).

Increase in dispersion in size

Structural change affects the sample design procedures applied in agricultural statistics. Most countries apply a disproportional stratified sample in their Farm Accountancy Data Network (FADN) or other business-related statistics with a type of Neymann-allocation to allocate the sample capacity to the different size classes. The calculation of the heterogeneity is often based on the variance of the economic size in a stratum. Due to structural change and the increasing farm size the heterogeneity in the largest stratum increases rapidly. Applying the Neymann allocation could therefore results in a large shift of the sample capacity to the largest strata in each of the types of farming. Taking into account the non-response rate, extra work on bigger (more complex) farms and the decreasing number of farms this results in infeasible sampling plans. An increased dispersion of farm sizes could make indicators such as averages more difficult to interpret and creates a need for alternative indicators (Lund and Price, 1999).

Decrease in number of farms

A decrease in number of farms reduces the costs of a census as data on less farms needs to be collected. However, such a decrease could complicate sample statistics because the choice of farms in a certain strata is more limited, which could increase the recruitment costs. Furthermore changes

in the distribution of farms over different farm types might require an adjustment of the sampling rates in different strata. In the use of the data, a decrease in population numbers could make it more difficult to publish results of subgroups because of a lack of data.

Increased specialisation

Given the trend to specialize production, the number of mixed farms is decreasing in almost all countries at a stronger rate than the farming population in total. Data on specialised farms are often more easy to collect (less relevant data items) and more easy to use (no arbitrary allocation of overhead costs and inputs to different agricultural activities). One exception is specialisation in niche markets (for example in horticulture producing a specific flower or plant). Such specialisation could reduce the willingness of farmers to participate due to a lack of relevant benchmarking information and the perception that data is competitive sensitive information.

Increased complexity

Changes in the legal structure of enterprises, multiple households related to one agricultural holding, agricultural activities intertwined with other commercial activities or other on and off farm income sources raise serious conceptual and practical questions.

A large share of farms supplement their farm income with income from other sources (off farm and on farm). Besides the traditional other gainful activities such as cheese production, nature management and farm tourism, also other activities such as care farming, investments in renewable energy (digesters, wind mills) become more and more important. Sometimes these activities are conducted in the same business holding, sometimes separate legal entities are started for these activities.

All these issues affect the definition of a farm and the farming sector. The definition as applied in agricultural statistics 'a single unit, both technically and economically, which has a single management and which undertakes agricultural activities' (REGULATION (EC) No 1166/2008) becomes more difficult to apply in practise.

There is an increasing difference how a farm is managed in practise and how the farm is recorded in the agricultural census. In the Netherlands more than 5% of the farms as recorded in the Farm accountancy data network have multiple recordings in the agricultural census. The reason of these multiple recordings can differ from manure application laws, entitlements for subsidy payments, financial and organisational structures (like having bought a farm at a second location that is then integrated in the mother farm but legally still registered as a separate farm).

This complexity also affects the participation rates in FADN. To some extent it is a challenge to fit in these complex structures in the normal FADN data collection, therefore data collectors might be tempted to exclude these type of enterprises from the sample which might result in a biased sample. Furthermore also the respondents might refuse to participate because they feel less connected to the agricultural sector and might not consider themselves as a 'representative' unit to be included in agricultural statistics (Vrolijk, 2005).

Financial structure

The idea of a family farm which is operated with a lot of own assets and some bank loans to finance new investments is becoming less common. Farming is a capital intensive activity, and therefore often requires large long-term loans. These developments have an impact on data collection and especially on the use of the data. In the use of the data this means that also an indicator like family farm income is a less suitable indicator to compare the profitability and distribution of income of farms. Johnson et al.(2007) propose to use net value added (NVA) at the micro level to reflect the participation of a wide variety of stakeholders (e.g. banks, land owners, paid labour) in the organization and output of farms.

Multi household farm business

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The increasing complexity of farm structures is also shown in the increasing complexity of collecting off farm income statistics and an a decreasing trend of the willingness among farmers to provide these data (increase in item non response). This not only asks for a re-evaluation of the relevance of off farm income for the operation of the farm, but also a revision of instructions which data items to collect for which persons in which households. (data for only the spouse of the farmer in family farms, or also for a broader set of household members of the farm holders of multi household farm holdings). Multi household farm businesses could also complicate recruitment processes in voluntary data collection because the commitment of several persons is needed.

Age structure

Old farmers are often less willing to participate. An ageing farm population could therefore make recruitment of farmers for a system like FADN more difficult. Willingness of participation is lower due to the idea that the farming business will end or be transferred in a few years' time. Furthermore there is a link between age structure and level of (agricultural) education. A higher level of education leads to a higher interest in useful management information and the willingness to benchmark farm performances and therefore increase the willingness of participation.

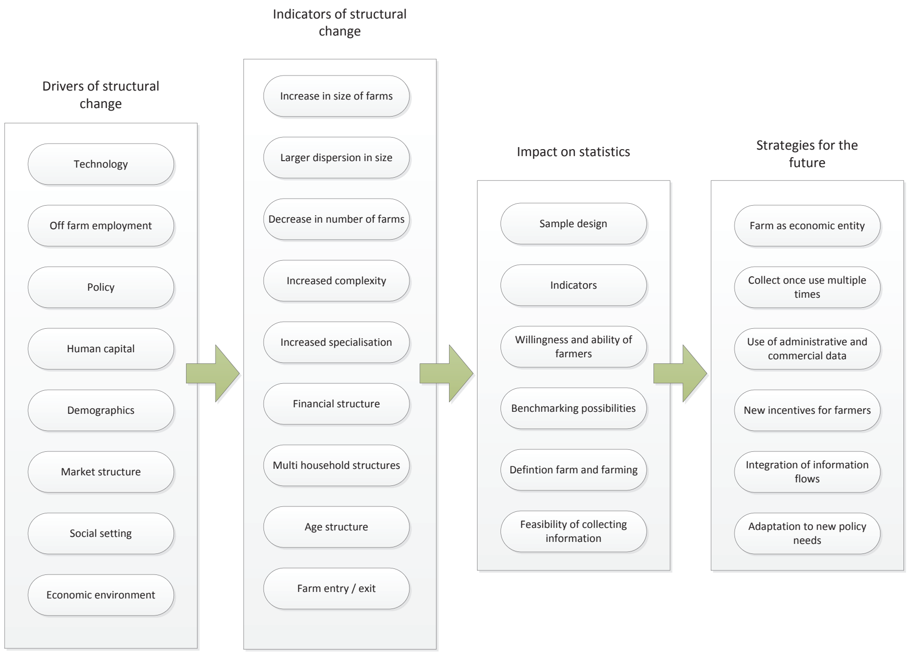
Farm entry exit

Farm entry and exit is an important indicator of structural change but is difficult to fully grasp by agricultural statistics. The farm accountancy data network (FADN), which provides extensive information on the economic performance of farms, is organised as a rotating panel, and the current statistics do often not allow determining whether a farm exits the survey due to the closing down of the farm or other reasons (Offerman and Margarian, 2014). The farm structural survey on the other hand provides information on farm entry and exits but also there it requires further analysis to understand the development of farms (merging of farms, change in juridical structure etc.).

5. Solutions and Future steps

Given the structural change of Dutch agriculture as described in section 3 and the potential impact of structural change on the compilation and use of agricultural statistics as described in section 4 there are some important challenges in the system of agricultural statistics. This section describes some principles and initiatives in the Netherlands to handle these challenges. Figure 4 provides the framework with drivers of structural change, the indicators of structural change, the impact on statistics and the strategies for the future. These strategies focus on the definition of the farm, the way of collecting data, the way of involving farmers and the need to reconsider the whole system of agricultural information.

Figure 4 - Structural change and the impact on future strategies in agricultural statistics



Definition of the farm and farming sector

In the past farmers who were in the farm register received an invitation to submit the agricultural census. Due to the focus on active farmers in the current CAP, the population of the agricultural census

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has been redefined as those enterprises registered at the chamber of commerce as an agricultural producer (according to the NACE coding system). This registration as an agricultural producer is also a requirement to receive agricultural subsidies. Besides adapting to changes in the CAP, this change also reflects the trend in the Netherlands that agricultural enterprises are treated as any other economic sector.

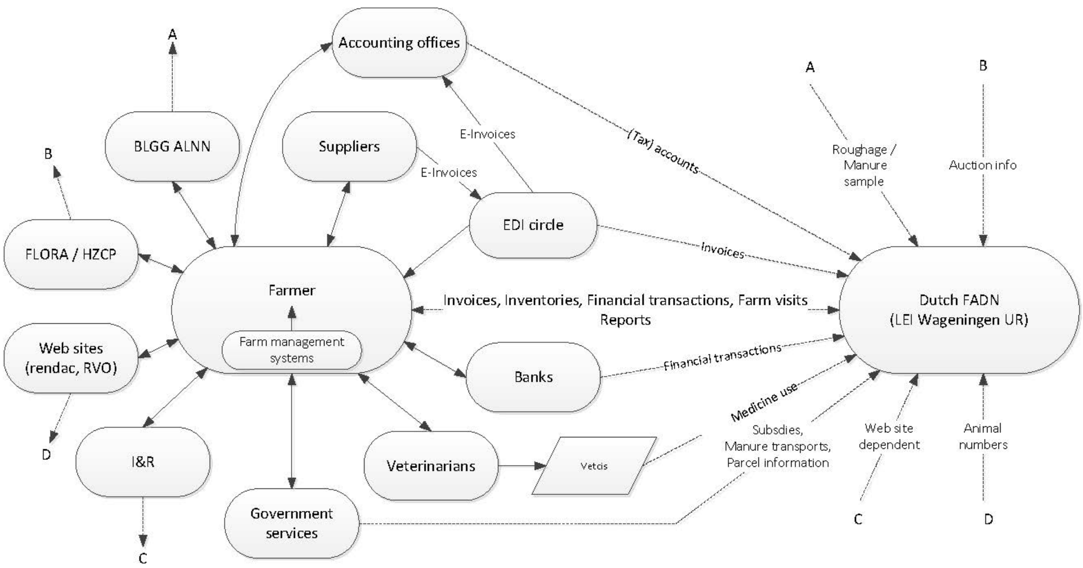
Collect once use multiple times

In Dutch agriculture there is an increasing group of farmers who only want to share information if it does not take too much of their time. For those farmers, the traditional data collection methods of a data collector and the farmer filling in forms at the kitchen table does not work anymore. This is not only true for farmers, but for all entrepreneurs. An important policy objective of the Dutch government is the reduction of the administrative burden. One of the core elements of this policy is the 'collect once use multiple times' principle. The government can only ask a specific data item once. If this item is needed for other administrative or statistical purposes the already collected data should be reused or the data collection should be integrated. This has resulted in an integration of data collection for administrative and statistical purposes.

Increased use of administrative and commercial data

As a next step, large benefits can be gained by re-using not only administrative data but also commercial data. In the Dutch FADN system there is a strong focus on the re-use of existing data to lower the administrative burden, to increase the efficiency of data collection, to increase the quality of the data and to enable a wider set of analysis. In Dutch FADN a wide set of data sources is used to compile the farm (bookkeeping) data. Figure 5 illustrates the data sources used. This varies from bank transactions to use of animal medicines, and from electronic invoices to information on the manure flows. All these data sources are used to compile the recordings for individual farms. At the end of the year, the system generates a list of missing data items which should still be asked from the farmer (for example labour hours or allocation of inputs to different crops). In this way the administrative burden for farmers is minimized by only asking the farmer, if there is no other information source available.

Figure 5 - Data sources in Dutch FADN



Incentives for farmers

In these systems it is also increasingly important to consider the benefits to farmers and the farming sector to share this information. New concepts need to be developed where all stakeholders benefit. Other incentives for farmers to participate are needed.

6. Discussion

This paper described structural change and the impact on agricultural statistics. Responding to these developments requires the adaptation of the content and working procedures on agricultural statistics. It is important to realise that this is not the only need for agricultural statistics to adapt.

Also the requirements for agricultural statistics change. New policy and research topics emerge that need to be analysed and for which relevant information is necessary. This requires the adaptation of the system of agricultural statistics to the new policy needs. At the EU level this is a slow process. In the Netherlands the ability to adapt to these changes has been a core design principle in the national FADN.

In this paper we have focused on farm level statistics. Structural change also has an impact on other types of agricultural statistics, such as price statistics. In certain sectors price statistics become more difficult to compile because of an increased heterogeneity in production (due to a strategy of product specialisation and niche markets) and due to a concentration in production and in chain actors. As a consequence, price information is more and more treated as competitive sensitive information. Also changes in the marketing of products from auctions to direct contracts reduces the availability of price information. Although some of trends make the access to information more difficult, at a broader scale the availability of information only increases.

With the trends of big data, internet of things and precision agricultural the availability of information will only further increase. Also the need for information in the agro food sector increases continuously. Traceability, certification, labelling, production planning require detailed data on production and production processes. This makes it even more necessary to consider the whole system of information flows in the agricultural sector to achieve a synergy between the different needs and applications.

All these developments make it necessary to not only look at the needs for agricultural statistics. Agricultural statistics should be an integral part of the whole system of information needs and information flows in and about the agricultural sector

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PL03

Structural transformation in North America: what does it mean for agricultural statistics?

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ABSTRACT

Farming in North America is undergoing a series of structural transformations: production is shifting to larger farms; farms are adopting more complex organizational arrangements; and consumer demand is changing, with a greater emphasis on more highly differentiated agricultural products. Analysis of these changes is complicated by another feature of farm structure—the farm size distribution is highly skewed, with many very small farms and a heavy concentration of production by a relatively small number of large farms.

Structural transformation creates a series of challenges for statistical agencies; the challenges are not completely novel, as statistical agencies have been dealing with each of these issues for many years. However, agencies may have to organize and design surveys in different ways to capture the key elements of transformation, and to continue to provide reliable measures of standard variables of interest. Even where existing surveys are adequate to the task, agencies may need to rethink the measures and reporting that they use to summarize survey results.

Keywords: Farm structure, farm size, farm organization, census of agriculture

PAPER

1. Introduction

Farming in North America is undergoing a series of structural transformations: production is shifting to larger farms; farms are adopting more complex organizational arrangements; and consumer demand is changing, with a greater emphasis on more highly differentiated agricultural products. Analysis of these changes is complicated by another feature of farm structure—the farm size distribution is highly skewed, with many very small farms and a heavy concentration of production by a relatively small number of large farms.

Structural transformation creates a series of challenges for statistical agencies; the challenges are not completely novel, as statistical agencies have been dealing with each of these issues for many years. However, agencies may have to organize and design surveys in different ways to capture the key elements of transformation, and to continue to provide reliable measures of standard variables of interest. Even where existing surveys are adequate to the task, agencies may need to rethink the measures and reporting that they use to summarize survey results.

We describe these elements of farm structure and structural change below, and then show how each affects statistical surveys and reporting. We use U.S. data from censuses of agriculture, including a 2014 followon to the 2012 census called to Tenure, Ownership and Transition of Agricultural Land (TOTAL) survey, which replaced USDA's large annual farm survey--the Agricultural Resource Management Survey (ARMS)--in that year.

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2. Structural Change

We focus on three key elements of structural change: shifts of production to larger operations, increasing organizational complexity in the farm sector, and increasing commodity differentiation. Analysis of each is complicated by an ongoing feature of the farm sector: the extreme skewness of the farm size distribution.

What do we mean when we say that the U.S. has a skewed distribution of farm sizes, and why does it matter? We use U.S. crop farms as an example, using data from the 2014 TOTAL survey (figure 1). Most crop farms are quite small: nearly half had less than 50 acres of cropland in 2014. However, those small farms collectively accounted for only 3.5 percent of cropland and less than 7 percent of the value of crop production. The distribution also features a long tail: over 50,000 farms had 1,000-2,000 acres of cropland, and the range extends to nearly 100,000 acres. Farms with at least 1,000 acres of cropland—6.2 percent of all crop farms--accounted for well over half of cropland and crop production.

The skewness is apparent in summary statistics. The mean farm size (261 acres of cropland) far exceeds the median of 50 acres. However, most cropland and crop production is on farms that are far larger than the mean: the midpoint, where half of all cropland is on larger farms and half is on smaller, was at 1,296 acres in 2014. The U.S. farm size distribution has grown more skewed in recent years, as the middle has hollowed out while farms and acreage have moved to the extremes (MacDonald, Korb, and Hoppe, 2013).

We have used cropland acreage as an example, but similar patterns appear for livestock (herd and flock sizes) and for distributions using farm sales or value of production. Most farms are very small, while most animals, acreage, or sales are on a relatively small number of large farms.

The skewness of farm sizes is particularly pronounced in the U.S. because of the way we define farms, using a commodity sales threshold that is relatively low ($1,000 worth of commodity sales, or land or animal assets capable of generating $1,000 in sales) and not adjusted for inflation. We have seen sharp increases in the reported number of very small farms since 2002; with increasing numbers of very small and very large farms set against declining numbers of midsize farms, and stable total cropland acreage, we see little change in mean size even as land shifts to larger operations. However, while skewness is extreme is the U.S., it is a feature of agriculture sectors in other OECD countries as well (OECD, 2015)

2.1 Production is shifting to larger farms

Why does a skewed distribution matter? It affects sample design choices, as we see below, but it also complicates reporting on structural changes. For example, the mean crop farm size in 2014—261 acres—was only slightly above the 1992 mean of 257 acres. If one looks only at the mean, easily calculated and widely reported in our official publications, one would not think that there was much consolidation in the U.S. farm sector (figure 2, using census data only). However, that conclusion is shaken by the trends in midpoint sizes. For cropland, the 2014 midpoint of 1,296 acres was noticeably larger than the 2012 midpoint of 1,201 acres, and much greater than the 1992 midpoint of 749 acres, which in turn represented a large increase from 589 acres in 1982 (figure 2). The U.S. has undergone a substantial shift of cropland and production to larger farms, but our simple measures don't capture it.

The shift of acreage and animals to larger operations is large, and an important element of structural change. It has been occurring in almost all U.S. states and almost all crop and livestock commodities, and has been persistent over time (MacDonald, Korb, and Hoppe, 2013). The census of agriculture provides enough commodity detail to track midpoints for harvested acreage in specific crops, as well as animal inventories and removals, from 1987 through 2012. We report estimates for selected crop and livestock commodities in table 1. Dramatic changes occurred in hog and in dairy sectors, but we can also see quite striking changes in fruits and vegetables and in field crops.

The pattern is not unique to the United States. A recent OECD study documented a general pattern of shifts of acreage and animals to larger operations, although the shift was most pronounced in the U.S. and in Canada (OECD, 2015).

2.2 Farm businesses are becoming more complex

Structural change also encompasses increasing organizational complexity, covering how agricultural tasks are allocated among firms, and how farms and other agricultural businesses are organized.

Consider how farms are organized. Some farms are now part of multi-farm businesses: for example, some family businesses own several large dairy farms, or large grain operations in several states, or multiple cattle feedlots. Farms may also operate non-agricultural "value added" businesses that complement the farm business. For example, a farm family may also operate a bed and breakfast agri-tourism business, or a cheese-making business linked to a dairy farm, or a trucking business growing out of the farm's livestock or grain movements. We think that each of these are growing phenomena, but we don't have comprehensive data on the topic.

In other instances, businesses that look as if they are based on a single farm operation may organize themselves into several ownership entities for purposes of minimizing taxes, maximizing government payments, or managing family conflicts (or example, a farm may organize a land-owning entity, held by various farming and non-farming family members, and an equipment owning entity also owned by family members; each entity may then rents land and/or equipment to one or more farming entities, also owned by various family members).

The above examples concern how farm businesses are organized. The other issue of complexity concerns the performance of agricultural tasks by non-farm businesses. For example, contract agriculture links independent farms and farm input providers through a network of contracts. For example, about 95 percent of U.S. broiler production is coordinated by 20 large integrators, which own hatcheries, feed mills, and processing plants (MacDonald, 2014). The integrators contract with farms to provide eggs for hatcheries, and they contract with about 15,000 independent growers to raise chicks to market weight. Contract growers, who invest in housing and equipment, are provided with feed, chicks, and support services by integrators, and their compensation reflects pay for growers' services rather than payment for the value of the birds. Similar arrangements, where farm production costs are shared by several different firms, can be found in egg, turkey, and hog production, and in some areas of vegetable production and horticulture. In these cases, farms provide only some of the inputs in agricultural production, while integrator, who are necessarily defined as farms provide the rest.

Similarly, some farm tasks may be performed by specialized service providers that are not farms. Crop tasks—like field preparation, planting, spraying, or harvesting—are frequently performed by custom service providers for a fee. Some custom providers are also farm operations aiming to use their equipment and labor more intensively, but others do not operate their own farms and are not captured in surveys. Other specialized service providers include labor contractors, farm management firms, and equipment lessors.

2.4 More differentiated agricultural products

There is growing interest in agricultural products with differentiated physical attributes, like taste, color, or size. Examples can be found in many fruit and vegetable products, such as eggplants, peppers, potatoes, tomatoes, cantaloupes or tangerines, but they can also be found in some meat products, such as pork from "heirloom" varieties of hogs.

However, there is also growing consumer interest in the processes associated with farm production, and therefore with products that are differentiated not by their physical attributes but by their production processes. Examples include livestock raised without antibiotics, pork from farms that don't use gestation crates, grass-fed beef, cage-free eggs, or food products that have no ingredients from genetically modified plants, to name a few. The common feature of these products is that the relevant attributes are features of farm-level production processes; consumers care about the processes, but cannot observe them. In these cases, consumers rely upon some sort of certification of processes, whether provided by farmer advertising, retailer assurance, third party certifiers, or government agencies.

There's also a growing interest in locally produced agricultural commodities, which bear some resemblance to products differentiated by production processes, in that consumers can't observe whether a product was actually produced locally.

There is every reason to believe that interest in these and other alternative agricultural products will continue to grow, and that statistical agencies will have to consider how to track and report on the products, and how to account for their influence in existing reporting.

3 Structural Transformations and Statistical Surveys

Statistical agencies have been dealing with each of these challenges for many years. They use stratified sample designs, with greater sampling probabilities attached to larger operations, to handle skewed size distributions, especially when the reporting of production or sales aggregates is the goal. They sort data into farm size classes—measured by acres, animals, value of production or sales—when reporting on the farm size distribution itself. They put extra—sometimes special—effort into handling complex farms and operations that are large enough to appear in many survey samples. In a sense, our story is about the accentuation of issues that statistical agencies have been dealing with for some time

3.1 Structural change, reporting, and survey design

USDA puts considerable effort into reporting on farm structure. For example, census of agriculture publications report the number of farms, harvested acreage, and production, sorted by harvested acreage class, for 31 different field crops (USDA/NASS, 2014). The classes are well thought out and their range updated for structural change, so that the largest class listed rarely accounts for more than one-quarter of acreage and production. For most of those crops, one could estimate the midpoints reported in table 1 with considerable accuracy, based only on publically available data and not the confidential data that underlie the table. One could also generate means and good estimates of medians from the data at hand, and could use the reported distributions to provide comprehensive information on changing structure.

However, the effort is not quite as successful in other vegetable and livestock commodities, where the largest size class reported frequently accounts for well over half of harvested acreage or animal inventories. In that case, one can't really generate a good estimate of a midpoint, and one can't use the full distribution table to track changes in structure. The critique also extends to several of the all-farm size distributions based on value of production or acreage (the summary tables), where the largest size class again includes most production or acreage.

Structural change affects survey design as well as reporting. With production consolidating in a smaller number of large farms, some farms now have a high probability of appearing in many surveys. Since many of these same farms are also approached by private data collectors, and since many of them also have regulatory reporting requirements, statistical agencies face a growing problem of respondent burden. Declines in large farm response rates, should they occur, would threaten the viability of many estimates.

One approach to dealing with the particular respondent burden faced by larger operations would be to take a more tailored approach to them. Statistical agencies could seek to acquire information in ways that reduce burden, by adjusting to the reporting systems used by large operations; by altering survey forms to ask for updates, rather than newly filed information in each visit; or by seeking to allocate common information acquired in one survey to other surveys as well. Each of these could be extended from statistical surveys to regulatory and administrative filings, in order to further reduce respondent burden, with one major caveat. Data collected in statistical surveys retain confidentiality protection, such that individual records cannot be disclosed to the public or to regulators; administrative and regulatory filings are not subject to the same protections.

3.2 Farm complexity: who and what to survey

Complexity creates several interrelated statistical challenges. USDA surveys generally use farm respondents to generate data on production, acreage, input use, financial outcomes, and other features of the agricultural economy. With a focus on farms as respondents, samples for agricultural surveys and censuses are drawn from sampling frames that are lists of farms, and considerable effort is put into building and maintaining lists.

With organizational complexity, farms are not always the best source of information. In contract production arrangements, where some inputs are provided by farms and some are provided by contractors, the contractor may be better informed (for example, about feed or chick expenses in contract poultry production). Similarly, for multi-farm firms, a central office may be better placed to provide information on certain expenses. Farms can provide information on expenses and tasks associated with custom services, but may not be informed about other specific features. Statistical agencies often maintain contacts with contractors and central offices to obtain these data in their normal course of business, but the relationships are often informal and non-systematic.

Because sampling frames are built from farms, USDA can also provide extensive reporting on farm structure. For the same reason, however, USDA surveys are not organized to support reporting on multi-farm firms, providers of farm sector services, or non-farm contractors. Efforts to track and report on multi-farm firms, agricultural service providers, or contractors would require a new effort to build business lists into sample frame. That exercise could use some non-comprehensive sets of linkages built by statistical agencies as part of their normal business. However, they would most likely need to use tax and other administrative records to build up to a more comprehensive file. In short, reporting on multi-farm firms and farm service providers would require an investment in building sampling frames.

The notion of complexity also includes "value-added" activities associated with farm businesses—such as further processing of agricultural commodities, or the joint production of farm and tourist services with farm inputs. Value-added activities matter for the agricultural sector farm income and productivity accounts produced by USDA: to the extent that they are joint products that depend upon at least some of the same inputs used for farm production, each account needs to take account of the returns to such farm-related activities. USDA surveys aim to elicit enough information on them to fulfill the needs of those accounts, but agencies do not aim to report separately on them.

3.3 Product differentiation: tracking and interpretation challenges

Because they are more costly to produce, differentiated products typically generate higher prices than conventional products. This can create challenges for reporting on farm productive and financial performance. If differentiated products are not reported separately from conventional products, then average measures of costs of production, gross returns, and net returns may be reflective of neither the conventional nor differentiated product, but an amalgam of them. Moreover, if differentiated products account for a growing share of production, or if their cost and price trends do not track conventional cost and price trends, then aggregate reported trends may not be reliable indicators or trends for either differentiated or conventional products.

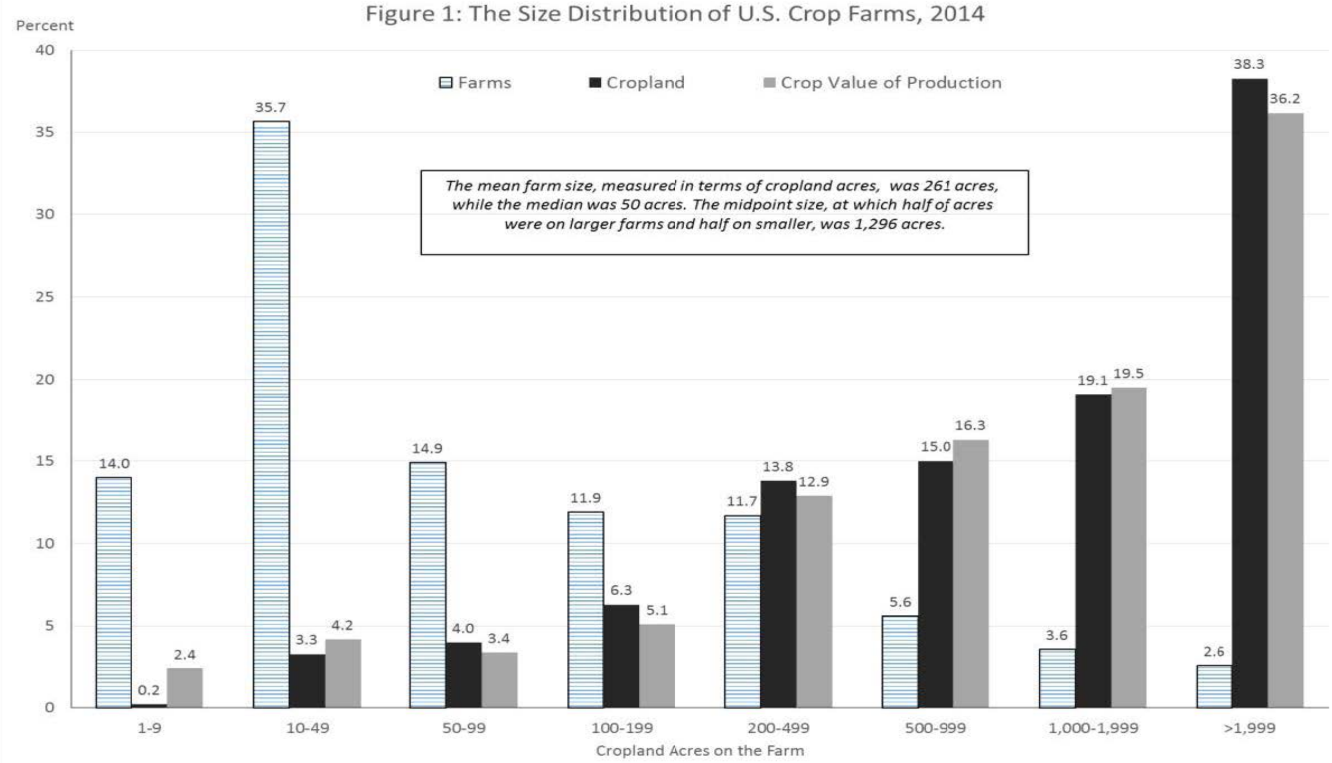
For this reason, but primarily because of interest by industry participants, differentiated products create new demands for reporting on specific differentiated commodities—for timely information on production, inventories, and sales as well as reporting on prices. These demands may sometimes be met through low-cost adjustments to ongoing surveys, but they also may require new surveys. These are standard tasks for statistical agencies, but doing new surveys can put resource pressures on agencies.

4. Conclusion

Structural change in agriculture results partly from changes in technology that allow farmers to manage more cropland or more animals, and to utilize more complex organizational forms. Some technological change results from innovations derived from biological sciences and some results from mechanical innovations; however, some also results from improvements in information technology (IT), bit directly and as applied in biological and mechanical innovations.

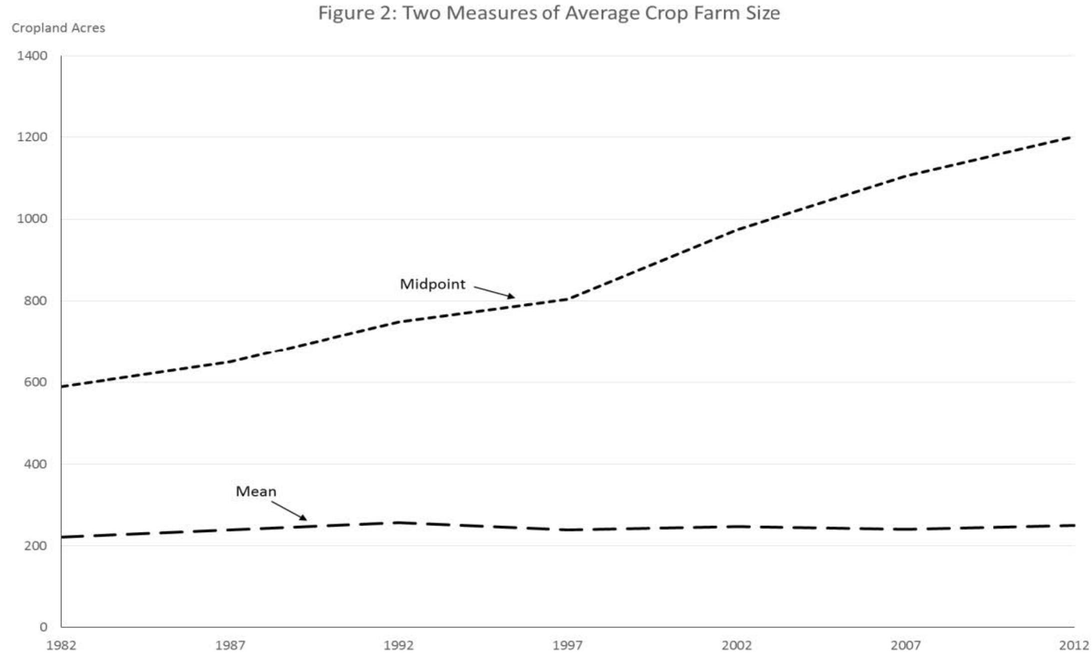
IT innovations also affect statistical agencies, by facilitating improvements in survey design, administration, and editing as well as facilitating more rapid and more widely disseminated reporting. Thus while structural change in agriculture create new challenges for statistical agencies, the accompanying changes in information technology create some opportunities for different ways of gathering and reporting on data.

Figure 1: The Size Distribution of U.S. Crop Farms, 2014



Source: USDA Tenure Ownership and Transtion of Agricultural Land (TOTAL) Survey, 2014

Figure 2: Two Measures of Average Crop Farm Size



Source: Economic Research Service calculations, from USDA census of agriculture

Table 1 Acreage and animals shift to larger operations

Crop commodities	Midpoints		Livestock commodities	Midpoints	
	1987	2012		1987	2012
	Harvested acres of crop			Inventory (cows/layers)	
Corn	200	633	Milk cows	80	
Soybeans	243	567	Beef cows	89	
Wheat	404	1.000	Egg layers	117.839	
Carrots	350	1.053		Head sold or removed	
Cucumbers	115	450	Fattened cattle	17.532	38.369
Potatoes	350	1.054	Hogs and pigs	1.200	40.000
Tomatoes	400	930	Broilers	300.000	680.000
Apples	83	179			
Almonds	203	547			
Oranges	450	961			
Strawberries	24	180			

Source: Economic Research Service calculations, from USDA census of agriculture records.
Note: the midpoint is the size of farm at which half of all acres, or animals, are on larger farms and half are on smaller. For livestock, inventories are at end of year, and removals are annual.

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Structural change in Brazilian agriculture

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ABSTRACT

The paper presents prominent aspects of the changes in the structure of Brazilian agriculture. The purpose was to address the main structural changes found in Brazilian agriculture, based on census data. Data from the 1960 census and 2006 are compared. The general outline of the changes reflects the industrialization process of agriculture, where old functions are absorbed by upstream and downstream activities. It was argued that a complete view of the agriculture structure should refer to the overall agriculture value chain. The lack of data was then discussed, as well as the growing demand for statistics relating to the value chain, particularly those revealing the phenomena of integration and quasi-integration in agriculture.

Keywords: agricultural statistics, agricultural structure, Brazil

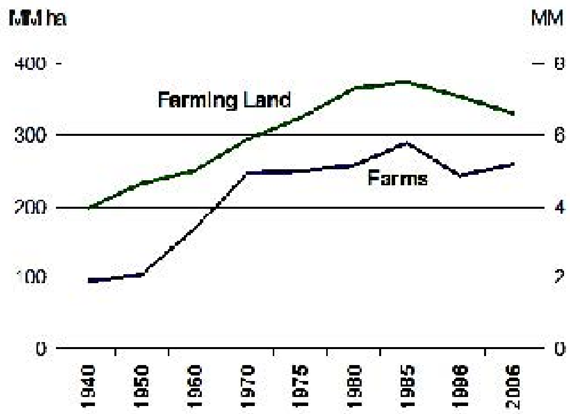
PAPER

1. Structural changes in Brazilian agriculture

Many changes in Brazilian agriculture are self-evident. They can be clearly associated with the modernisation and industrialisation processes of Brazilian agriculture that has seen a major boost since the 1960s.

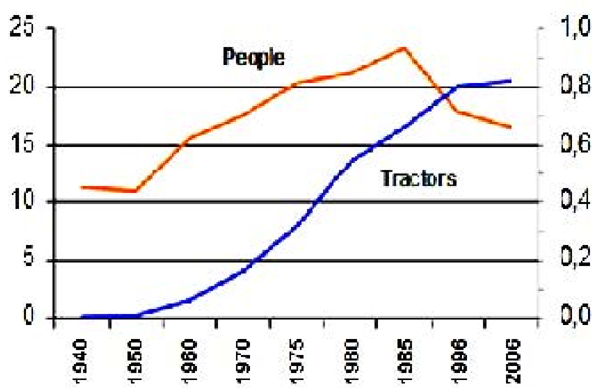
In this context the differences in scale are considerable: just considering the growth and size achieved in the activities developed there, in the course of the last fifty years. Since 1960, there was an increase in cattle herds threefold, daily production sixfold, poultry ninefold, grain production sevenfold and sugarcane production tenfold. This implied an increase of 33% in farming land, 2.7% in the cropping area, and 1.3% in pastureland, with almost another two million farms, the total number of which rose from 3.3 to 5.2 million. On the other hand, the contingent of people occupied in farming has dropped around one million from 16.6 to 15.6 million.

Graph 1: *Number of farms and farming land, Brazil, 1940-2006*



Source: IBGE – Censo Agropecuario

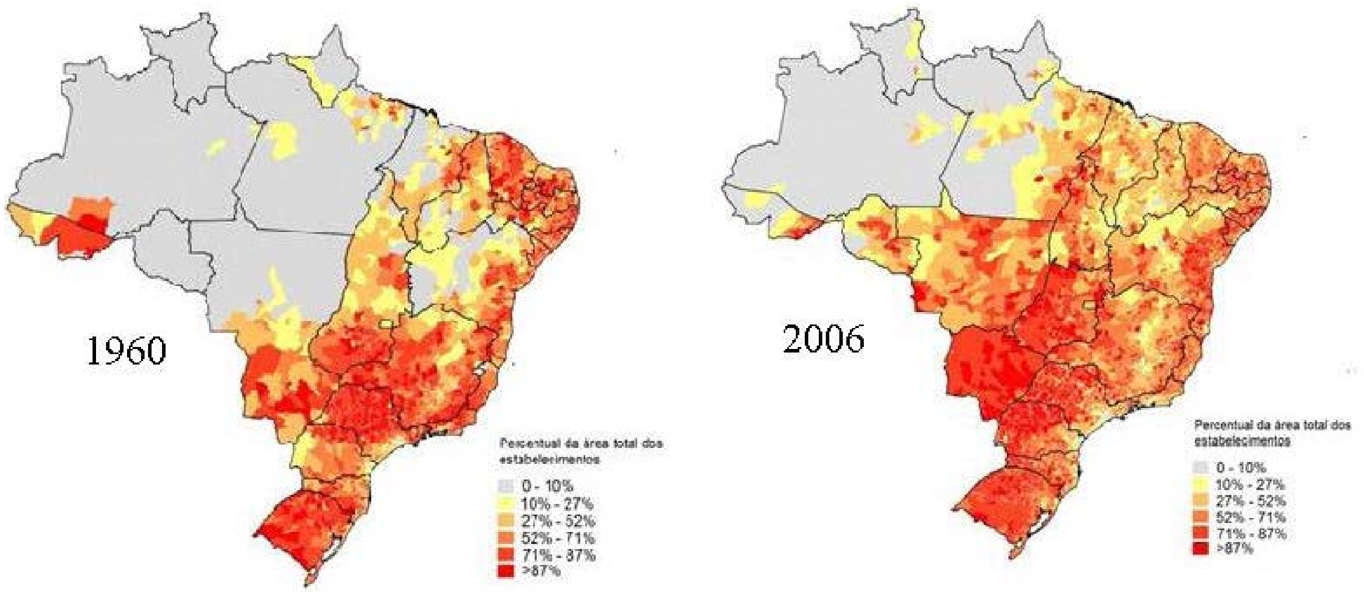
Graph 2: *People occupied and number of tractors, Brazil, 1940-2006*



Source: IBGE – Censo Agropecuario

Expansion meant the addition of new areas and more intensified farm production. The following cartograms show changes observed in the density of agricultural exploration in national territory, noting the occupation of land by farming enterprises, intensity of cropping and cattle farming, as well as the degree of mechanisation, expressed by the availability of tractors in relation to the total surface of each municipality. The same stratifications (legends) were used for 1960 and 2006, in order to demonstrate the changes. In 1960 large areas of land in Pará, Maranhão, Mato Grosso, Rondônia and even Bahia had a very low occupation per farming enterprise 1960, (less than 10%), and today they are considerably more apropriated and explored (Figure 1).

Figure 1 - Intensity of farming occupation - Brazil, 1960/2006



Source: IBGE – Censo Agropecuario
Note: Total area of farms over the land surface of the municipality (%).

The change in the pattern of Brazilian agriculture results in major changes to the production composition. For example, it is worth noting in the case of soybean today as one of the principal crops with 17 million hectares harvested in 2006, while in 1960 its area was not even considered worthy of census calculations. Also iconic is the fact that coffee plantations currently cover less than half the area covered in 1959.

The farming activity is still considerably concentrated in terms of space, conforming to the most suitable edaphoclimate conditions. It is strongly intensified in São Paulo and South Brazil, especially in Paraná, with its agriculture even more concentrated in the northern part of the State and its amazing displacement towards the savannah regions, with important enclaves in Mato Grosso, Goiás and Bahia.

Intensification, displacement and spreading are much more noticeable in livestock farming. Its expansion over the last fifty years evidenced a major increase in its intensity over vast regions in Pará, Mato Grosso, Rondônia, Acre, Mato Grosso do Sul and Paraná, and the abandonment of certain regions with more profitable farming alternatives, as occurred in São Paulo. As figure 2 demonstrates, between 1985 and 2006 cattle farming was replaced by cropping in the regions more favorable to agriculture, and the intensity of both activities increases in the western and northern regions

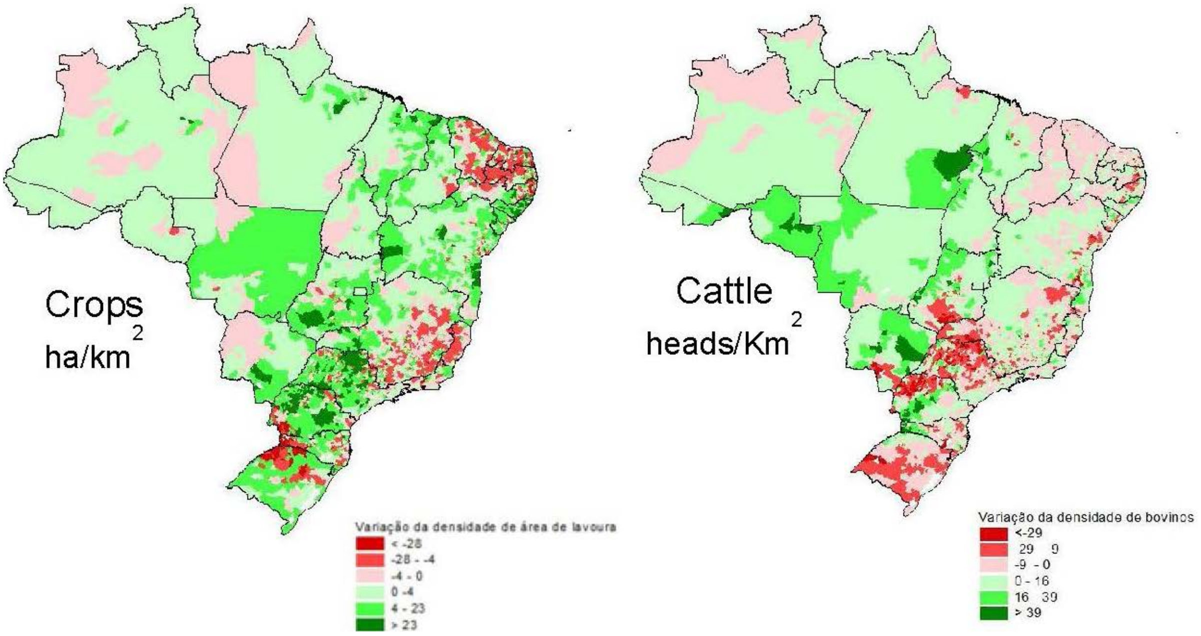
In 2006, around 30% of farms used mechanical power for farmwork while in 1959 this percentage was scarcely more than 1% . Tractors were counted in tens of thousands and today are hundreds of thousands. In the 1960 Census, the investigated maximum power limit of tractors was 50 CV and in the 2006 Census the minimum limit was 100 CV. The types of equipment researched have diversified and almost doubled in number, considering that the current models have more power and in general are mechanically driven.

Figure 3 shows the generalisation of the tractor's presence in the Brazilian countryside today, compared to the shortage prevailing in the mid-20th century. It also illustrates that the use of mechanized farming, which had been confined basically to São Paulo, spread throughout the country, although it is still highly concentrated in that State and in southern Brazil.

The use of so-called modern inputs has definitely expanded. In 1960, 157,000 farms stated that they used chemical fertilisers while in 2006 no less than 1.3 million said that they used the input. So little was used that the 1960 Census did not even inform the number of farmers using insecticides and fungicides, while in 2006 the farmers using agrochemicals totalled 1.4 million.

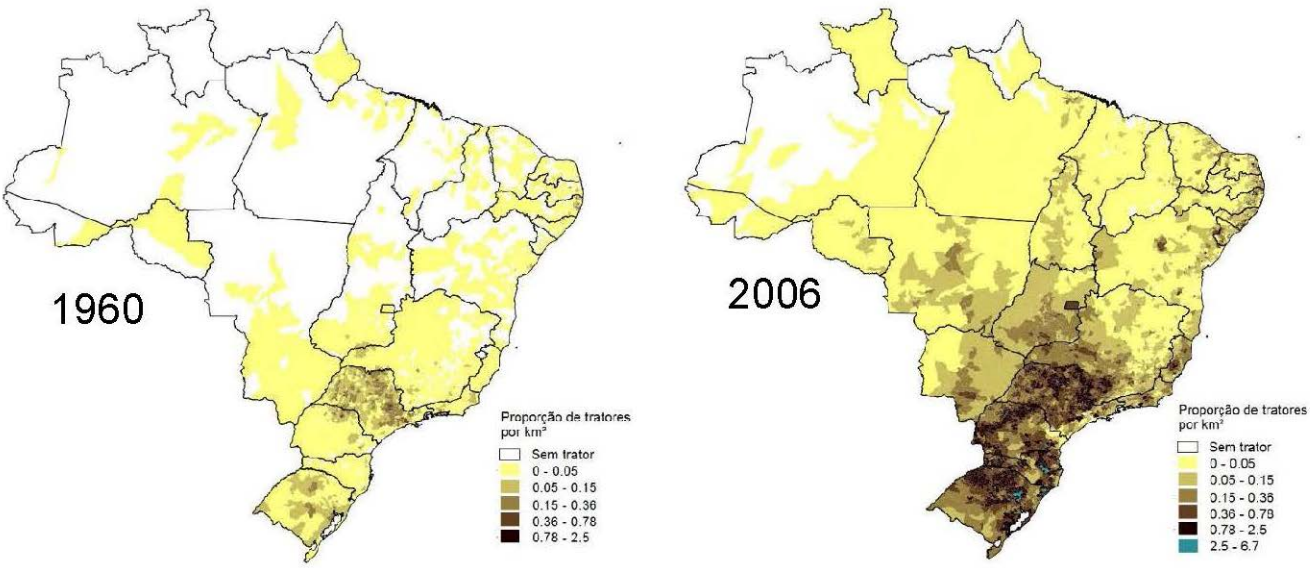
The increase in the quantities of farm instruments and agricultural inputs, whose use and availability, together with genetic improvement and the advance of agronomic techniques, explain the gains in productivity. The significant spread of some of them, due mostly to credit incentives and other farming policy instruments, has changed the aspects how Brazilian agriculture is perceived, today on a par with the world's sstate-of-the-art.

Figure 2 - Variation in the density of crops and cattle - Brazil, 1985-2006



Source: IBGE – Censo Agropecuario

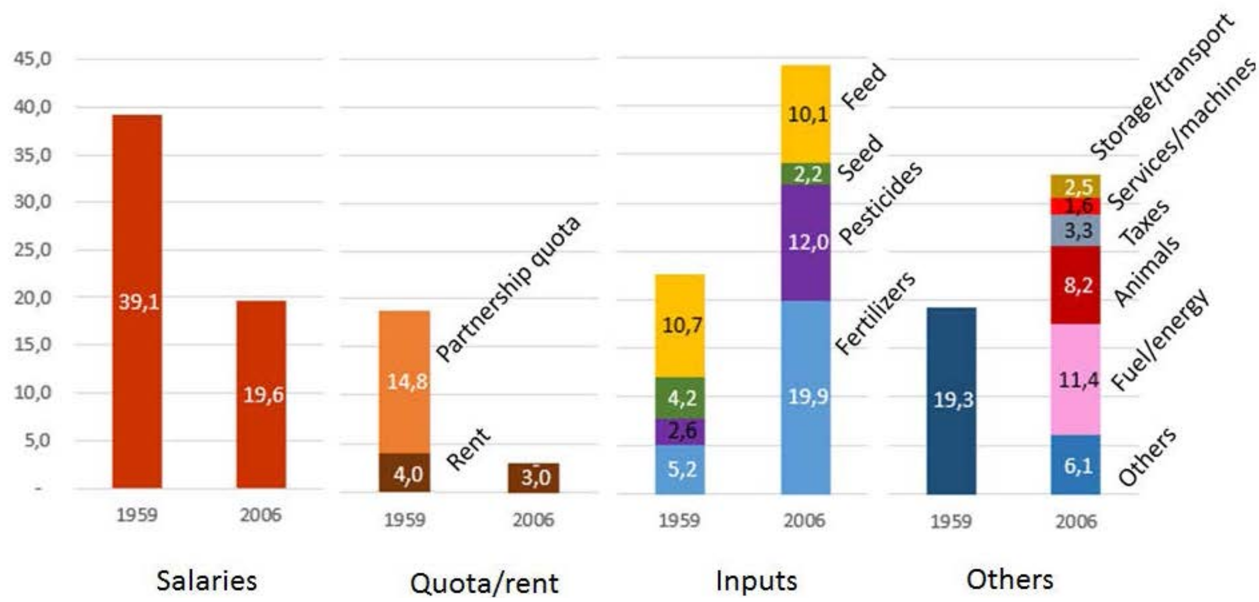
Figure 3 - Intensity of mechanisation - Brazil, 1960/2006



Source: IBGE – Censo Agropecuario
Note: Total number of tractors on the surface of the municipality (tractors/Km2)

The changes found in the spending pattern of farms illustrate the drastic alterations resulting from the modernisation process due to industrialisation of the production process (Graph 3). Wage expenditure, which had been the main item in expenses in 1959, representing almost 40% of the total, was now reduced to half that figure. The participation in the payment of share partners, which in 1959 was 14% of expenses, was reduced to a minimum. On the other hand, the share in inputs rose 20 percentage points, with emphasis on spending on fertilisers, correctives and agrochemicals, which were 12% of the expenses in the mid-20th century and today they total 34% of expenditure of agricultural businesses. Moreover, other expenses such as, for example, electricity and fuel, animal procurement, storage and transport, taxation and financnial costs have soared.

Graph 3 – Profiile of farm expenditure – Brazil, 1959/2006



Source: IBGE – Censo Agropecuario

Major changes have also been observed in labour relations. Table 1 shows that fifty years later the contingent of occupied personnel in the a partnership relationship and another condition (residents and households), which was almost half the permanent personnel with no family ties to the farmer, has plummeted. This group, which in the past numbered the same as the permanent employees, is less than 10% today.

Table 1: Non-family permanent occupied personnel, Brazil 1960-2006

Categories	1960		2006	
	Abs.	%	Abs.	%
Non-family permanent personnel	**2,801,534**	**100.0**	**1,494,957**	**100.0**
Permanent employees	1,428,950	51.0	1,369,074	91.6
Partner / Partner employee	All	32.7	83,060	5.6
Other	916,039	16.3	42,823	2.9

Source: IBGE - Census of Agriculture

It is worth mentioning that wage-earning became more prevalent due to the drop in other forms of hiring labour, since the number of wage-earners in farming, both permanent and temporary, is lower today than half a century ago. The number of permanent employees calculated in the Census of Agriculture 2006 corresponds to 96% of those in the Census of Agriculture 1960, and only 76% of temporary employees.

Table 2: Number of farms by status of the person in charge, Brazil 1960-2006

Status of person in charge	1960	2006	Difference
Total	**3,337,769**	**5,175,636**	**1,837,867**
Owner	2,234,960	3,745,528	1,510,568
Settler farmer without definitive title deed	...	182,671	...
Leaseholder	327,136	221,587	-105,549
Partner	252,833	138,125	-114,708
Occupant	356,502	405,219	48,717
Administrator	166,236	227,487	61,251
Landless farmer	102	255,019	254,917

Source: IBGE - Census of Agriculture

The total number of farms in the same period increased 55%. And also in the other direction, the number of farms run by leaseholders and partner farmers has dropped, the latter diminishing to almost half of those in 1960 (table 2). The drop in the partnership and in households and residents and the increase in the use of modern technical resources occurred to a greater or lesser degree all over Brazil.

Brazilian agriculture has undergone major structural changes over recent decades, although with little change to the basic features of its constitution. Particularly with regard to the case of land distribution, a more basic structural characteristic of agriculture. In fact, despite the industrialisation of Brazilian agriculture, the pattern of inequality in land distribution has stayed very much the same. Since the 1960s the proportion of the very small and largest farms increases while the proportion of other categories decreases (see table 3), while the high value of the Gini index for land distribution was more or less stable over time, at around 0.85.

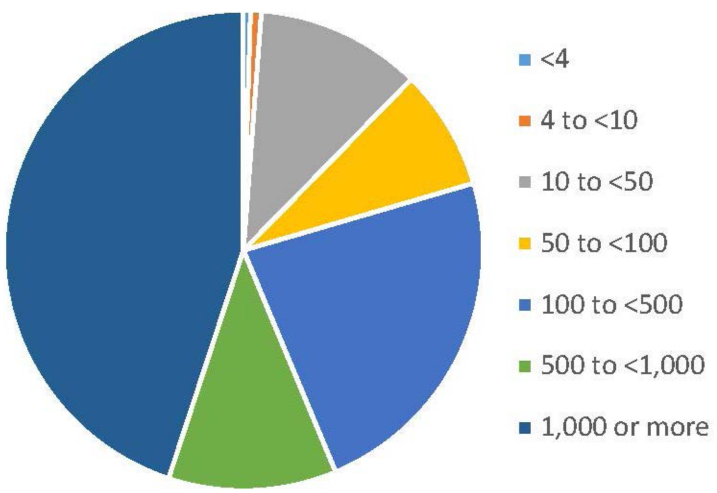
Table 3: Farms by size - Brazil, 1960-2006

Farms	1960	2006	Variation %
Number	3,333,746	4,920,617	47.6
Size (ha)	Distribution (%)		
<2	12.3	21.3	73.3
2 to<5	18.6	16.1	-13.4
5 to <10	14.0	12.9	-7.4
10 to <50	36.6	32.1	-12.1
50 to <100	8.2	7.9	-2.9
100 to <500	8.2	7.5	-8.5
500 to <1,000	1.2	1.1	-10.0
1,000 to <5,000	0.9	0.8	-1.5
5,000 or more	0.1	0.1	4.9
Total	100.0	100.0	…

Source: IBGE - Census of Agriculture
Note: Landless farm holding is not included

Nowadays half the land in Brazil is managed in large farms over 1000 ha in size, and more than three quarters of the land belongs to farms over a 100 ha. The millions of small farms, as say, in the case of Brazil, with less than 10 ha, control a very **marginal proportion** of farm land (Graph 4tra). Moreover, three quarters of the land is managed by non-family farms and over 30% by hired managers.

Graph 4 – Farm land distribution, by size – Brazil, 2006



Source: IBGE – Censo Agropecuario

Alberto Passos Guimarães (1963) in the middle of last century foresaw the occurrence of the following processes: landownership concentration, small-scale landownership fragmentation, substitution of landholding crops for extensive cattle farming and the (slow) introduction of advanced techniques (chemical and mechanical) and of capitalist wage-earning. A situation reflecting the crises of the first half of the 20th century and the capitalist development of the country and Brazilian agriculture, which mean the downfall of the old landownership system and the coming on stage (formation) of the "capitalist property" . Some iconic references in his work are the substitution of the bangüê (traditional sugarmills) by the central industrial plant and the emergence of the new "coffee barons", converting landowners in millowners or "manufacturers", concentrating land and offering better commercial, farming and industrial organisation. The majority that fail to pursue this path become suppliers, sell their land or take refuge in extensive cattefarming. If we assume the proxy suggested by Guimarães according to which the extreme classes of "less than five hectares" and "more than 1000 ha" represent the small-scale farms and large estates respectively, the process he indicated has followed its course.

Guimarães compared "two agricultures: export agriculture based on the large freehold estates, and subsistance farming based on capitalist ownership and on peasant ownership", the former being a retrograde obstacle that must be overcome and the latter holding the keys to development (Guimarães, 1981, p. 208).

The movement of "capitalist transformations" as it was called at that time recalls a parallel with contemporary work that foresaw a "new phase" of Brazilian farming, according to which large-scale productive and technological efficiency is a requirement for the survival of farms: on one hand "a very small group of extremely able farmers" capable of accounting for the entire farm production, including exports and expanding their activities, and on the other "the vast majority of low-income farmers, ... small and medium in size", whose development process will become "redundant" and, therefore, destitute and dependent on a public policy to survive (BUAINAIN et al, 2013, p.114).

It is worth mentioning that in the mid-20th century the partnership-based latifundio was predominant. The absentee landlord farmer would keep the countryside lagging behind and curb development. Although still incipient or restricted to certain regions, it was foresseable that the freehold farmer and director of the modernising enterprise with capitalist relations would change the face of the Brazilian countryside.

Today, the modern freehold farmer predominates. New competitive demands appear to demand absolute liaison with markets and financial and technological capacity. Although embryonic, there are signs of corporate farmer protagonism or agricultural entrepreneur free from land ownership. The share owner is now the minority partner and, in addition to being absentee, is merely a rentier. The landowner, ditto, operates under contract regulations and standards in new partnerships (Bolliger, 2014)

The structural changes in Brazilian agriculture reflect the known industrialising process of agriculture. A phenomenon marked by so-called modernisation of agriculture with emphasis on mechanisation, agrochemicals, genetic improvement and, more recently, microinformation technology, telecommunications, genetic modification and biotechnology. New technologies are now seen to reach remote regions, different farming activities and large and small farms. In this process, primitive farming, characterised by fully integrated systems, has also undergone gradual disintegration of its functions, making way for an intricate supply chain of inputs and services (Rehber, 2000)

Added to this is the striking transformation process of the agrifood sector at a global level at which open markets have been replaced by strongly structured agrifood chains.

It is acknowledged that the combination of these kinds of changes is associated with a trend toward greater professionalism in conducting the different productive segments of agriculture in Brazil. On one hand, the displacement of the former large landowner, holder of large explored areas with low productivity and, on the other, larger numbers of small farmers integrated in market, or through agroindustrial businesses or public policies.

Therefore, today the farming structure can no longer be addressed without reference to agribusiness or, more specifically, the agricultural value chain. This is clearly true for Brazil: some of the biggest agroindustrial enterprises are Brazilian and a large part of the top global corporations operating in the agroindustial chain are present in Brazil. However, as we will see below, it seems to be the same in most countries.

These facts were once linked to the well-known phenomenon of a change in the profile of demand and marketing process of agricultural production verified over the past century when direct selling to the consumer and middlemen and commercial networks lost ground to the agroindustries, cooperatives and more recently to supermarket chains.

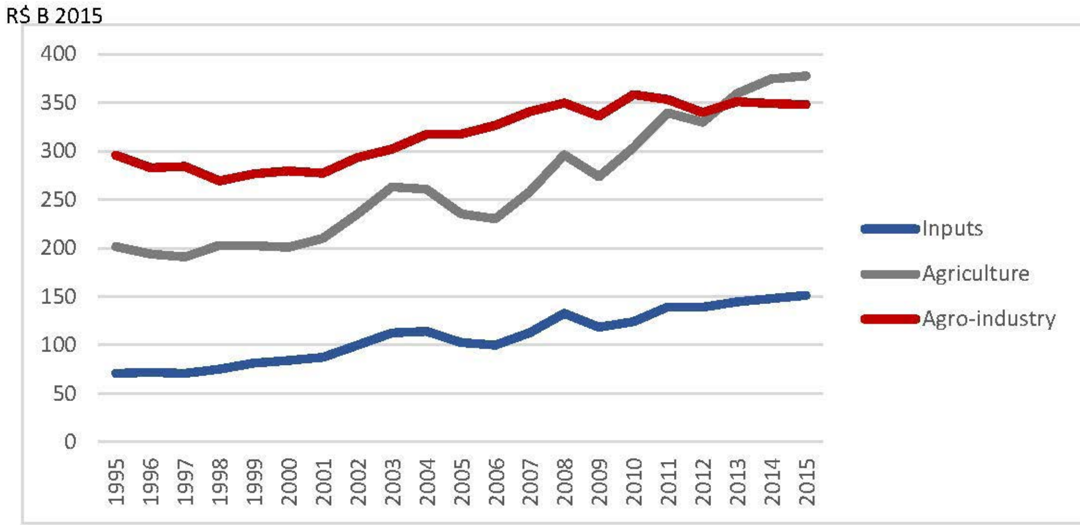
2. Brazilian agricultural value chain data

National Accounts present a set of concepts and data fully in favour of preparing analyses relating to the value chain. There are many studies therefore on the topic based on the national accounts relating to dimensioning and dynamics of the agricultural chains and complexes and on the economic relationships between sectors and sub-sectors of the activity, particularly analysing the effects of backward and forward linkages in the matrix of inter-industrial relationships.

The most commented data by analysts and policy drivers merely concern the relevance of the overall agrifood chain whole. The aim is to highlight the importance of the set of related activities, very often with political motivation and not uncommonly with some exaggeration .

The IBGE, the institute responsible for Brazilian official statistics, has never adopted the task of creating satellite accounts related to the agroindustrial complex. The Advanced Studies Centre in Applied Economics (CEPEA, ESALQ/USP) demonstrates a series of data for the Agribusiness GDP, which goes back to 1995 and is regularly updated, based on national accounts data. Countless studies are being carried out in the country to analyse the relationships and dynamics of the Brazilian agroindustrial complex based on the same data. Their main restriction concerns the level of aggregation provided by the accounts data. Given the nature of the national accounts data, the information is simply too clustered. Efforts have been made to obtain estimates with pieces of interest, such as, for example, the book on the Family Farming GDP (2007), published by the Ministry of Land Development, but which inevitably depend, however, on many assumptions.

Graph 5 – Value added - Agribusiness – Brazil, 1995-2015



Source: USP-CEPEA

On the other hand, a multiplicity of studies on particular agroindustrial chains and/or regional segments of specific chains are undertaken by university centres and economic research institutes. Many of them analyse in detail the relationships and functioning of the links in the chain, collecting their own data. In general, with firm basis on qualitative research, many are quite restricted case studies. Important ones can be found in an Agribusiness Studies Centre named PENSA at the University of São Paulo and others in the Contract Framing Resource Centre maintained by FAO .

Therefore, a complete view of the farming structure now requires the broader perspective of the production chain in which it is incorporated: in actual fact, both services and flows downstream and upstream from agriculture. In the literature on agricultural economy, this view is provided by analysing the agricultural value chain. However, official statistics have yet to follow the same path.

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PLENARY SESSION

04

FINANCING THE MODERNIZATION OF AGRICULTURAL STATISTICS: STATISTICAL CAPACITY DEVELOPMENT INITIATIVES AND RESOURCE MOBILIZATION

Session Organizer
C. Duhamel | FAO | Rome | Italy
F. Lawson | African Development Bank | Abidjan | Ivory Coast

ABSTRACT

For many countries it remains a challenge to obtain the funding required for statistical development, particularly for developing countries which face a lack of financial resources for producing the data needed to develop appropriate policies, to target scarce resources, to measure progress, to make effective use of aid and to monitor and evaluate outcomes. The international community has emphasized again the necessity of these improvements and this has been recognized in the Busan Action Plan of Statistics in 2011 where "an increase of resources for statistical systems would entail continued investment to break the vicious cycle of neglect and disuse of statistics". Countries will have to be prepared for greater challenges such as the post 2015 development agenda and address the underlying question of financing the modernization of statistics, particularly in the agricultural sector. As element of the national statistical system, the agricultural statistics sector has been facing a dramatic situation from the beginning of the 1980's with a decline in the quantity and quality of statistical data. In order to respond to this specific issue, the international community has set up a concerted effort to strengthen agricultural statistics which has resulted in particular in the launching of the Global Strategy to improve Agricultural and Rural Statistics, to support countries in strengthening their capacities and helping them to prepare sustainable and long-term plans for the development of the agricultural statistical sector. Additional advocacy efforts and calls for stakeholders will be necessary for ensuring that funding will be made available in a sustainable way, in particular for collecting data, and to collectively identify new funding modalities. The aim of the session is to: i) Highlight success stories of concerted approaches at international level aiming at providing support in the field of statistical capacity building: which value for money? ii) Review the existing mechanisms of integration of agricultural staistics within the overall National Statistical Systems, particularly under the financing point of view : should agricultural statistics be funded independently ? iii) Explore innovative approaches, tools and financial instruments used by the countries, e.g. pooling through basket funds, budgetary aid, mechanisms of dialogue between the government and the donors, SWAP approaches grounded to national development policies: what are the good practices? iv) Address the challenges for countries in terms of financing data collection and meeting international requirements from a financing perspective: who will pay for it and how? The session will welcome thematic papers focusing mainly on these areas.

LIST OF PAPERS

Modernization of agricultural statistics: how to make it happen? European statistical system experience
M. Kotzeva | Eurostat | Luxembourg | Luxembourg
DOI: 10.1481/icasVII.2016.pl4

Agricultural statistics in the era of Sustainable Development Goals (SDG'S)
M. V. Belkindas | Open Data Watch | Washington, DC | USA
DOI: 10.1481/icasVII.2016.pl4b

PL04

Modernization of agricultural statistics: how to make it happen? European statistical system experience

M. Kotzeva Eurostat | Luxembourg | Luxembourg

DOI: 10.1481/icasVII.2016.pl4

ABSTRACT

Today's fast changing landscape of emerging new data sources and digital technologies poses significant challenges to the capacity of national statistical offices and international organisations to modernise agricultural statistics. If we want to develop strategies for producing high quality agricultural and rural statistics that meet users' needs and the increasing demand for evidence-based policy making, we need tomobilise resources, develop new skills and introduce innovative ways to provide training and capacity building. With the more active use of administrative data and new information sources such as big data, building up partnerships outside the statistical community is becoming an increasingly important way to mobilise resources for the successful transformation of agricultural statistics.

The presentation looks at how the European Statistical System is developing its capacity to moderniseagricultural statistics in the supranational context of the EU. The presentationshares results achieved and lessons learned that might be useful for other institutions undergoing similar modernisation programmes

Keywords: agricultural statistics; capacity building; modernisation; European Statistical System

PAPER

1. Introduction

Over the last decade, the shift towards evidence-based policy making in general and output-oriented development policies in particular hasgenerated an ever increasing demand for high quality official statistics across the globe. As a result, national statistical offices (NSOs), other national authorities and regional and international organisations now more than ever need the capacity to provide data. A range of technical assistance and capacity-building initiatives have been launched in various statistical domains, including the agriculture and food sector. A major part of thisworkhas focused on enhancing NSOs' human resources capacity and on developing their technical skills. In agriculture,this related to sampling techniques, planning and conducting agriculturalcensuses and building food supply balance sheets. In addition, the Paris 21 consortium of international development institutions has been assisting countries to develop national statistical development strategies and makeagriculture an integral part of them.

Over the years, the European Commission has supported agricultural statistics byco-financing actions as part ofthe FAO's'Global Strategy to Improve Agricultural and Rural Statistics' (GSARS, 2016) and through the Paris 21 partnership. To mention one example, the EU is supporting capacity building for agricultural statistics through the 'Information for Nutrition Food Security and Resilience for Decision-Making Programme' (INFORMED) (FAO, 2016).The EU is contributing EUR 20 million, or 59 %, for the project duration until June 2019. INFORMED supports decision-making by improving the availability of regular, timely and early warning information. It also produces evidence-based analysis on food security, nutrition and resilience. Three outcomes are expected:

- better and more integrated data systems for long- and short-term trend analysis of food crisis situations;
- strengthening of the Integrated Food Security Phase Classification (IPC) process largely applied at country level;
- improved resilience programming byapplying a common methodology to measure resilience.

Eurostat has a multi-faceted role in international cooperation over statistics. Firstly, it represents the Commission in the United Nations Statistical Commission (UNSC), in bilateral relationships with international financial institutions such as the IMF, the World Bank and regional development bank and on the OECD Statistics Committee (CSTAT). Secondly, Eurostat cooperates with these international statistical agencies to:

- set up international standards for statistics;
- improve the comparability of statistical information;
- improve the coordination of international statistics-related activities;
- support financially and technically national statistical systems in building capacity to deliver data on agriculture and food.

This work involves on-the job and formal training in country-level field projects, study tours, international, regional and national training seminars and workshops, and preparing and disseminating methodological and technical guidelines.

Despite the efforts and investment in statistical capacity building, we are having to cope withnew data demands. These are triggered by the latest trends in agriculture and rural developmentand the increasingly important role of sustainable management of natural resources in response torising concerns about climate change, biodiversity loss and water and soil quality. The analysis of the available data for monitoring and evaluating the recently adopted UN Sustainable Development Goals (SDG) identified a number of data gaps linked to the availability of geo-referenced and regional data and challenged statistical capacities across countries. The increasing global interconnectedness of agricultural production structures, prices, yields and supply chains callsfor detailed data in this area. This will make it possible to carry outrapid crisis responses and have more effective policyin general. At the same time, the astonishing developments in information and communication technologies and the instantaneous availability of information are openingup new opportunities to produce statistics faster and cheaper and to improve theirquality. Accessing the emerging new data sources requires new capacities. Statisticians'classical role in designing and carrying outsurveys and turning the results into statistics isno longer sufficient. Capacitiesto adapt to rapid change, acquire knowledge and innovate are becoming the most valuable assets for any statistical office, whether in developing ordeveloped countries. As stated in the Report *A World that counts: mobilizing the data revolution for sustainabledevelopment* prepared by the Independent Advisory Expert Group (IAEG, 2014) established by the UN Secretary General on data revolution, '*...improving data is a development agenda in its own right, and can improve the targeting of existing resources and spur new economic opportunities. Existing gaps can only be overcome through new investments and the strengthening of capacities.*'.In other words, modernising statistical production now depends on one'scapacity todo so, making this latter issuea universal problem.So far, discussions about statistical capacity building at various international fora have focused largely on less developed countries. However,nowadays the challenges and opportunities triggered by the data revolution are faced byall NSOs and systems, including the most developed ones, as well as by international organisations. In the age of data deluge and digital transformation, capacity building has expandedto include thecapacity to modernisestatistical production. Changing user needs mean that statisticians need to have an open and broadapproach in order to respond to the requestsmade to them. Continuing the traditional approach by creating additional surveys or by adapting existing surveys is not a feasible option in times of resource constraints at all levels. Instead, smart ways of producing statistics are needed. This paper looks specifically at agricultural statistics and how the European Statistical System is developing its capacity to modernisestatistics in this field in the supranational context of the EU. It shares results achieved and lessons learned that might be useful for others undergoing similar modernisation programmes.

2. New capacity for high quality agricultural and rural statistics in the EU:results achieved and lessons learned

Thispaper is based on the idea that building capacity to provide high quality statistics goes beyond technical skills. Building capacity involves establishing a robust and sustainable institutional set-up and a legal framework that requires interaction with many other national authorities. Building sustainable statistical capacity is a long process that requires more than just money. Even in the area of mobilising financial resources, new business models of partnership and financial instruments could be explored. The current context of digital transformation and data deluge even demands this.To build and provide the technical assistance needed to boost skills, we needto beinnovative and to embracethe opportunities offered by information technology. Finally,we also need leadership and high-level political support and national ownership ofthe capacity-building processif we want to modernise agricultural statistics and strengthen our capacity to stay relevant to evolving user needs.

The EU context: a common agricultural policy

Since the early 1950s statistics on agriculture in the European Union has developed with the aim of supporting the policy design, implementation, monitoring and evaluation of the common agricultural policy (CAP) and ofenvironmental and rural development policies. In response to the evolving policy needs and increasing role of evidence-based policy making in the EU, agriculture statistics has developed in a rather consistent manner among the EU Member States over the past 60 years. Over 77 % of the EU's territory is classified as rural (47 % is farm land and 30 % forest) and is home to around half its population (farming communities and other residents). Agriculture accounts for almost 40 % of the EU budget and is supported almost exclusively at the European level, unlike most other sectors, which are governed by national policies. With an annual budget of around EUR 59 billion,the CAP aims to providea stable, sustainably produced supply of safe food at affordable prices for consumers, while also ensuring a decent standard of living for 22 million farmers and agricultural workers in the EU. Agriculture also plays an increasingly important role in the sustainable management of natural resources against the backdrop ofrising concerns about climate change, biodiversity loss andwater and soil quality.

The CAP's focus has moved away from structural measures to modernise farmsand guaranteed prices to encouragefood production towards environmental protection, the development of rural areas and responding to consumers' concerns. This has led to new data needs and new phenomena that need to be measured and described. For example, cereals have started to be used for energy production and not for food and feed only. Greenhouse gas emissions from agriculture also are a telling example of the clear link between agriculture and climate-related policies.

The value proposition of agricultural statistics — Link betweenstatistics andthe systems for monitoring and evaluation of policies

The active use of official statistics in the design, monitoring and evaluation of the CAP and rural development policy over the years has been a strong driving force inthe evolution of statistics and the strengtheningof the capacity of both Eurostat and NSOs. Here comes the first useful lesson from EU experience. A stronger link between country capacity-building programmes and systems for monitoring and evaluating agricultural and rural development policies could help to break the vicious circle betweenunder-resourced NSOs, low-quality statisticsofno use and demand for official statistics that exists in a number of developing countries. This could also facilitate the involvementof potential resource partners interested in investing in agricultural statistics.

Communicating the value proposition of agricultural statistics to users, in particular to national governments and international donors, has played an essential role in mobilising resources for building sustainable statistical capacity. The starting point in theprocess is the mechanism for permanent review of data needs and user engagement in settingpriorities. In the EU context, a crucial role has been played by the European Statistical Advisory Committee and regular hearings with the European Commission departmentsthat implement agricultural, environmental and rural development policies. On many occasions, these stakeholders have served as promoters and supporters ofthe need for investment toextend capacity building for measuring new phenomena and modernising statistical production.

A holistic approach and integrated framework for agricultural statistics

Starting from user needs, it has been crucial to follow a holistic approach and plan an integrated framework for agricultural statistics that canserve multiple policy purposes.In 2014, Eurostat initiated a review of the current state of the European agricultural statistical system and a discussion with Member States on the system's future.

In line with the Global Strategy to improve agricultural and rural statistics, the plannedEuropean2020 integrated framework of agricultural statistics involves a combination of the Agricultural Census and intercenialcore, module and adhoc sample data collections (surveys).Following the approach recommended by the FAO's World Programme for the Census of Agriculture 2010 (FAO 2005), the Agricultural Census will continue to be a core data collection instrument that provides statistics on farms at the lowest geographical level. An essential novelty in the framework are the flexible adhoc surveys that will focus on special topics not traditionally part of the EASS, i.e. surveys which aim to cover variables that fulfil new and emerging data needs. Their exact content will be determined later, prior to their implementation.They are not planned to be carried out at fixed intervals, but may be repeated when needed[1].

The integrated framework of agricultural statistics has made it easier to present them to users and to wintheir support, including financial support.It has also helpedwithbetter planning of diminishing budget resources available to carry outthe planneddata collections. Similar approaches could be useful for developing countries because they help to ensureinterest by national and international resource partners in investing in statistical capacity building. A targeted integrated framework that at the same time includes opportunities to add some ad hoc data modules could attract and guide potential donors and investors who would like to receive statistical outputs and services after initial investment in building statistical infrastructure and capacity.

Embrace opportunities provided by new technologies and multiple data sources

[1] A seguito della istituzione del nuovo comune di Valsamoggia (legge regionale 7 febbraio 2013, n. 1, in vigore dal 1° gennaio 2014), in provincia di Bologna, avvenuta mediante fusione di cinque comuni, appartenenti a zone altimetriche diverse, per il criterio della prevalenza della superficie, la percentuale di territorio collinare complessivo passa dal 41,64 al 41,65 per cento, mentre il territorio di pianura dal 23,17 al 23,16 per cento.

While agricultural statistics in the EU havebeen evolving, a set of administrative registers have been set up in individual countries and at EU level with the primary objective of enablingimplementation and monitoring of the CAP. Technological advances lead to ever more data: aerial images are nowadays available without cost, whilesmart farming creates another data source. These new sources have created a treasure trove of information that is worth exploiting for the benefit of official statistics, topotentiallyreduce the burden on respondents andto reducethe costs of statistical production.In order to cope with the challenges, a number of steps have been taken in the European Statistical System (ESS).Some useful lessons could be derived from that experience as well. In 2014, the headsofthe national statistical institutes and Eurostat adopted the ESS Vision 2020 (ESS, 2014). The ESS Vision 2020 aims to increase efficiency, reduce response burden, cut the cost of compiling statistics and respond better to user needs byexploiting new and emerging data sources, innovative data collection methods and digital technologies. The basic elements of the ESS Vision 2020 were implemented in concrete modernisation programmes in the core statistical domains.

Wider use of administrative sources has occupied a central place in the modernising of agricultural and rural statistics in the EU. In the past, administrative data weremostlyused for sampling frame construction or as auxiliary information in estimation processes and in analysing and validating the data from surveys. However, recently administrative data have been more and more used as a direct data source. The motivation is two-fold: to reduce costs and to decrease theresponse burden. The results indicate that integrating administrative registers with censuses and sample surveys is a cost-effective way of producing statistics while reducing the burden on respondents. The quality dimension 'accuracy' is a key issue for further development to improve quality when integrating registers and surveys in farm structure statistics.

Sharing and promoting best practices

Pilot projects to setup and improve the use of administrative data in producing agricultural statistics were launched in 14 countries between 2013 and 2015, with financial support fromEurostat.Results were presented at a thematic seminar with directors of agricultural statistics in 2016 in Belgrade. Poland shared itsexperience on creating an agricultural holdings register using administrative data sources, whileGreece shared its experience on upgrading the quality and timeliness of agricultural statistical survey with the farm register. Serbia explained the integration of administrative data for crop production data collection and Slovenia focused on using administrative data in the context of the preparation/provision of annual crop statistics. Sweden showed how information from control bodies is incorporated in statistics on organic farming. During the animal statistics working group meeting in February 2016, Hungary shared itsexperience of using administrative data in animal production statistics and Poland presented the first insights fromits investigation ofdata validation in animal production statistics.

Strong legal basis that ensures the use of administrative data sources

While exchange of best practices and methodological solutions in using administrative data for statistical purposes has proven to be a driving force for innovation and strengthening statistical capacity in the EU, it is equally important to have a strong legal basis that ensures access to these sources by NSOs. At EU level, the access to administrative data for statistical purposes in general is provided for by the Statistical Law[2].

Article 17a of the Statistical Law lays down the right of the national statistical institutes and Eurostat to access and use, promptly and free of charge, all administrative records and to integrate them with statistics, to the extent necessary for the development, production and dissemination of European statistics. More specifically, the current EU Regulation for the Farm Structure Surveys[3] in the EU Member States includes an article explicitly ensuring access to three administrative data sources available in EU Member States: the Integrated Administration and Control System (IACS), the System for the Identification and Registration of Bovine Animals and the Organic Farming Register.

Partnership with owners of the administrative registers

While the legal base foraccessing administrative data is laid down by law, the practical implementation is not immediately given. In order to be useful for statistics production, data from other sources need to be available in a usable form and in a timely manner. Experience in several EU Member States has shown that building a trusting and process-oriented relationship with the owner of the administrative register is essential to success. Even if the holder of the register is legally obliged to give statisticians access to the information, the statisticians need to invest in explaining the 'user needs of the statistics' and to influence the content of the register so that it isas useful as possible for statistics production. This cooperation needs well-defined governance and can by no means be left to the technical level or individualgoodwill.

Increasing use of administrative data sources

[2] Article 17a of Regulation (EC) No 223/2009 as amended by Regulation (EU) 2015/759.

[3] Regulation (EC) No 1166/2008 of the European Parliament and of the Council of 19 November 2008.

The EU Member States are more and more consideringthe use of administrative sources to reduce expenditure ondata collection and significantly decrease the response burden. Several lessons could be derived from the experience so far that might be useful in building statistical capacity in the rest of the world:

- The first step in the process should be the mapping of the existing information (data sources) followed by the elimination of sources which could not provide the level of information requested.
- Statistical data (unit of observation, coverage, definition of characteristics, classifications, periodicity for data collection, reference period etc.) are mainly regulated by statistical legislation or clearly defined in methodologies for data collection. Therefore, the difference for any variable will imply a reduction in data quality.
- The use of administrative data for statistical purposes depends very much on cooperation and communication between the statistical office (or the responsible body for the agricultural data collection and dissemination) and the owner of the administrative data. It is important that the authorities responsible for agricultural statistical data collection are formally and regularly involved in preparingadministrative data.
- All the available options should be taken into consideration, including the possibility to adapt statistical collection methods or slightly adapt administrative data collection channels.
- The use of a common identifier that would make it possible tolink observed units in the various statistical data collections with the administrative register(s) is one of the key points of the whole process, together with the management of metadata (storage, maintenance, transmission procedures, etc.).
- Generally, the transition from statistical survey data collection to the use of administrative data takes time, needs resources and usually cannot be completelyimplemented from one year to another.

Institutional and financial capacity to deal with new data sources

Private data sources need to be identified, while their suitability and potential for sustainability need to be evaluated. It would also be worthwhileto analyse whether any obligation exists to report such data to an administrative body in the Member State, as this could provide for access without additional cost to the statistical office.

In view of the scarce resources available, EU Member States and Eurostat combine resources through cooperation in modernisation programmes via networks and ESSnet projects[4] to exploit the potential of new data sources. Building partnerships,firstly with other countries inside the ESS and secondly with actors outside the statistical community, with private data owners and with the owners of administrative data, is becoming an increasingly important way tomobilise resources for thesuccessful transformation of agricultural statistics. Statisticians will no longer be self-sufficient in designing and carrying out data collection and in producing statistics. The traditional role of statisticians will need to be supplemented by the capacity to work with others in a partnership.

New quality framework for the use of new data sources and for the combination of data sources

Although the advantages of administrative data use are quite evident, it is also necessary to consider the possible disadvantages and shortcomings of such a practice. Although it is often believed that administrative data are free of errors, this is not always the reality. Administrative authorities also use some kind of collection processes, which inevitably produce different kinds of errors in the collected data. Besides these measurement errors, which are due to the 'hidden' collection processes, some other quality issues mayalso exist. Theseare specific to the administrative data and should be studied in as a detailed manner as possible before deciding to includesuchdata in the production process of official statistics. Data matching and data linking is usually easily feasible if unique identifies are used for the observation units. In the agricultural sector, this might for example be farms, people or land parcels. Using a unique identifier in different data sources will generally lead to higher quality data than if no such identifier is available. This is just one example that illustrates the need for a new quality framework.

3. Conclusion and way forward

Capacity building goes beyond the traditional approach of training and resource allocation. The lessons drawn from the experiences gathered in the EU and summarised in this paper couldbe of relevance for any statistical institute that is modernising agricultural statistics in today's fast changing landscape of emerging new data sources and digital technologies. While we have long known a lot about the pros and cons of some of these technologies in agricultural statistics, promoting the better use and improving the quality of administrative data for statistical purposes appears to be the most significant innovation for improving the existing statistical systems.

[4] 'ESSnet project'means'A network of several ESS organisations, aimed at providing results that will be beneficial to the whole ESS'.

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Building partnerships together in the ESS with actors outside the statistical community, including with private data owners, is becoming an increasingly important way to mobilise resources for the successful transformation of agricultural statistics. In the age of data deluge and digital transformation, capacity building is expandingto include the capacity tomodernise statistical production. If we want to develop strategies for producing high quality agricultural and rural statistics that meet users' needs and the increasing demand for evidence-based policy making, we need tomobilise resources, develop new skills and introduce innovative ways to provide training and capacity building.

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Agricultural statistics in the era of Sustainable Development Goals (SDG'S) [1]

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ABSTRACT

This paper deals with measurement of SGD's related to agriculture. It shows the variety of SGD indicators which are or can be related to agriculture and rural development. It briefly looks at a set of National Strategies for Development of Statistics (NSDS) to see how well improvement in agricultural statistics are covered in the documents. It also analyses how open are data on agriculture as measured by the Open Data Inventory (ODIN) conducted by Open Data Watch (ODW). Lastly it looks at the issues of financing statistics in the era of SDG's and the ongoing data revolution.

Keywords: Data OpennessFinancing Statistics

PAPER

1. Indicators to Measure SDG's

The era of Millennium Development Goals ended in 2015 and the World embraced new targets which will guide policy makers over the next 15 years. With the creation of the SDG's and the accompanying data revolution statistics havebecome even more important. While the achievement of the SDG's will make the world a better place to live, measureable indicators are imperative to know whether or not such goals are achieved. In this paper we look at the SDG's and indicators which relate to agriculture, rural development and food security. Among the 17 SDGs, there are 11 goals, 45 targets, and 58 indicators relating to agriculture. Goal 2 to End Hunger, Achieve Food Security, Improved Food Nutrition, and Promote Sustainable Agriculture appears to be the main goal covering agriculture. It contains targets for increasing agricultural productivity, diversity, and investment. However, there are additional goals that include targets and indicators that measure agriculture or other elements that impact agriculture. Goal 12 on Responsible Consumption and Production, Goal 14 on Life Below Water, and Goal 15 on Life on Land include targets directly related to agriculture, focusing on food waste, fisheries, and use of genetic resources. These goals also include targets with an indirect relationship to agriculture, measuring nutrition, pollution, consumption of natural resources, marine conservation, and protecting terrestrial ecosystems. Goal 6 on Clean Water and Sanitation, Goal 9 on Industry, Innovation, and Infrastructure and Goal 13 on Climate Action also include such targets, focusing on water management, resilient infrastructure, and climate change resilience. In total, within Goals 2, 12, 14, and 15 there are 11 targets with 15 indicators directly related to agriculture and within Goals 2, 6, 9, and 12-15, there are 34 targets with 43 indicators indirectly related to agriculture.

Goal 2 (End hunger, achieve food security and improved nutrition and promote sustainable agriculture) includes five targets with nine relevant indicators that directly relate to agriculture.

Indirectly, Goal 2 includes three targets with five indicators. These indirect targets are important to agriculture as they serve as proxies for the effects of successful agricultural production. For example, although Goal 6 (Ensure access to water and sanitation for all) does not relate directly to agriculture, water resources are a crucial component of agricultural production. Goal 6 includes six targets with nine relevant indicators. Likewise,while Goal 9 (Build resilient infrastructure, promote sustainable industrialization and foster innovation) does not directly track agriculture, resilient infrastructure and control of CO2 emissions are important to agricultural production. Goal 9 includes two targets with three relevant indicators. Goal 12 (Ensure sustainable consumption and production patterns) includes one target and one indicator directly related to agricultural production. Indirectly, Goal 12 has two targets and three indicators on managing natural resources and pollution as proper management of natural resources and reduction of pollution both have significant impacts on agriculture. Although Goal 13 (Take urgent action to combat climate change and its impacts) includes targets and indicators that do not directly measure agriculture, efforts to mitigate climate change and increase resilience have a strong

[1] This paper benefited from inputs of ODW staff.

impact on agriculture as well. Goal 13 has four targets and four relevant indicators that relate to climate change mitigation and resilience. Goal 14 (Conserve and sustainably use the oceans, seas and marine resources) includes four targets and their four indicators directly related to agriculture in terms of fishing. Indirectly, Goal 14 has six targets and six indicators with impacts on agriculture related to fishing.

Indirectly, Goal 14 has six targets and six indicators with impacts on agriculture related to fishing. Marine conservation efforts are crucial to sustainable fishing activities. Goal 15 (Sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss) includes one target with a direct relationship to agriculture. This target focuses on fair and equitable sharing of the benefits of genetic resources in relation to plants and fauna.

As displayed by this list above, many of the Goals and measurable indicators are related to agricultural statistics.

2. Coverage of Agricultural Statistics in NSDS

Recently ODWconducted an assessment on how well National Strategies for Development of Statistics (NSDSs) adhere to guidelines from the Partnership in Statistics for Development in the 21st Century (PARIS21) where importance of sectoral statistics is prominent. As part of this project, ODW gathered 23 NSDSs of 20 countries and assessed the degree to which the NSDSs incorporate agricultural statistics. The results vary. Of the 23 assessments, fewer than ten NSDSs thoroughly detailed agricultural statisticsas a strategic task within its sectoral statistics. For example, Botswana's NSDS for 2015-2020 provided a subsection on agricultural statistics, consisting of current challenges, objectives, and priority initiatives as well as its total budget to address these challenges, objectives and initiatives. Additionally, Lao PDR's NSDS provides a working program on agricultural statistics within its objectives of increasing the development of sectoral statistics.Over ten NSDSs provided some references to agricultural statistics. For example, Benin's NSDS for 2014-2016 has a subsection on the current state of agricultural statistics, rather than a subsection on strategies for enhancing agricultural statistics. Furthermore, Macedonia's NSDSs, consisting of three publications for years 2014-2016, 2015-2017, and 2016-2018, do not address agricultural statistics as a detailed strategic task, but rather, elements of agricultural statistics are highlighted as an already-accomplished task.For other countries, the presence of agricultural statistics remains absent. For example, the NSDSs of the Dominican Republic (2014-2017), New Zealand (2010-2020), and Palestine (2014-2018) do not incorporate agricultural statistics. This brief assessment demonstrates that the coverage of agricultural statistics is uneven in the NSDSs. With the increasing demand for data on agriculture and rural development as per SDG indicators the future NSDSs will have to demonstrate actions for improvement in this sector more prominently.

3. Agricultural Statistics in ODIN

It is not only important to plan for improvement of statistics and to collect and process data but to publish data as open as possible. We would like to demonstrate how agricultural data are being open in countries around the world. ODIN is an assessment conducted by ODW of the coverage and openness of data provided on the websites maintained by national statistical offices (NSOs). In 2015, ODIN assessed the coverage and openness of official statistics in 125 mostly low- and middle-income countries across 20 statistical categories, two of which relate directly to agricultural statistics: Land Use and Resource Use.Both of these categories were assessed on five elements of coverage and five elements of openness. Each category is made up of a set of indicators. The indicator that comprises the category Land Use is: land area, and the indicators within the category Resource Use are: fishery harvests, forest coverage and deforestation, water supply and use, and major mining activities. The overall ODIN score for each category is an indicator of how complete and open an NSO's data offerings are.

The following is a summary of the global and regional trends in agricultural statistics that emerged from ODIN 2015, as well as two unique examples that illustrate different scenarios on each side of the spectrum.The average score for the 125 countries in the category Land Use is 26 percent and the average score for the category Resource Use is slightly higher at 28 percent (Table 1). In general, ODIN assessments found that environmental categories (which include Land Use and Resource Use) score among the lowest compared to economic and social data categories.

In addition, openness subscores for the categories Land Use and Resource Use tend to be lower than other categories with median scores of 10 and 20 percent. However, this trend is less specific to agricultural data as no data category received a median openness score upwards of 30 percent.

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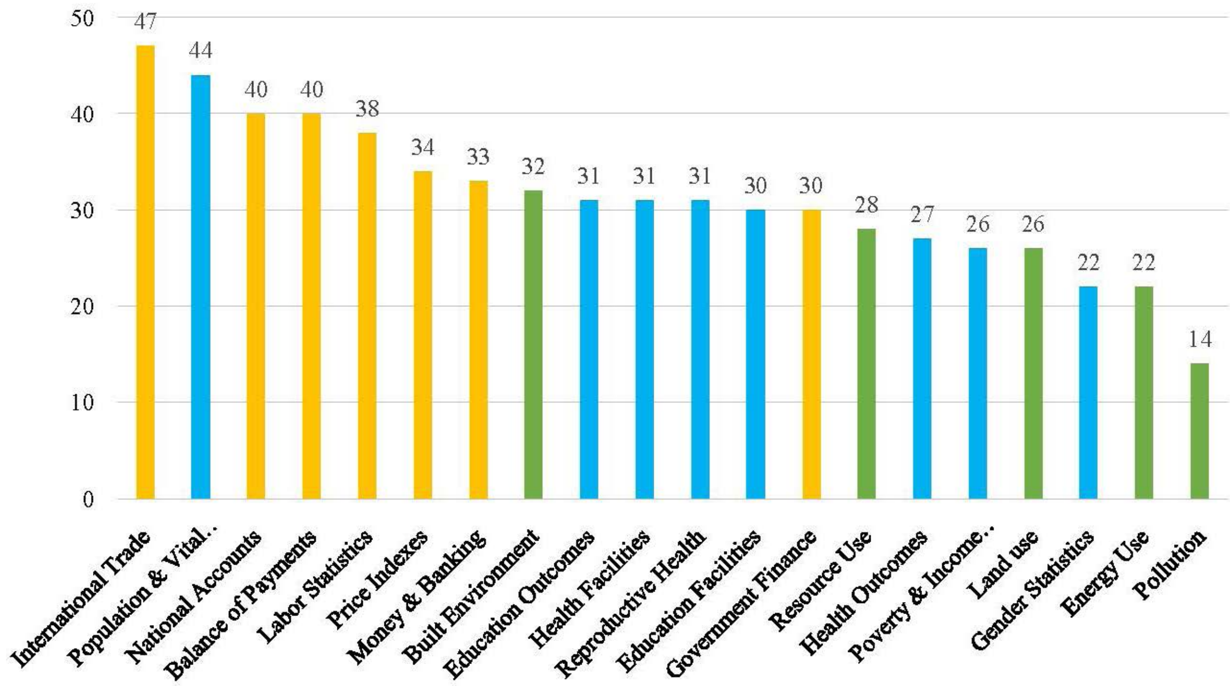
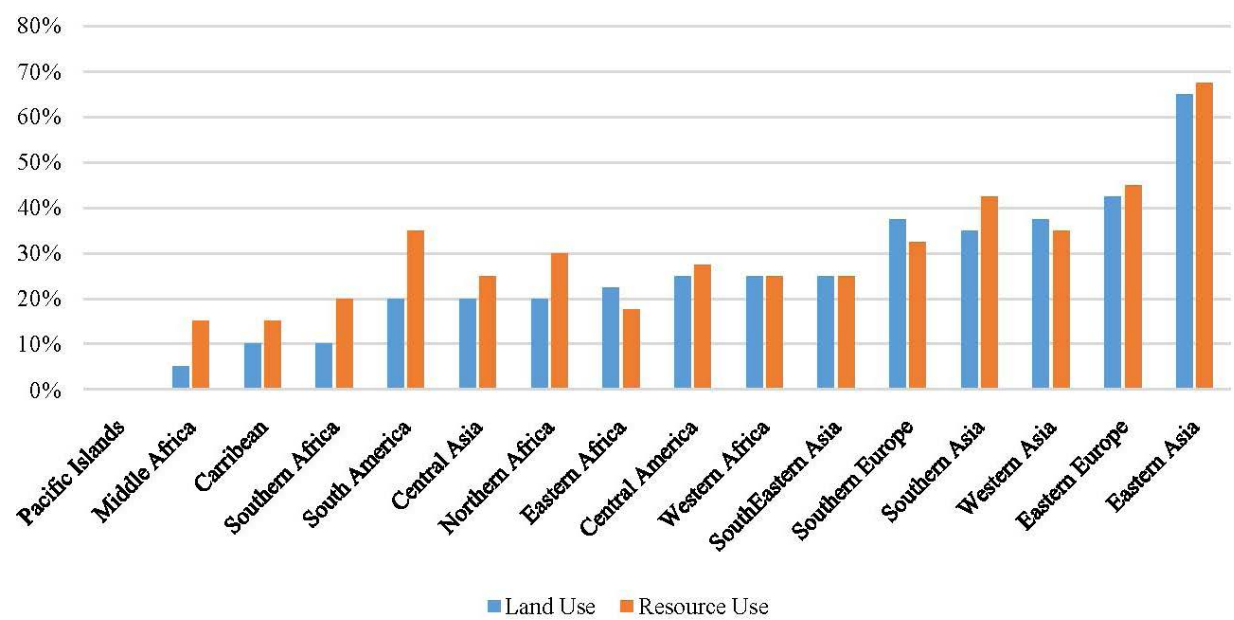
Across the 16 regions which ODIN spans, there is great disparity between ODIN scores within the categories Land Use and Resource Use. Looking at median scores between regions, the Pacific Islands received a median score of 0 percent across both categories. On the other end of the spectrum is Eastern Asia which scored 65 percent in Land Use and 68 percent in Resource Use (Table 2).

Table 1 - Average ODIN Scores by Data Category



Despite the great score variations between regions, the overall trend shows that the coverage and openness of agricultural data is often neglected. Thirteen of the 15 regions did not score over 40 percent in either agricultural data category and eight of those countries did not score over 25 percent in either category. The poorest performing regions in agricultural data include: The Pacific Islands, the Caribbean, all regions of Africa except Northern Africa, and Central and SouthEastern Asia. The highest performing regions include: Eastern Asia and Eastern Europe. Vietnam, showcases how agricultural statistics can be prioritized in a country's national statistical system. Vietnam is the only country included in ODIN 2015 assessments where the agricultural categories Land Use and Resource Use scored the highest out of all social, economic, and environmental categories. In the category Land Use, Vietnam scored 80 percent and in Resource Use they

Table 2 - Median ODIN Scores for Agricultural Data Categories by Region



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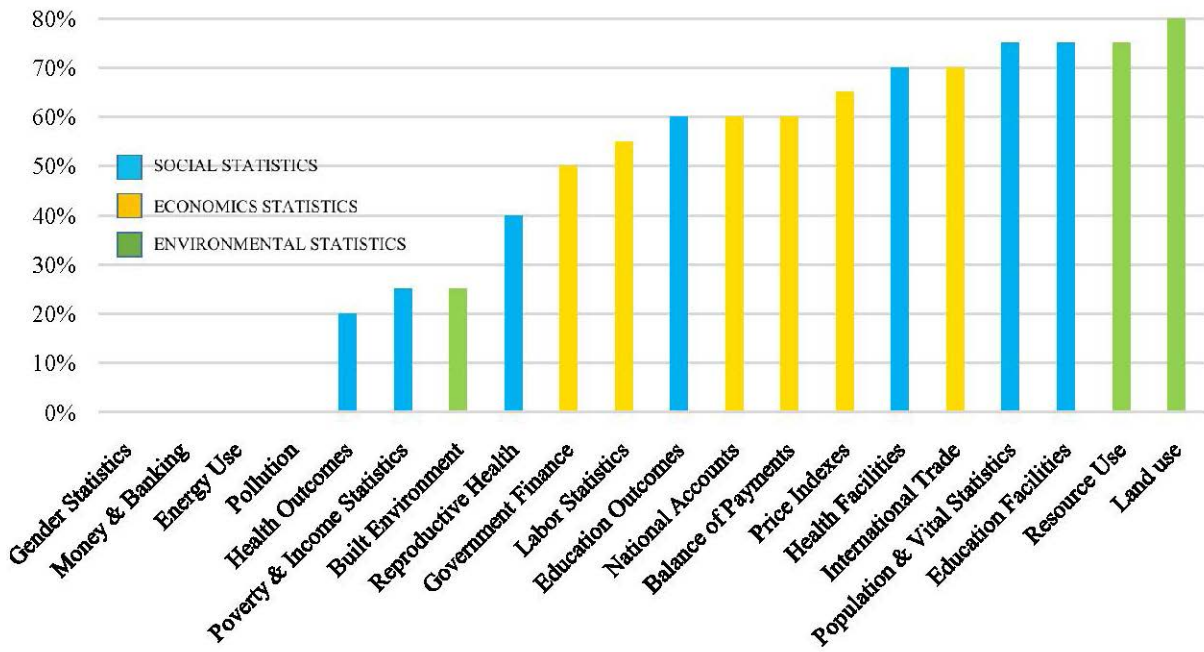
received a score of 75 percent (Table 3).

The country's national statistical office, General Statistics Office of Vietnam, hosts an interactive data portal in which users can select a number of agricultural indicators under the categories "Administrative Unit, Land and Climate" and "Agriculture, Forestry and Fishery" to download, often displaying data over 10 years old and at multiple administration levels.

Though the country scores highly in two of the lowest scoring categories across all countries, their overall ODIN rank is 15th place, partly because data in four out of 20 data categories is not made

Table 3 - ODIN Scores for All Data Categories for Vietnam



available. Nonetheless the country is an excellent case of how agricultural statistics can and should be made available to users.

According to ODIN assessments, agricultural and other environmental data are currently a low priority in many national statistics systems across all regions and particularly in comparison with social and economic data. While certain countries provide exceptions such as in Eastern Asia (China and Mongolia) and Vietnam, there is still room for improvements, especially in regards to the openness of such data.

4. Financing Measurement of SDG's

In the Marrakesh Action Plan in 2004 the international community costed out six actions needed to measure the achievement of MDG's. A similar exercise was done recently to see how much measurement of SDG's will require additional resources (SDSN,2015). The "Data for Development: A Needs Assessment for SDG Monitoring and Statistical Capacity Development" looked through the sources of data needed to cover the SDG's which includes census data, household surveys, agricultural surveys, administrative data, civil registration and vital statistics, economic statistics, including laborforce and establishment surveys, and trade statistics, geospatial data and other environmental data. The annual needs estimate for 77 IDA countries are between 902 and 941 million USD. The report compares the need assessment with the data provided by Paris21 (PRESS 2013) and other sources and come up with the annual gap in official development assistance (ODA) between 100 and 200 million USD. In 2016 two new reports, The State of Sustainable Development Data Funding (SDDF) and

PARIS21's Partner Report on Support to Statistics (PRESS 2016), review the financing of statistics in developing countries. These reports provide valuable information on the status of development data funding and propose concrete actions to increase and sustain funding for measuring the SDGs. They show that the financing needs for statistics are far greater than currently mobilized funding. According to the SDDF report, the total estimated annual costs for producing SDG data is $2.8 billion and $3.0 billion while the total estimated annual aid to support the production of SDG indicators is $635 to $685 million. This total cost is for 77 IDA-eligible and 67 IRBD countries. Based on current funding levels for statistics and data, an annual increase in aid of $350 to $400 million will be needed to support the production of SDG indicators.
An inventory of instruments used to finance statistics (ODW, 2016) looks at the ecosystem of aid for statistics. The study looks at the financing instruments such as loans, trust funds, technical

assistance provided financed with trust funds and other relevant instruments. The 2016 report contains expanded coverage from the 2015 report to include of multilateral development banks, intergovernmental organizations, bilateral donors, and private foundations. The major instruments used to finance agricultural statistics in this report are the Global Trust Fund for the Global Strategy to Improve Agricultural and Rural Statistics (GAO) managed by the Food and Agriculture Organization of the United Nations, a similar trust fund for Africa managed by African Development Bank, Living Standard Measurement Program managed by the World Bank, and Global Open Data Agriculture and Nutrition. The estimated annual value for agricultural statistics reported by participants in the 2016 survey was approximately $32.5 million USD. Of course the support for agricultural statistics is not fully captured by these trust funds and deeper analysis is needed as to come up with more precise estimates. The fact that the ODA gap to support statistics is quite sizable and the agricultural statistics cover many SGD indicators calls for a sizable increase in financing of agricultural statistics.

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THEMATIC SET

INDICATORS OF RURAL DEVELOPMENT

A01

Session Organizer
F. Sotte | Università Politecnica delle Marche | Ancona | Italy

ABSTRACT

The first assumption with rurality measures is that the concept is not univocally determined. Rurality evolves over time and takes different features in space. As a consequence it is difficult, ifnot impossible, to find a synthetic solution for rural development statistics, suitable for all times and latitudes. The traditional indicators based on the weight of agriculture (measured in some way: rate of employment, output, etc.) or even with demographic density (as the one proposed by OECD in the Nineties and subsequently adopted by the EU and others) need to be integrated with other measures useful to help in analyzing the potential development and convergence. Two are the relevant directions for this integrations. The first takes into account and adapt to rural areas the measures of well-being. The second considers the peripherality: rural territories have different opportunities in terms of cohesion and convergence in relation to their localization close or far from urban areas and the physical and virtual connection opportunities. The aim of the session is to explore how the diversity of rural areas can be measured in the different geographical and historical contexts.

LIST OF PAPERS

Possibilities to improve rural development statistics in support of the sustainable development goals in Mongolia
D. Enkhzaya | National Statistics Office | Ulaanbaatar | Mongolia
E. Erdenesan | National Statistics Office | Ulaanbaatar | Mongolia
DOI: 10.1481/icasVII.2016.a01

Indicators on rural development in Kenya
J. Mburu | KNBS | Nairobi | Kenya
DOI: 10.1481/icasVII.2016.a01b

Measuring EU rurality: an updated peripherurality indicator
F. Pagliacci | Università di Modena e Reggio Emilia | Modena | Italy
R. Esposti | Università Politecnica delle Marche | Ancona | Italy
B. Camaioni | CREA | Rome | Italy
F. Sotte | Università Politecnica delle Marche | Ancona | Italy
DOI: 10.1481/icasVII.2016.a01c

A01

Possibilities to improve rural development statistics in support of the sustainable development goals in Mongolia

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DOI: 10.1481/icasVII.2016.a01

ABSTRACT

Since Sustainable Development Goals (SDG) post-2015 agenda that will shape the next 15 yearsof world development has been commenced, it is important to propose possible new ideas,specifically in agriculture and rural development. As of being one of the countries where SDGs willbe implemented, Mongolia is in favour of supporting the SDGs and its further activities due to highexpectations of results from SDGs.Until recently, Mongolia has been recognized as agricultural based country, heavy dependence on livestock husbandry. Even though, share of agriculture sector has been diminishing in overall economy as rise in share of mining sector and service industry for last decade, contribution of agricultural sector on livelihood of population is remaining high.

Mongolia has unique agricultural practice as form of agricultural holding, which is mostly a single household. As of 2014, around 1 million people are living in rural area out of total population of 3 million, which is one-third of the total population. The livelihoods of these 1 million people in rural area are directly and indirectly depending on the agriculture and livestock. In that rural population, 0.3 million herders livelihood source is primarily livestock husbandry. The poverty is the one of the primary focus of SDGs as well as for Mongolia. About 20 percentof population is living under some degree of poverty and poverty levels for urban and rural areas are 18.8 per centand 26.4 percent respectively. Therefore, it could be evidently said that agriculture has great importance for reducing poverty. Promoting well-being and achieving SDGs would directly support livelihood of rural population of Mongolia. In order to do so, first thing to be done is identifying and measuring necessary indicators of agriculture. Main focus of this paper is to identify the measures of well-being of rural development statistics rather than localization opportunity measures and propose possible ways to improve well-being indicators of rural statistics that can provide possibility for tracking performance of the SDGs. Firstly, comparative analysis of SDGs as well as national statistics of Mongolia will be conducted broadly. The result from this section will provide information on capacity and coverage of the national statistics for measuring SDGs performance. Secondly, based on comparative analysis, paper will propose possible indicators for rural development statistics in several different pillars to be included in national statistics. Some indicators could be already included as a part of national statistics (rural poverty, income, expenditure and some rural well-being indicators),some indicators could require only segregation between rural and urban, and some could be totally new. Finally, possible cost-effective ways to produce proposed indicators of rural statistics for Mongolia will be produced.

Keywords: Sustainable Development Goals,urban areas, rural areas, rural development statistics, agricultural sector, poverty, national statistics,comparative analysis of SDG, possible indicators, cost-effective ways, sustainable income growth, environment and natural resource

PAPER

1. Introduction

SDG post-2015 agenda was an outcome of deliberations by the global society, through the United Nations, to try and find ways of addressing socio-economic and environmental challenges following the expiry of the Millennium Development Goals (Sovacool & Drupady, 2016). The global society realized that in the fight to eliminate poverty and improve living standards, it was important to ensure that there is sustainability in the economic activities. Scientists have raised concern over the rising global temperatures and a change in climate due to massive pollution. As such, the global society is trying to find ways of achieving development that is sustainable. Mongolia is one of the nations that have strongly supported the post 2015 SDG as a way of improving its economy without jeopardizing the ability of the future generation to meet their needs. For a long time, Mongolians have heavily relied on agriculture as the main source of their income. About one third of the country's population lives in the rural areas. Most of these rural dwellers depend directly or indirectly on agriculture.

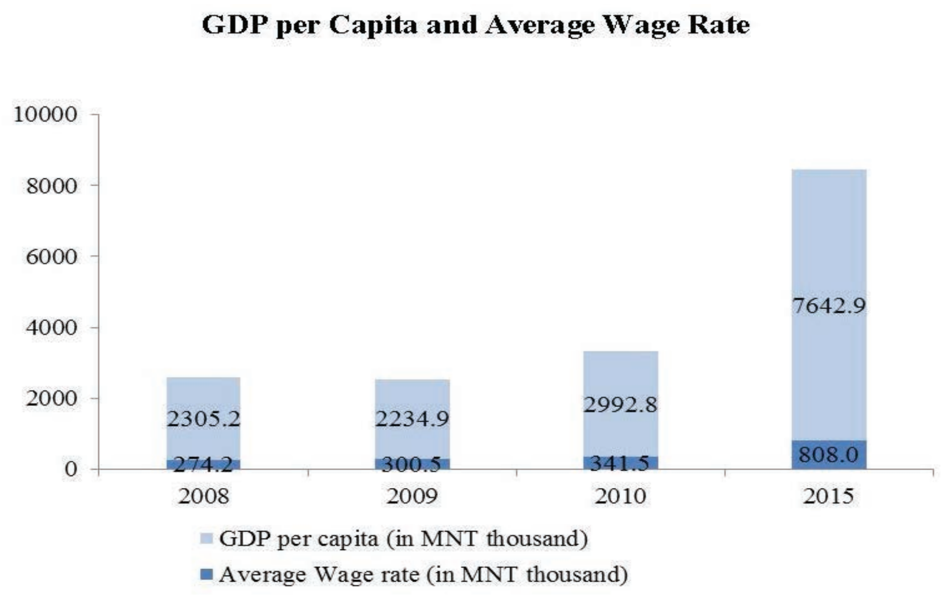
Gungaadorj (2002) says that agricultural production in Mongolia has significantly dropped within the last two decades. The reduction in agricultural production has been blamed on climate change. The regular rains that benefited farmers have become erratic. Cases of destructive storms are also on the rise. There is also the issue of rural to urban migration, especially among the younger population whoare now seeking white-collar jobs. A comparative analysis of the lifestyle of the city dwellers to that of the people living in rural settings shows that rural dwellers have lower living standards. They are more vulnerable to poverty. In this paper, itseeks to identify the measures of well-being of rural development statistics and propose possible ways to improve well-being indicators of rural statistics that can provide ways of tracking performance of the SDGs.

2. Comparative analysis of SDG in Mongolia

2.1 Focus on SDG in Mongolia

It is important to understand the fundamental differences between millennium development goals (MDG) and sustainable development goals (MDG). According to Smith (2015), while MDG primarily focused on poverty eradication, SDG looks athow livelihood of people can be improved today and in the future. SDG goes beyond achieving economic success and complete poverty eradication. It also looks at ways of protecting our environment and a number of other socio-political factors that not only affects the current but also the future generation. SDG is one of the nations that have embraced SDG as a way of addressing the socio-economic and environmental issues affecting it. The country is very optimistic that this program will help its population lead a better life than what is currently witnessed. The figure below shows the progress that has been made in achieving the MDG from 2008 to 2015.

Figure 1 - Progress made in achieving MDG in Mongolia



Source: the Millennium Development Goals Implementation in Mongolia: Fourth National Report, Ulaanbaatar, 2011

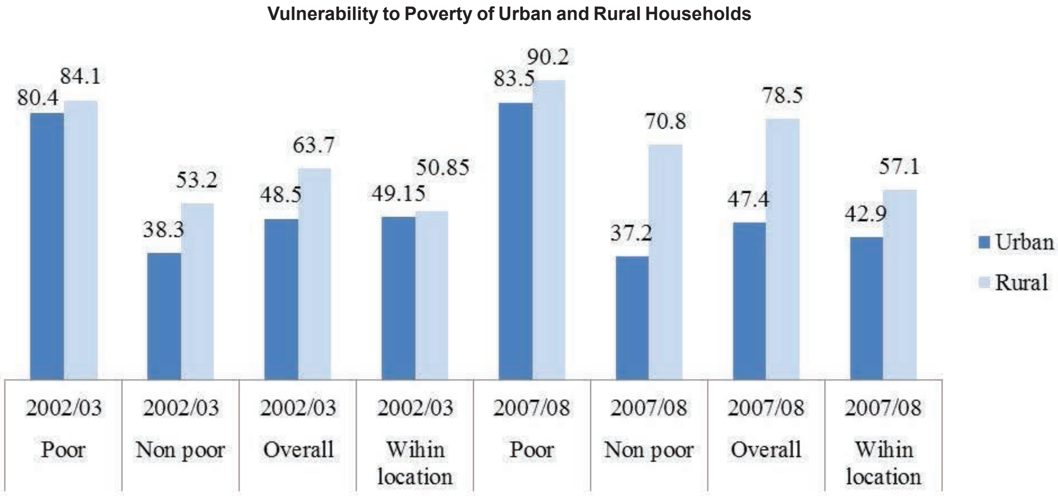
As shown in the above statistics, Mongoliahas made impressive steps in achieving MDG. The statistics show that the Average Wage Rate (AWR) increased consistently since 2008. It means that on average, Mongolians' earnings are on the rise. The Gross Domestic Product per Capita (GDP per Capita) is also increasing consistently. The GDP per Capita in 2015 was about triple the value that was registered in 2008. It is a sign that on average, life is getting better in Mongolia. The well-being indicator shows that more people are migrating from below the poverty line to the middle class. However, Smith (2015) warns that GDP per Capita often makes a major assumption that may make the nation forget a section of its population. The GDP is an average earning. As more people become very rich, the GDP will rise even if a section of the society still lives in object poverty. It means that this measure do not give a clear picture of wealth distribution in the country. In an effort to achieve SDG, it is important to have a more comprehensive focus on the entire population, including the new section of the poorest that have for a long time been ignored in the statistical surveysof the past. In this paper, the focus of SDG will be narrowed down to the fight against poverty as one of its fundamental principles.

2.2 Poverty profile in Mongolia

When MDG was developed in 2000, it was expected that by 2015, poverty shall be completely eliminated among the nations that had ratified it. However, it became apparent that many people still live in object poverty when SDG was developed in 2015. As such, poverty eradication was one of the key objectives of SDG that was developed in 2015. In Mongolia, poverty is still an issue that the government is still trying to address among its people. A Living Standards Measurement Survey conducted by Gungaadorj (2002) showed that poverty headcount remained unchanged in Mongolia for the period of 1995-1998. Poverty level was estimated to be 36%. Another statistics conducted by the World Bank showed that there was a new trend in wealth gap that most studies have always ignored, the gap between the poor and the poorest. The statistics showed that the gap between the poor and the poorest was widening almost at the same rate as that between the rich and the poor. This worrying trend was confirmed by a survey conducted by the National StatisticsOffice of Mongolia which indicated that there was an emerging population among the rural dwellers whose annual earnings were way below the poverty line (Gungaadorj, 2002). As a section of the society continued to amass more wealth that rival that f the richest people in the world, another section was sliding deep into poverty than what had previously been captured.

According to Smith (2015), it is possible that this new segment of the poorest had been ignored for a long time because of the parameters used in measuring wealth and income in the past. Studies often focused on asking the respondents if their earnings were below a specific level that was considered a poverty line. However, the recent surveys that ask respondents to state their average income per given period has revealed that some Mongolians are barely managing to get the basic needs such as food, shelter, and clothing. Majority of them are rural dwellers who rely on subsistence farming to earn a living. When rains fail, they get seriously affected because they rely on their crops almost entirely. A small section is urban dwellers that lack properly defined jobs and have no skills to be hired in some of the emerging companies in the region. The figure below shows a comparative analysis of the vulnerability to poverty among the rural and urban households in Mongolia.

Figure 2 - Comparative analysis of vulnerability to poverty among the rural and urban households



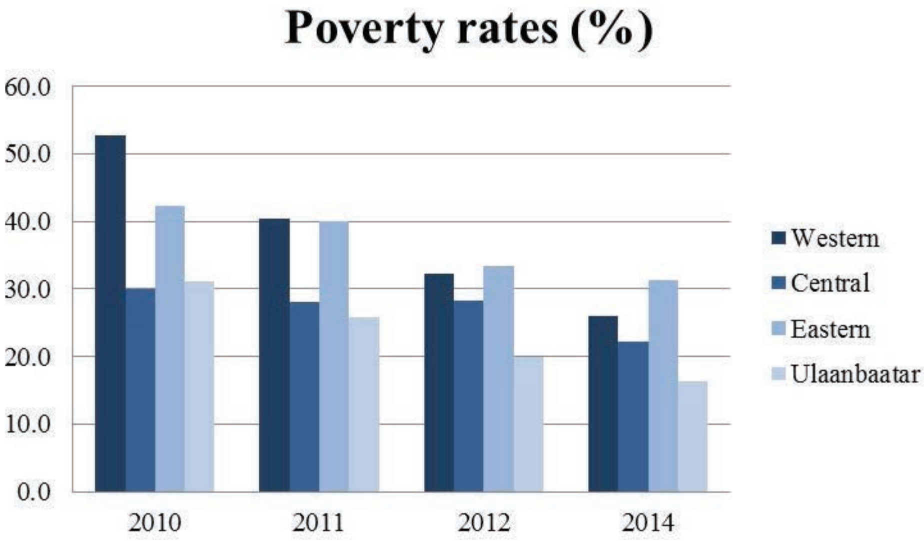
Source: Findings of ADB-financed "Analysing Triangle Relationship between growth, Inequality and Poverty in Mongolia, based on Household Socio-Economic Survey of 2002/03, 2007/08 studies

In this comparative analysis, the population is classified into three different groups and the overall. They include the poor, the non-poor, and those within location. There is a multiple comparison of people in different social classes, in different years, and based on their residence (rural and urban). As would be expected, the poor are more vulnerable as compared to the other groups. Smith (2015) attributes thisvulnerability to the rising trend where the rich are amassing more wealth at the expense of the poor. Although the average wage rate has been on the rise, there are still some people who earn very little because they lack alternative jobs due to their limited skills. A comparative analysis of vulnerability to poverty for the years 2002/2003 and 2007/2008 shows a shocking outcome as shown in the above statistics. It is clear that people are becoming more vulnerable as time goes by.

The poorest are the worst affected group, possibly become they rely more on subsistence farming that has become very unreliable become of erratic weather patterns. This is evident when comparing the vulnerability of the rural dwellers to that of the urban dwellers. In 2002/2003, 84.1% of the rural poor households were vulnerable compared to 80.4% of the urban poor households. The vulnerability increased in 2007/2008. In this period, it was estimated that 90.2% of the rural poor were vulnerable compared to 83.5% of the urban poor. A further comparative analysis of those within location shows the gap in vulnerability among those in urban centres compared to those in rural settings. In 2002/2003, it was estimated that 49.15% of the urban households and 50.85% of the rural households were vulnerable. The gap between the two groups was about 1.7%. In the period 2007/2008, it was estimated that 42.9% of the urban households and 57.1% of rural households were vulnerable. The gap between the urban and rural households in vulnerability had increased by over 4%.

In the above comparative statistics, one fact that comes out clearly is that the rural households are becoming more disadvantaged economically than the urban households. The vulnerability of the poor rural dwellers is now over 90%, and there are clear signs that show it may become worse if actions are not taken soon enough. The comparative statistics below confirms the argument that those in the rural areas still have to deal with the issue of poverty more than their colleagues in the urban centres.

Figure 3 - Regional poverty rates in Mongolia



Source: World Bank

As shown in the above statistics, the average poverty rate in Mongolia is dropping. However, it is clear that reduction rate is greater in urban (Ulaanbaatar city) than in the rural settings. Improving rural development statistics in support of SDG is, therefore, very important and the stakeholders should focus on improving the existing measures. As the lifestyle of the urban households improves, efforts should be made to ensure that rural households are not left behind.

3. Possible Indicators for Rural Development Statistics

It is estimated that about one third of the Mongolians (1 million people) live in the rural setting. Most of these rural dwellers largely rely on agriculture. According to Sovacool and Drupady (2016), "the country has very little arable land as most of its area is covered by grassy steppe with mountains to the north and west and the Gobi Desert to the south," (p. 56). It is clear that farming using traditional methods which wholly rely on nature is almost impossible in the region. It explains why the rural dwellers are more vulnerable to poverty than those in urban centers. It is important to find indicators for rural development statistics in different pillars for these rural households. Based on the above comparative analysis, the following are the proposed pillars that should be given a serious focus.

3.1 Sustainable income growth for the rural households

Rural poverty can only be eradicated by creating sustainable income growth in these regions. The aim is to ensure that their expenditure capacity is improved significantly and sustainably. As Gungaadorj (2002) says, the solution should be long-lasting other than being a quick-fix. The government should find ways of increasing the rural household's income through various strategies discussed in the section below. The approach should be broad based on the source of livelihood of individual families. Whether they are employed hence expect to be paid salaries or they are self-employed in the agriculture or mining sectors, there should be a consistent rise in their income. This will help in reducing their vulnerability to poverty.

3.2. Quality social service delivery for the rural people

Social services such as healthcare, access to sporting and entertainment facilities, good security, clean water supply, and many other government-sponsored services also define the quality of life of people. In most cases, these amenities tend to be more concentrated in the urban settings as opposed to the rural areas. This should not be the case anymore. The rural households need these social amenities just as much as the urban dwellers. Their well-being is dependent on them.

3.3. Sustainable use of environment and natural resource

The rural households are better placed to enjoy natural resources than those who are in urban centers. Farming and mining are some of the best ways of using the environment and natural resources sustainably. The fact that the country is sparsely populated makes it easy to practice commercial farming if modern methods are effectively employed. Livestock keeping can also be another aspect of farming that the rural households can consider. A report by Smith (2015) indicates that over 80% of Mongolia's exports are minerals, a sign that this industry is doing well. However, more can be done to help improve the living standards of the people living in rural areas.

3.4. Increased involvement in policy making

Public participation in policy making is becoming a major issue in various parts of the world. People now demand to be consulted whenever it is necessary to come up with major policies that may affect their life in one way or the other. The well-being of the rural people depends on the policies embraced by the government. There is no better way of taking care of the well-being of these people than to involve them in making policies. It may be an involving process but it is important as the country tries to achieve SDG.

4. Cost effective ways to produce proposed indicators

The proposed indicators should be realized in order to help improve the well-being of the rural dwellers in Mongolia. It is necessary to come up with cost effective ways to produce each of these indicators.

4.1. Sustainable income growth for the rural households

In order to have sustainable income growth for the rural households, the national government, in collaboration with the local authorities and foreign investors, should invest in local industries in the rural settings, especially the areas where the population is high. These industries will assure the locals of sustainable income through stable jobs. Farmers should be supported through grants and soft loans to mechanize their production.

4.2. Quality social service delivery for the rural people

Affordable healthcare should be considered a basic need for all the Mongolians, whether theyare staying in rural or urban areas. More healthcare facilities should be put up in the rural areas. These hospitals should be fully equipped. These people should also have access to properly equipped learning institutions. Running water is important, especially for those staying in the drier parts of the country. Other social amenities such as banks should also be available. This can be achieved through public-private partnerships.

4.3. Sustainable use of environment and natural resources

The environment is one of the three pillars of sustainable development. There should be a sustainable use of natural resources and environment. This can be done by avoiding pollution and overexploitation of these resources. In the mineral industry, the use of state-of-the-art machines can help in reducing wastage, pollution, and increasing productivity. Farming should be done in a way that it poses no threat to the country's biodiversity.

4.4. Increased involvement in policy making

The government should come up with community-based organizations (CBOs) that will allow the public to express their views on matters that affect their life either directly or indirectly. Through relevant departments, the government can coordinate with these CBOs to get to know the views of the people over various policies, especially if the policy turns out to be of public interest. The people of Mongolia have representatives in the parliament. In most of the cases, it is these representatives who ensure that public opinion is treated as such. However, sometimes it may be necessary to directly involve the people themselves. This is specifically so if the policy targets a small group of people whose needs cannot be effectively addressed by the parliament.

5. Conclusion

Improving rural development statistics in support of the sustainable development goals is in the interest of the government of Mongolia. It is easy to assume that the country is making positive economic progress while in real sense it is only a few people who are making abnormally high income while the rest of the population are getting poorer. The comparative statistical analysis shows that rural households are more vulnerable to poverty than those living in the urban settings. These rural dwellers have a higher percentage of people who fall in the category of the poorest. In an effort to improve rural development, focus should be laid on sustainable income growth, quality social services delivery, sustainable use of environment and natural resources, and increased involvement of the locals in policy making.

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Indicators on rural development in Kenya

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ABSTRACT

Agriculture is the mainstay of the Kenyan economy with 70.1 per cent of the population residing in the rural areas. The sector contributes about a quarter of the Gross Domestic Product, and is a major source of export earnings and rural employment. However, the quantity and quality of agricultural statistics in Kenya has deteriorated over time due to a multitude of factors. To address these challenges, the Kenya National Bureau of Statistics (KNBS) with support from the African Development Bank (AfDB) and in conjunction with stakeholders in the Agricultural Sector has developed a seven year Strategic Plan for Agriculture and Rural Statistics (SPARS) spanning the period 2015/16 to 2021/22. The Kenyan SPARS is the first of its kind in Anglophone Sub-Saharan Africa and is in tandem with the recommendations of the Global Strategy for the development of agriculture statistics and the African Action Plan for 2011-2017. The SPARS for Kenya is expected to form a major input into the yet to be finalized National Strategy for the Development of Statistics (NSDS) in Kenya.

The Global Strategy in one of its key pillars proposes the development of a minimum core set of indicators to address the dearth in availability of quality agricultural statistics. While the set of plausible and measurable agricultural indicators is clear, the same may not be the case with rural indicators. The probable set of rural indicators for Kenya provides a particularly interesting scenario due to the rapid progress in ICT that has taken place in recent times affecting many sectors of the economy across the country. This paper proposes a critical set of indicators that are relevant and key to the development of the rural areas in particular. The proposed indicators are expected to be Specific, Measurable, Achievable, Realistic and Time- bound (SMART) and easy for development practitioners among other users to utilize to monitor and evaluate progress or lack of it in rural areas. In Kenya, a set of statistical activities have been proposed in the SPARS_KEN that will make the generation of these indicators plausible when you factor in the requisite technical support from the KNBS.

Keywords: Rural indicators, Global Strategy

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1. Introduction

The Kenyan economy is dependent on agriculture with the sector accounting for about a quarter of the Gross Domestic Product. The sector is a major source of foreign exchange and rural employment (GOK 2015). The leading sub-sectors and major export earners include tea and horticulture. In 2015, the two commodities earned the country a combined KSh 208.8 billion equivalent to over US$ 2 billion (GOK 2016a). About 70.1 per cent of the population is resident in the rural areas. This is also where the bulk of agricultural production continues to take place through smallholder crop and livestock production. This is typical of several African countries as documented by Wiggins (2009) and Salami, et al, (2010). Despite this impressive performance, the quantity and quality of agricultural statistics in Kenya has deteriorated over time due to a multitude of factors. Key among them being limited funding for the requisite surveys and censuses (GOK 2016c).

However, in the recent past, financing of Statistical activities has risen in tandem with the rise in the profile and visibility of official Statistics. This has been amplified by renaming of the former Ministry of Devolution and Planning to the Ministry of Planning and Statistics (MPS). In addition, the current Principal Secretary in the MPS is a former Director of the Kenya National Bureau of Statistics. The promulgation of the 2010 Kenya constitution brought with it the county system of government as well as devolution of resources and services to the rural areas. However, the new system of government increased demand for data and statistics for county level planning, monitoring and evaluation The Bureau is in the process of developing annual County Statistical Abstracts (CSAs) using data that is currently available in the counties as well as data from ongoing household surveys.

1.2 Global Strategy for Agriculture

The Global Strategy proposes a multidimensional approach to address the deteriorating situation of agriculture statistics especially in developing countries. First through a core set of Agriculture and Rural Indicators coupled with the development of a master sampling frame for agriculture surveys (United Nations, 2011a). Africa is the first region to implement the Global Strategy through the development of the Action Plan for Africa. In this plan, while taking into account the comparative advantage of institutions, the African Development Bank (AfDB) was assigned the responsibility of providing to African countries technical assistance and governance; the United Nations Economic Commission for Africa (UNECA) was assigned the responsibility of providing training; while the Food and Agriculture Organization of the United Nations (FAO) was assigned the responsibility of conducting research (United Nations, 2011(b) and GOK 2016c).

1.3 Strategic Plan for Agriculture and Rural Statistics for Kenya

To address these challenges, the Kenya National Bureau of Statistics (KNBS) with support from the AfDB and in conjunction with stakeholders in the Agricultural Sector developed in 2014/15 a seven year Strategic Plan for Agriculture and Rural Statistics (SPARS_KEN) spanning the period 2015 to 2022. The Kenyan SPARS is the first of its kind in Anglophone Sub-Saharan Africa and is in tandem with the recommendations of the Global Strategy for the development of agriculture statistics and the African Action Plan for 2011-2017. The SPARS for Kenya is expected to form a major input into the yet to be finalized National Strategy for the Development of Statistics (NSDS) in Kenya.

1.4 Rural versus Urban areas

Rural areas are characterized by scattered population and tend to lack most if not all the facilities/amenities found in the urban areas such as proper sanitation, road infrastructure among others. Urban areas tend to have higher population density and are more endowed in terms of facilities. Peri-urban areas are somewhat to urban area but to a lesser extent. In these areas, only some of the facilities found in urban areas exist and the population concentration is moderate (GOK 2010). Rural statistics refer to broad range of statistics (economic, social, demographic, agricultural, etc.) covering the rural areas of a country. In this case rural statistics refer to those statistics that are agriculture related (GOK 2016b).

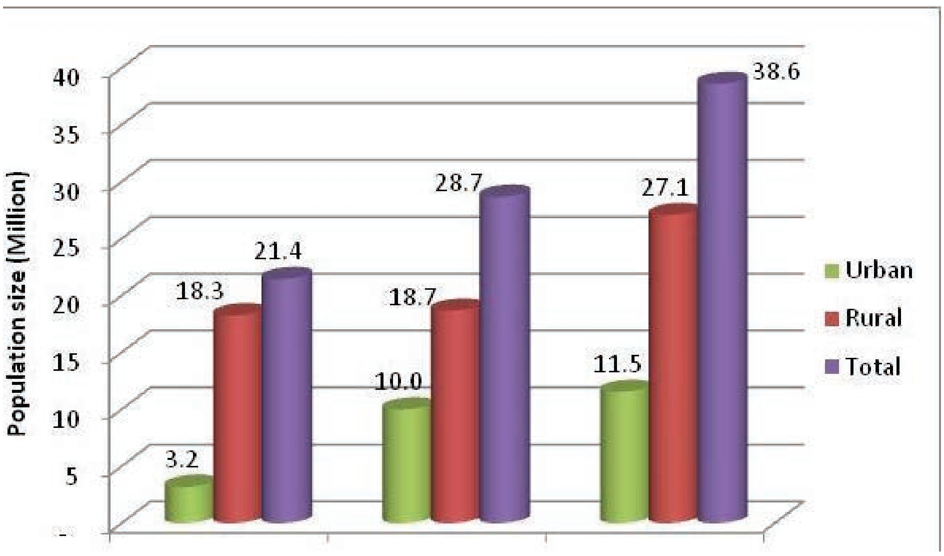
1.5

Generation of rural statistics though important is not sufficient without the urban component, if only for comparison sake. Available population statistics indicate that Kenya has been urbanizing very rapidly. Areas that were previously rural have changed to urban areas with time as population rose and in-migration took place. Indeed, some of the former agricultural farms near Nairobi have changed use to real estate. The desire to produce own food and hence ensure own food security in urban areas has resulted in urban and peri-urban agriculture. This needs to be considered in agriculture production as well as part of consumption. The Figure 1 below shows trends in population growth in urban and rural Kenya over the last three census years.

1.6 The Policy Environment

The long term development planning in Kenya is guided by the Vision 2030 through the Medium Term Plans (MTPs). The Vision has three pillars namely economic, social and political and envisions a prosperous and globally competitive country by year 2030. The policy recognizes Agriculture, Livestock

Figure 1 - Trends in Kenya's Population by Rural and Urban areas, 1989, 1999, 2009



Source: Kenya National Bureau of Statistics and Fishries as well as the Information Communication and Technology (ICT) sectors as a key enabler of this vision (GOK, 2007). Towards this end, the National Information Communication and technology (ICT) Authority developed the national ICT policy and subsequently the 2014-2017 National Master Plan with the aim of facilitating the realization of Vision 2030 (GOK 2006 and GOK 2014). The implementation of the ICT masterplan has some of the outcomes expected by 2017 as the creation of 180,000 direct jobs, recognition of Kenya as a regional ICT hub and increased public value of e-Government services with 50 per cent of adults accessing atleast one e-Government service (GOK, 2014). This has been backed up by several positive developments in several areas such as the deployment of five under sea fibre optic cables, Electricity connection to more households and most of the public primary school as well as all government institutions both at the national and county levels as well as high schools and other institutions of learning have operational websites. Provision of laptops/tablets for every child joining standard one in all public primary schools in Kenya is currently underway and it is supposed to facilitate e-Learning in public primary schools. The Government has institutionalized e-Government where services are shared through Huduma centres. This is also the case with e-Procurement and e-Recruitment where procurement and application for Government jobs is done online. The KNBS is gradually shifting from paper based questionnaires in survey administration to Computer Assisted Personal Interviews (CAPI) using tablets and smart phones in data collection.

1.7 The ICT Context

Annan *et al* (2015) in one of the articles observes that Africa has gone digital with investments in fibre optic technology, increased access to mobile broadband and use of low cost smart phones and smart phones. Analogously, the number of mobile-cellular telephone subscriptions by population aged three years and above in Kenya rose from 82.5 per 100 inhabitants in 2013 to 86.2 per 100 inhabitants in 2014 as reflected in Table 1. The figures are based on. The access to mobile-cellular telephone has cut across both rural and urban areas. Mobile phones have multiple uses which include calling, Short Messaging Service (SMS), internet connectivity as well as mobile money transactions. In Kenya, mobile money transactions have been used very extensively and include transfers, payments, loans (i.e M-Shwari), mobile banking among others. Table 1 further shows that the total funds transfers through mobile telephony rose from KSh 1,902 billion in 2013to KSh 2,372 billion in 2014. This has resulted in significant financial inclusivity especially in rural areas. According to GOK (2016b), financial exclusion of the rural populations reduced from 40.7 per cent in 2006 to 22.0 per cent in 2016. Similarly, financial exclusion of the urban populations reduced from 42.8 per cent in 2006 to 9.5 per cent in 2016.

The use of mobile telephony has resulted in Kenyan youth joining social media (facebook, whatsap, instagram, twitter, you tube etc). This has facilitated learning and information exchange among the youth and farmers in general. Some examples of relevant information exchange groups include: a) Kilimo Biashara; b) Onion and water melon farming gurus; c) Mukulima smart d) Mkulima bora e) Mkulima ni ujuzi f) Smart farm g) Shamba shape up Closely allied to this innovative extension approach is the agribusiness oriented farming where smallholder irrigation of horticultural produce under green houses is gradually taking root in Kenya. The farmers produce French beans, tomatoes, onions among others for local and export market, The benefits of this information exchange coupled with green house irrigation are bound to positively transform productivity at the farm level resulting in a shift from subsistence small holder rural agriculture to commercial market oriented, profit driven farming in Kenya.

Table 1: Selected Internet and Mobile telephony indicators, 2010-2014

Indicator	2010	2011	2012	2013	2014*
Internet subscribers per 100 inhabitants (Both wireless & fixed)	8.0	15.6	20.9	31.6	38.3
Mobile-cellular telephone subscriptions per 100 inhabitants	71.5	75.1	82.4	82.5	86.2
Wireless internet subscribers per 100 inhabitants	8.9	17.1	-23.0	-34.7	-42.2
Broad band subscriptions per 100 inhabitants (wireless)	0.5	0.6	5.0	6.4	10.7
Mobile money Transfer Agents	32,949	42,313	49,079	93,689	121,924
Mobile money Transfer Service Subscribers ('000)	10,615	17,396	19,319	26,016	26,023
Total transfers (KSh billion)	732	1,169	1,544	1,902	2,372

Source: Economic Survey, 2015
* Provisional

1.8 Local on-line platforms

Kenyans have developed several online platforms such as „iprocureč which prescreens its vendors to provide reliable local procurement services connecting agricultural businesses and institutional buyers. „Sendyčprovides a platform that connects customers with motor cycle couriers to offer delivery services payable with mobile money. „Ushahindič and „Uchaguzičare crowd sourced applications that report and map election violence in Kenya. „Nairobitsča youth organization in Kenya exposes underprivileged young people from informal settlements to web design and other ICT skills while „Akirachixčreaches out to „geek girlsčamong others (United Nations, 2016).

1.9 Indicators of Rural Development

Indicators are very useful in monitoring, and evaluation. Good quality indicators are Specific, Measurable, Achievable, Realistic and Time-bound (SMART) and easy for development practitioners among other users to utilize to monitor and evaluate progress or lack of it in rural areas. At the international level, indicators that had been developed to monitor the Millennium Development Goals are examples of SMART indicators . The Wye Group has in the recent past compiled a set of indicators for monitoring rural livelihoods as shown in United Nations (2007). More recently, Bryden J. (2011) did compile rural development indicators in the European Union. The Global strategy proposes on a minimum set of core indicators that countries should focus on in an effort to improve the quality and quantity of agriculture statistics. This paper does not dwell on the core indicators which very clear but focuses on the less clear rural development indicators using the Kenyan context as the basis. Table 2 below shows selected indicators for monitoring various aspects of rural development in Kenya.

Table 2 Selected Indicators for Measuring Rural Development in Kenya

Issue	Indicator	Sub-Populations	Source
Agriculture	Green house irrigation	Number, Area, Crop types	Economic Survey
Demography	Population Density	Rural, Urban	Population and Housing Census
	% population aged 64 years and above	Sex	Population and Housing Census
	Infant Mortality rate	Sex	Demographic and Health Survey, Population and Housing Census
	Under 5 Mortality Rate	Sex	Demographic and Health Survey, Population and Housing Census
Employment	% of the population that is self employed	Rural, Urban	Economic Survey
Health	Life Expectancy at Birth	Sex	Population and Housing Census
ICT	Internet access	Rural, Urban	ICT survey, Population and Housing Census
Malnutrition	Proportion of children under five who are underweight	Sex, Rural, Urban	Demographic and Health Survey
	Proportion of children under five who are stunted	Sex, Rural, Urban	Demographic and Health Survey
	Proportion of children under five who are wasted	Sex, Rural, Urban	Demographic and Health Survey
Poverty	Food Poverty	Rural, Urban	Kenya Integrated Household Budget Survey
	Absolute poverty	Rural, Urban	Kenya Integrated Household Budget Survey
	Hard core poverty	Rural, Urban	Kenya Integrated Household Budget Survey
Sanitation	Population with access to clean water	Increased specialisation	Demographic and Health Survey, Population and Housing Census
Water	Population with access to clean water	Rural, Urban	Demographic and Health Survey, Population and Housing Census

1.10 Conclusion

While agriculture continues to be the mainstay of the Kenyan economy the state of agricultural statistics has not been very good. In response to this state of affairs, the Global Strategy for the improvement of agricultural statistics provided the necessary impetus which culminated in the development of SPARS_KEN. The Kenya government has provided an enabling environment for the proliferation of various forms of ICT. Through Public Private Partnerships (PPP), the government has partnered with a leading telecommunication firm in Kenya so as to facilitate provision of affordable fertilizer to smallholder farmers through a fertilizer e-Subsidy programme. A crop insurance initiative is being piloted in selected counties by the government along a similar PPP approach. In Kenya, technology adoption especially around mobile telephony has been very vibrant and has had a major positive impact in the development of the rural areas in Kenya. The introduction of laptops and tablets in public primary schools is expected to lead to consumption of less paper. This will over time earn environmental dividends over time leading to reduced deforestation, less pollution and hence a cleaner rural environment. The KNBS is gradually shifting from paper based questionnaires in survey administration to Computer Assisted Personal Interviews (CAPI) using tablets and smart phones in data collection. This is similarly expected to result in similar benefits. The focus of this paper was on indicators of rural development within the foregoing Kenya context. The paper acknowledges that there are an infinite number of indicators that can possibly be generated but as Table 2 below shows, only afew very crucial rural indicators have been selected bearing in mind the unique Kenyan context.

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A01

Measuring EU rurality: an updated peripherurality indicator

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ABSTRACT

In the last decades, EU rural areas have been experiencing major transformations, which have made any traditional urban-rural divide outdated (OECD, 2006). Going beyond urban-rural dichotomy, the paper moves from the analysis of the PeripheRurality Indicator (PRI), computed by Camaioni et al. (2013) for all EU NUTS 3 regions. For each of them, PRI includes both conventional socio-economic indicators and geographical characteristics. Nevertheless, this paper enriches PRI's original territorial and geographical dimension, by taking explicitly into account even the degree of rurality of neighbouring regions. Eventually, it returns 16 EU typologies of urban-rural areas. Then, such a classification is tested on 2007-2011 Common Agricultural Policy (CAP) expenditure data. Indeed, the paper considers the coherence of fund allocation with the real characteristics of EU rural space.

Keywords: Rurality, Peripherality, Spatial analysis

PAPER

1. Introduction

This paper aims to enrich the role of territorial and geographical dimensions in assessing the degree of rurality of EU-27 NUTS 3 regions. Rural regions still play a key role within the EU economy and society, although major transformations and an increasing heterogeneity have occurred since EU Eastern enlargements. With regard to those transformations, Camaioni et al. (2013) introduced a composite and comprehensive PeripheRurality Indicator (PRI), which updates traditional urban-rural divides suggested by OECD (2006). PRI provides a new representation of EU rural geography, jointly considering conventional rural features (e.g., low population density, key role of agriculture, etc.) and geographical aspects, such as remoteness.

Nevertheless, space and geography play an even larger role in defining rurality at local level. Indeed, when considering remoteness, even neighbouring areas' one may affect it: two regions, which share the same extent of rurality according to the PRI, can actually differ if the former is close to a large metropolitan area while the latter is surrounded by other rural areas. Indeed, the current post-industrial rurality framework (Sotte et al., 2012) stresses integrations across rural space and between rural and urban territories as critical. When sharing a neighbouring space, two regions may affect each other on given common issues (e.g. policy implementation). Thus, any indicator of rurality should carefully consider even the degree of rurality across the neighbourhood (Camaioni et al., 2013). Furthermore, a more spatially-integrated approach in policy formulation could also result in better framed policies (Esposti, 2011): for instance, the policy Common Agricultural Policy (CAP), which supports the EU agriculture and its rural space, would largely benefit from a more spatially-integrated approach at local level. In fact, CAP fund allocation is largely unbalanced across EU urban-rural regions.

The paper is organised as follows. Section 2 shortly discusses the PRI in the light of the wider debate about defining EU rural areas, from the most "conventional" approaches to more innovative and multidimensional ones. Section 3 analyses PRI territorial distribution across Europe, by also considering the role of the neighbouring regions in affecting major differences observed at local level. By jointly considering those two dimensions, it is possible to disentangle 16 different typologies of urban-rural regions. Section 4 applies this classification to the analysis of the allocation of CAP expenditures across Europe. Section 5 concludes the paper.

2. The PeripheRurality Indicator in the light of alternative definitions of rurality

In a multidimensional perspective, the need for a new classification of rural areas comes from the evolution of the concept itself of rural areas. Lacking a strong theoretical foundation, the concept has largely evolved over time (Johnston, 1970; Timmer, 1988; Esposti and Sotte, 2002; Sotte *et al.*, 2012). Changes in the main definitions of rural areas call for new approaches in their classifications (Camaioni *et al.*, 2013). Since the 1990s *post-industrial rurality* has emerged. Accordingly, two features now characterise rural areas (Sotte *et al.*, 2012): i) a greater importance of territorial issues (e.g., stronger integrations across the rural space and between rural and urban areas[1]); ii) their polymorphism (i.e., the co-existence of different forms of rural-rural and rural-urban integration patterns).

In particular, polymorphism has been seldom tackled by conventional measures of rurality (especially those based on sector-based or demographic indicators). It couples with the lack of homogeneous definitions of rural areas[2], which is due to remarkable differences in terms of demographic, socio-economic, and environmental conditions occurring across the EU rural space (European Commission, 2006; Hoggart *et al.*, 1995; Copus *et al.*, 2008).

Despite those difficulties, some homogeneous definitions of urban-rural typologies have been provided at EU level. Both OECD (2006) and the EC (Eurostat, 2010) follow a similar approach in defining them: they just refer to population density at local level and the presence of large cities. Such an approach just measures rural areas through a single indicator, eventually collapsed into a discrete ordinal variable. Such a measure returns just three urban-rural typologies, seeming too rough to capture increasing polymorphism across Europe.

Moving from those major pitfalls, many works have classified EU rural areas, adopting a multidimensional approach (Copus, 1996; Bollman *et al.*, 2005; Copus *et al.*, 2008; Terluin et al., 1995; Psaltopoulos et al., 2006; Lowe and Ward, 2009). Camaioni *et al.* (2013) suggest further improvements to this field of study, by defining a PeripheRurality Indicator (PRI). They apply conventional Principal Component Analysis (PCA) to a 24-variables dataset, which covers socio-demographic features, economic structure, land use, accessibility/remoteness (over different territorial scales). Their analysis refers to NUTS 3 territorial level, considering 1288 regions[3]. Firstly, PCA returns a standardised score for each region on five uncorrelated Principal Components (PCs)[4]. Eventually, according to them an ideal urban benchmark (i.e., a region with the most urban features across Europe) is identified. In particular, the urban benchmark is represented by the cities of Paris and London. Secondly, the statistical "distance" between any EU region and this benchmark is computed (Camaioni et al., 2013). So, by construction, the greater the PRI the more rural and peripheral a given region is. Thus, the PRI captures both a socio-economic and a spatial distance from urban features, hence its definition (Camaioni *et al.*, 2013).

Besides the large number of regions taken into account[5], an additional novelty of that work refers to the fact it explicitly refers to geographical issues: indeed, the PRI considers both the physical distance of each region from major EU urban areas and its accessibility according to physical infrastructures. Thus, it provides an original representation of the EU urban-rural geography, shedding light on the integration between rural and urban areas (Camaioni et al., 2013).

Nevertheless, the set of territorial information the PRI provides can be enhanced further. Indeed, a spatially-enriched PRI can be obtained by explicitly including more information on the rural-urban characteristics of the neighbouring space, as well.

3. The PeripheRurality Indicator: Which Role for Neighbouring Regions?

Figure 1 (left panel) returns PRI main patterns across Europe: the greater its value, the more rural and peripheral is any given region. Camaioni et al. (2013) already observe that the lowest values occur across capital-city regions and, more generally, across the central Europe urban space. On the contrary, PRI highest values occur throughout EU peripheries (Mediterranean regions, Eastern Europe, Northern Scandinavia). From a more general perspective, PRI wide variability sheds light on a new EU geography, suggesting a long-standing core-periphery pattern.

Additional information on those territorial divides also comes from the analysis of the spatially-lagged values of the PRI, which were already computed in Camaioni *et al.* (2015). Per each NUTS 3 region, the right panel of Figure 1 returns the average value of the PRI across its neighbours. This value is computed through a (*n* x *n*) row-standardized spatial weights matrix (**W**), whose generic element w_{ij}, is defined as:

$$w_{ij} = w^*_{ij} / \sum_{j=1}^{n} w^*_{ij} \qquad (1)$$

In (1), the generic element w^*_{ij} can take two different values: $w^*_{ij} = 1$ when $i \neq j$ and $j \in N(i)$; $w^*_{ij} = 0$ when $i = j$ or $i \neq j$ and $j \notin N(i)$, where $N(i)$ is the set of neighbours of the i-th region. Here, a *first-order queen contiguity matrix* defines neighbourhood: two regions are considered as

[1] Rural regions are now assigned the role of supplying urban societies with a larger set of services associated to public goods, such as environmental and cultural goods (Sotte et al., 2012).

[2] Even the identification of those areas where rural development policy (i.e. a EU policy) is expected to be implemented is assigned to Member States, which are autonomously in charge of defining their own rural areas.

[3] They adopt the NUTS 2006 classification, excluding those regions that are located far away from Europe (e.g. the French Departements d'outre-Mer). Further comments and caveats on the dataset selection are returned in Camaioni et al. (2013).

[4] They range from "Economic and geographical centrality" to "Manufacturing in rural areas" and to "Land use: forests vs. agricultural areas" (Camaioni et al., 2013).

[5] Previous studies, such as Shucksmith et al. (2005), had just focused on NUTS 2 level regions.

neighbours only if they share a common boundary or vertex (Anselin, 1988)[6]. A major issue refers to islands, which show no contiguous regions. For the purpose of this work, we assume that for those regions the lagged PRI equals the PRI itself[7]. As for the PRI, the greater the spatially-lagged PRI value, the more rural and peripheral the neighbours of a given region are.

By jointly comparing these two values, it is possible to disentangle those regions that show different urban-rural characteristics compared to their neighbours. In general terms, we observe the PRI showing a positive spatial dependence across EU NUTS 3 regions. Both the value of the Moran's I statistics (Moran, 1950; Cliff and Ord, 1981), being equal to 0.547, and the Moran's plot shown in Figure 2 confirm it: most of EU regions show similar levels of rurality compared to their neighbours. Nevertheless, deviations from this tendency also arise: some rural regions are close to urban neighbours, while some cities are surrounded by rural areas. To detect those different regional typologies, we can split the Moran's plot, by referring to PRI's quartile distribution. Thus, 16 (i.e., 4X4) different partitions of the EU space are returned (Figure 2).

Figure 1 – PRI and lagged PRI across Europe (values by NUTS 3 region)

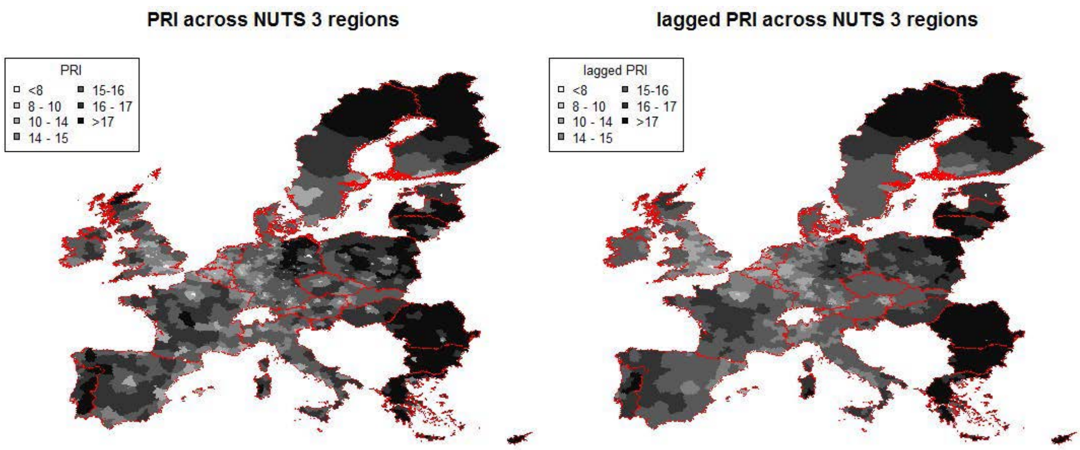
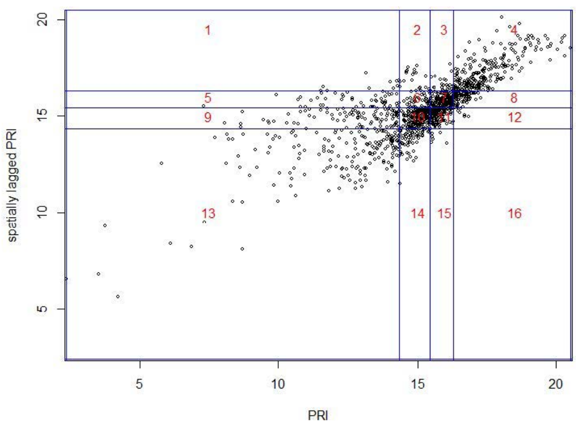


Figure 2 – Moran's plot for the PRI and typologies of regions

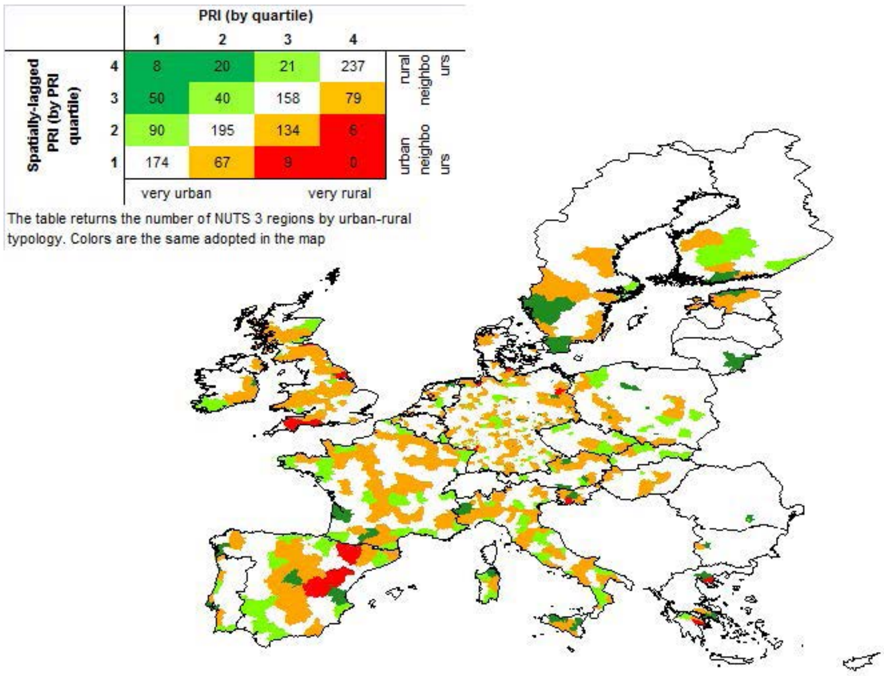


Each regional typology comprises a different number of regions. As already pointed out, most of observations occur along the main bisector: those regions share similar urban-rural features with their own neighbours. Nevertheless, 78 urban regions are surrounded by more rural areas (typologies #1, #2, #5 in Figure 3). Other 15, rural regions are spatially close to urban areas (typologies #12, #15). The territorial distribution of each of the aforementioned urban-rural typologies sheds light on a new urban-rural EU geography. For instance, some EU capital cities such as Madrid or Helsinki are urban areas, but they are surrounded by very rural regions. Conversely, some of the UK rural areas, which show very high PRI values, have urban contexts as their neighbours, being highly affected from them. In more general terms, the regions across the Eastern and Northern peripheries of the EU seem to share similar values of the PRI and spatially- lagged PRI. On the opposite side, in Western Europe, urban and rural are more deeply intertwined (e.g. in France, Germany, Italy and Spain). This is probably due to the specific characteristics of the medium-sized cities network, which exists in those countries.

[6] The first-order queen contiguity matrix and the spatially-lagged PRI are computed using the package 'spdep' (Bivand and Piras, 2015) in the R software (R Core Team, 2013).

[7] Camaioni et al. (2015) make alternative assumptions on islands and their neighbours.

Figure 3 – Urban-rural typologies across Europe and number of NUTS-3 regions in each typology



4. The allocation of CAP expenditure across different urban-rural typologies

This new urban-rural classification, which takes into account even spatial spillovers, may widely improve the analysis of CAP expenditure allocation throughout the EU. The topic has been widely debated: Camaioni *et al.* (2013; 2015) have already analysed the territorial distribution of Rural Development Policy (RDP) ex-post expenditure. In particular, they have stressed the importance of three main drivers: a 'country effect'; a 'rural effect' (i.e., the more rural a region the larger the amount of support); a 'pure spatial effect' (i.e., the influence of the neighbouring space and of its degree of rurality), which has been estimated adopting alternative spatial model specifications (Camaioni *et al.*, 2015). Camaioni *et al.* (2014) have also analysed the distribution of the overall CAP expenditure across the EU space, disentangling it by pillar (Pillar One and RDP) and by measure. Eventually, correlation between CAP expenditure at NUTS 3 level and rurality (as expressed by the PRI) is assessed: CAP expenditure seems to be less "rural" and less "agricultural" than stated. Indeed, when considering expenditure per unit of land and per unit of labour, the CAP supports urban and central regions more than rural ones (Camaioni *et al.*, 2014).

This work updates that descriptive analysis, by underlining major territorial unbalances in CAP ex-post expenditure across the aforementioned 16 urban-rural typologies. This analysis refers to the same data used by Camaioni *et al.* (2014), namely 2007-2011 payments from both EAGF and EAFRD. Data source is the European Commission (DG Agriculture): here, individual data have been aggregated to NUTS 3 level, to keep the anonymity. For the sake of simplicity, here we just refer to three broad typologies of expenditure, namely total CAP expenditure, Pillar One expenditure and Pillar Two (RDP) expenditure. Two pillars largely differ in their own ultimate goals: Pillar One is aimed at supporting agricultural activities and farmers' income; the second Pillar (namely RDP) implements several measures to support competitiveness of agricultural holdings in rural regions, diversification of the economy in rural areas, improvement in the qualit y of life within rural areas. In particular, here we refer to three indices of CAP expenditure intensity: expenditure per hectare of utilised agricultural area (Euro/UAA); expenditure per annual work unit employed in agriculture (Euro/AWU); Expenditure per thousand Euros of agricultural gross value added (Euro/.000 Euro)[8].

Nevertheless, Camaioni et al. (2014) point out that when expressing the intensity of CAP support by means of agriculture-related variables, extremely high values may occur across urban areas. This situation happens when values for UAA, AWU and agricultural gross value added are particularly small: it implies artificially-high levels of expenditure intensity for some of the most urban regions, throughout Europe. Thus, in order to get rid of those distortive effects, 30 urban regions were already excluded from the analysis in Camaioni et al. (2014). Here, same decisions are undertaken: of the excluded observations, more than a half (16 out of 30) are in typology #13 (i.e., the most urban regions with the most urban neighbours); 7 are in typology #9; 6 are in typology 5 and 1 is in typology #2. Even latter typologies refer to urban regions, but, in this case, they show rural neighbours.

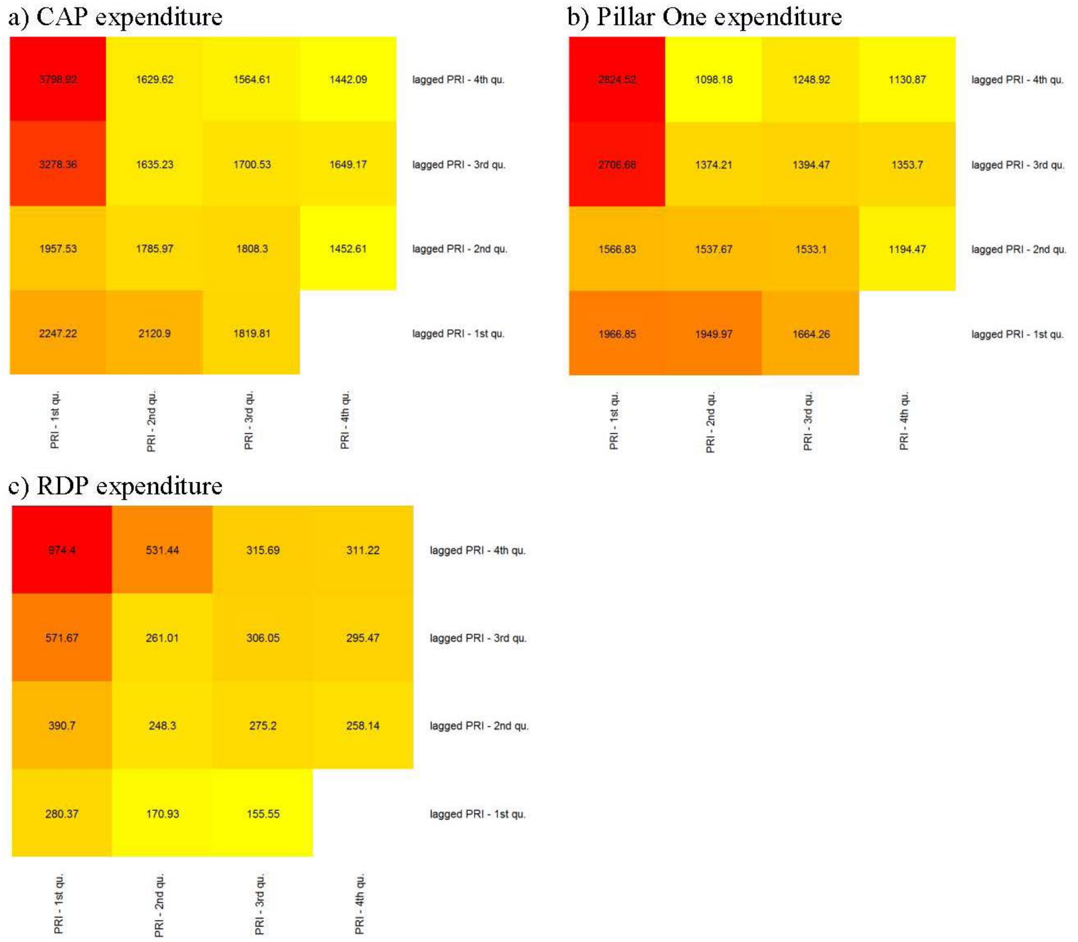
For the sake of simplicity, Figure 4 just refers to the expenditure intensity per hectare of UAA. Average

[8] Further details about adopted methodology to compute those indicators are shown in Camaioni et al. (2014).

expenditure intensities of total CAP, of Pillar One and of Pillar Two are returned for each of the aforementioned urban-rural typologies[9]. These results represent a refinement of previous studies. They confirm that urban regions are generally more supported than rural ones throughout the EU. Nevertheless, some specific typologies of EU urban regions appear to be extremely supported by the CAP (in both its first and second pillars): they mostly are very urban regions that are also surrounded by very rural areas. Results slightly change when disentangling both Pillar One and Pillar Two expenditure. Indeed, Pillar One expenditure intensity is also above the average for those regions that, although showing mixed urban-rural features, are surrounded by urban areas. On the opposite side, when focusing on RDP expenditure intensity, rural regions which are spatially close to other rural areas appear to be supported as well. By converse, all those regions that show more urban neighbours are expected to receive a lower amount of intensity support. Indeed, in this case, the least supported regions are the ones in the second and third range of the PRI quartile distribution, whose neighbours are in the first range of the PRI quartile distribution.

Furthermore, and in more general terms, even this analysis confirms the well-known compensation effect between Pillar One and Pillar Two expenditures at territorial level. Indeed, some typologies of regions that are little supported in terms of Pillar One expenditure tend to be more supported by Rural Development expenditure and vice-versa (Camaioni *et al.*, 2014).

Figure 4 – Expenditure intensity (Euro per hectare of UAA), by urban-rural typology



5. Conclusion

This paper aims to update previous works on the analysis of major urban-typologies across Europe. Moving from the composite and comprehensive PRI, computed by Camaioni et al. (2013), this paper returns 16 different urban-rural typologies, which also include information about urban- rural characteristics in the neighbouring space. Indeed, according to a multidimensional approach in defining rurality, geography plays an important role in shaping the integration (and the

relationships) between urban and rural areas. Although showing the same extent of rurality according to the PRI, two regions actually differ if the former is close to large metropolitan areas while the latter is surrounded by other rural areas. Furthermore, the returned taxonomy is definitely richer than the three urban-rural typologies suggested for instance by the OECD (2006). In fact, a more complex urban-

[9] Figures referring to alternative intensity expenditure indices are available upon request.

rural geography characterises the EU space, and policy-makers could benefit from being supplied with new enhanced tools to measure their own policies at territorial level.

Indeed, the complexity of EU geography is likely to matter in affecting the spatial allocation of CAP expenditure throughout Europe. This paper actually confirms the results obtained by Camaioni et al. (2015), which have already pointed out two major findings: the existence of a negative rural effect in the allocation of RDP expenditure (namely, the less the region is rural, the higher the expenditure intensity) and the existence of a positive spatial effect. Furthermore, by jointly considering these two drivers (i.e. rurality and space together), some more detailed results seem to be returned. Indeed, this analysis makes possible the identification of the most supported regions in Europe: they are those urban regions that are also surrounded by very rural areas. This is true for the overall CAP expenditure, as well as when considering disentangled expenditure.

Thus, the 'urban-rural integration', whose existence was found by Camaioni et al. (2015), mostly results in the allocation of additional resources to the urban areas rather than to the rural countryside. When being located close to cities and other metropolitan areas, rural regions are likely to be even weaker in their ability of attracting EU funds.

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THEMATIC SET

A02 INDICATORS OF RURAL DEVELOPMENT

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ABSTRACT

The first assumption with rurality measures is that the concept is not univocally determined. Rurality evolves over time and takes different features in space. As a consequence it is difficult, ifnot impossible, to find a synthetic solution for rural development statistics, suitable for all times and latitudes. The traditional indicators based on the weight of agriculture (measured in some way: rate of employment, output, etc.) or even with demographic density (as the one proposed by OECD in the Nineties and subsequently adopted by the EU and others) need to be integrated with other measures useful to help in analyzing the potential development and convergence. Two are the relevant directions for this integrations. The first takes into account and adapt to rural areas the measures of well-being. The second considers the peripherality: rural territories have different opportunities in terms of cohesion and convergence in relation to their localization close or far from urban areas and the physical and virtual connection opportunities. The aim of the session is to explore how the diversity of rural areas can be measured in the different geographical and historical contexts.

LIST OF PAPERS

An agricultural statistical classification as a decision support tool for the definition of territorial local policies
A. Djouak | HEI ISA ISEN GROUP | Lille | France
M. Stankowiak | HEI ISA ISEN GROUP | Lille | France
E. Comont | HEI ISA ISEN GROUP | Lille | France
M. Descamps | HEI ISA ISEN GROUP | Lille | France
F. Delbende | HEI ISA ISEN GROUP | Lille | France
J. Christiaen | HEI ISA ISEN GROUP | Lille | France
DOI: 10.1481/icasVII.2016.a02

Living in the countryside of Tuscany: are they really better off?
S. Turchetti | IRPET | Florence | Italy
DOI: 10.1481/icasVII.2016.a02b

A02

An agricultural statistical classification as a decision support tool for the definition of territorial local policies

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DOI: 10.1481/icasVII.2016.a02

ABSTRACT

This work aims at exploiting a set of data collected from a prospective agricultural diagnosis conducted on the local authority named "Communauté de Communes de Desvres-Samer" (CCDS in Pas-de-Calais (France). Agriculture and agricultural sectors are a pillar of this land: that's why elected officials needed a precise analysis in order to adapt local policy to local needs. Based on data collected during this diagnosis, this classification intends to establish a territorial agriculture typology. Statistical and analytical processing-based, this typology has enabled to characterize more finely the landscape entities constituting the study area, with coherent farm units and similar issues. This work therefore provides a useful tool to deepen the understanding of the field reality and to guide future community's choices and territorialized action plan.

Keywords: Territorial statistical classification, diagnosis, data analysis, decision support tool

PAPER

1. Introduction

Territory development issues evolved from a local level to transversal approaches, which transformed process from a simple plots to multifactorial classification methodologies. Local urban masterplans ("Plan Local d'Urbanisme Intercommunal" - PLUI in French) are development tools built through a co-constructed and shared territory project. Besides the cadastral management, it is important for the concerned community to act on all components of its territory, whether in the environment fields, living environment, or economy (any activity sector including agriculture). Indeed, local urban masterplans require communities to achieve common agricultural diagnostics, to characterize local agriculture and to identify weakness sources (urbanization, for example), Melot (2009), Martin (2006).

Working on regional agriculture knowledge, GRECAT[1] laboratory has built from its multidisciplinary skills, its own analysis and regional foresight tool: the OPCRA®[2], several times amended since its inception, in order to fit to local authorities expectations.

In the context of CCDS agricultural diagnosis, GRECAT realized statistical data analysis to better exploit collected territorial information. In next section, a brief contextualization of this area is needed.

With 31 communes, the CCDS, territory of "Caps et Marais d'Opale" regional natural park remains mainly rural (fewer than 100 inhabitants/km2 and 250 farms in 2013). However, CCDS is close to the coast and various urban centers, which makes it an attractive region and causes suburbanization at the cost of agricultural lands. A strong agribusiness presence (Novandie Andros group) explains the major economic position of agriculture, with 20% of local jobs and over 30% of local businesses related to agriculture. Moreover, dairy farming is predominant in this territory, with almost 71% farms concerned in 2013 with a milk total production of 60 million liters (5% of regional production). This explains the bocage landscape: nearly 31% of total CCDS area were grassland in 2009 and almost 1 151 km of hedgerows were identified in 2012. Beyond loss of land, this landscape is threatened by serious difficulties in the dairy sector (e.g. milk price volatility, particularly given that production costs are high in this type of territory). Thus, nearly 38% of dairy farms have doubts about their medium-term life, which would imply a weakening of territorial dairy industry and impacts on environment and landscapes territory.

It is therefore essential for this territory to find appropriate responses to maintain its rural and agricultural character. Even if milk farming is dominant, other agricultural systems are observed too, which demonstrates the link between agriculture systems, environment and territory. Then, it was necessary to take into account these local disparities by crossing spatial and statistical approaches in order to provide appropriate and relevant recommendations.

[1] Research and concerted studies group on agriculture and territories in Nord-Pas-de-Calais (HEI-ISA-ISEN group).
[2] Permanent Observatory of rural and agricultural change.

The issue is to demonstrate coherent agricultural entities, which defined using a data segmentation tool based on collected information during surveys of farmers.

2. Materials and methods

The aim of this work is to develop a communal farm typology of the CCDS. Indeed, the study produced a large amount of data. This database is a valuable source to divide the whole territory by the most representative agricultural indicators.

2.1 Survey and collecting data

In the literature, the agricultural typologies are often based on two types of methods: Those based on surveys, Perrot (1990), and those resulting from an analytical and statistical processing of existing data, Ilari & al (2003), Trouve & al (2004), Alvarez-Lopez & al (2008).

For this study, data was collected through surveys conducted face-to-face with farmers. This choice resulted from the absence of complete and updated data characterizing the territory, and from the need of local authorities to understand local agricultural issues (land data, for example).

The study was conducted from November 2012 to December 2013. Preliminary work began with a literature review and interviews with resource persons whose activities cover CCDS. All these territorial actors have also been regularly consulted through technical committees (e.g. agricultural commission) in order to monitor the study (in co-construction scheme). Other actors (economic actors, consumers, agricultural industries ...) have been also associated to improve the competitiveness of territorial agriculture and its various sectors.

After those preliminary steps, all farmers have been interviewed about their farms and territorial issues: 348 famers involved in 250 farms located in 31 municipalities.

The final questionnaire fit to various CCDS' expectations: make an inventory of territorial agriculture (past, current and future dynamics), identify strengths and weaknesses of the local agricultural sectors, highlight causes of farmland fragilities in some sectors and finally suggest territory evolution scenarios which better consider agriculture. The questionnaire was based on both quantitative and qualitative data collection, but also on parcel data. A significant variables number was collected, however, only 40 were used in the quantitative analysis (Table 1). All Open questions were excluded, as well as closed questions with too few responses.

Table 1: Summary of variables used for statistical analysis

Quantitative variables	Qualitative variables
- Farmer Age	- Farmer gender, marital status
- UAA (utilized agricultural area)	- Commune name
- Agricultural work unit (AWU)	- Farming type
- Milk Quota	- Landscape category
% fruit, market gardening	- Status : individual, societary
% industrial crops	- Direct selling: presence, types, forms…
% animal farm turnover	- Acces to property
% vegetal farm turnover	- Financial health
% cereals, oilseeds and protein crops	- Succession in 10 years
% grassland area % woodland area	- Permanent and temporary grassland
	- Diversification: activities, interest …
	- Membership structures (cooperatives, syndicates…)

2.2 Data analysis methodology

Before analysis, a preliminary step of validation was performed in order to check data coherence and ensure information quality (outliers, missing data ...).

Statistical analysis was structured around the factorial multivariate statistical methods, Izenman (2008). The interest of such methods is their powerful ability to synthesize a large mass of data and identify significant relationships between discriminating variables. These approaches have also proved effective in various agricultural issues, Choisis & al (2012), Debeljak & al (2007).

In this work, three main methods were used.

A. Principal Component Analysis (PCA). This technique allows a simple description of a complex reality. In other words, it can extract the maximum information from a large number of quantitative variables and draw conclusions on these variables and associated individuals. Another - essential - objective is to identify the most relevant variables that characterize individuals from the whole variables set in order to optimize statistical analysis results. The last aim is to eliminate redundant variables and data without significant effect on the overall problem variability.

B. Multiple Correspondence Analysis (MCA). As for PCA, MCA aims to graphically represent a large set of data (qualitative in this case) by reducing problem dimensions. This method is also useful because it highlights the relationship between the terms of used variables. PCA and MCA techniques will serve as "pre-classification" stages as they bring out the most characteristic variables of the desired typology. These variables will be used as input data for the classification stage.

C. Hierarchical Ascendant Classification (HAC). An iterative classification technique that may -according to the quality of the input data - get a partial or complete typology of analyzed individuals, based on their most relevant indicators. This method involves building a partition of the population into homogeneous clusters (low within-variability) which are different the ones from the others (high between-variability).

The expected objectives with this analysis scheme are summarized as follows:

- Highlight communes with farmers groups showing similar characteristics, and determine homogeneous agricultural entities;

- Compare these agricultural entities with landscape categories previously established by CCDS;

- Highlight the main agricultural characteristics of each entity.

- Identify agricultural issues and actions related to other dimensions such as environment and landscape. There is obviously a strong link between agriculture, economy, environment and landscapes on the CCDS;

- Identify priority areas in terms of difficulties to optimize needed actions.

In summary, this both additional analytical and decision making tool is the subject of this work, which is also dedicated to help CCDS to develop a rational and efficient agricultural policy.

3. Results

The methodology described in the previous section achieved a territorial farmers classification (and therefore the associated farms). Moreover, six classes have been obtained, all 348 farmers and 250 farms have been categorized. The size and the name of each class are detailed in Table 2 below. Moreover, a synthesis of the characteristics associated with each class is provided in Table 3.

Table 2: Distribution of farmers number per class

Farmers number per class	
Class 1 = Landscape 1 : « Coeur du territoire » in French (CT)	43
Class 2 = Landscape 2 : « Plateau Ouest et vallée de la Course » in French (POVC)	80
Class 3 = Landscape 3 : « Basse vallée de la Liane » in French (BVL)	25
Class 4 = Landscape 4 : « Clos du territoire et moyenne vallée de la Liane » in French (CTMVL)	63
Class 5 = Landscape 5 : « Fond de la boutonnière, la porte du bocage » in French (FBPB)	78
Class 6 = Landscape 6 : « Seuil Nord du territoire » in French (SNT)	59

The statistical analysis produced a very similar classification to six landscape entities characterizing CCDS (Figure 1). Differences are related to one or two farms located in "Le Wast" (attached to class 4) or "Desvres" (attached to Class 2). These small differences are explained by the fact that those two municipalities only have one farm, whose characteristics belong to other classes. Also, it should be noted that "Longueville" municipality is not attached to any class because no farm was based there.

Figure 1 – Comparison between the obtained typology and landscape categories

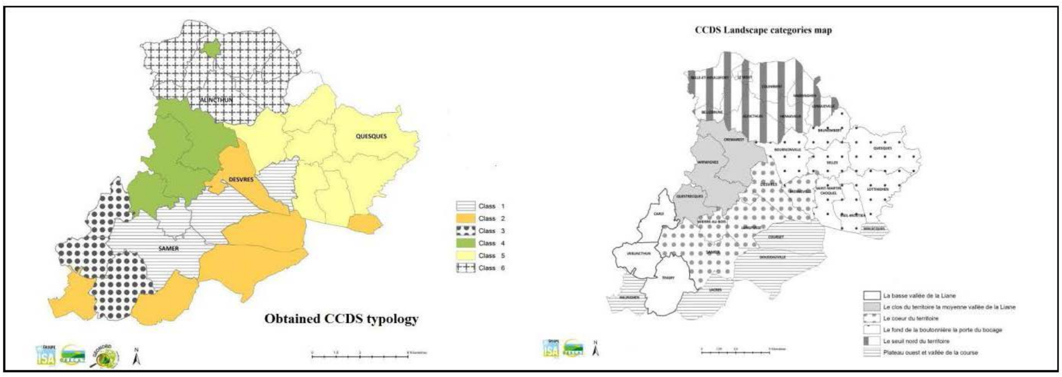
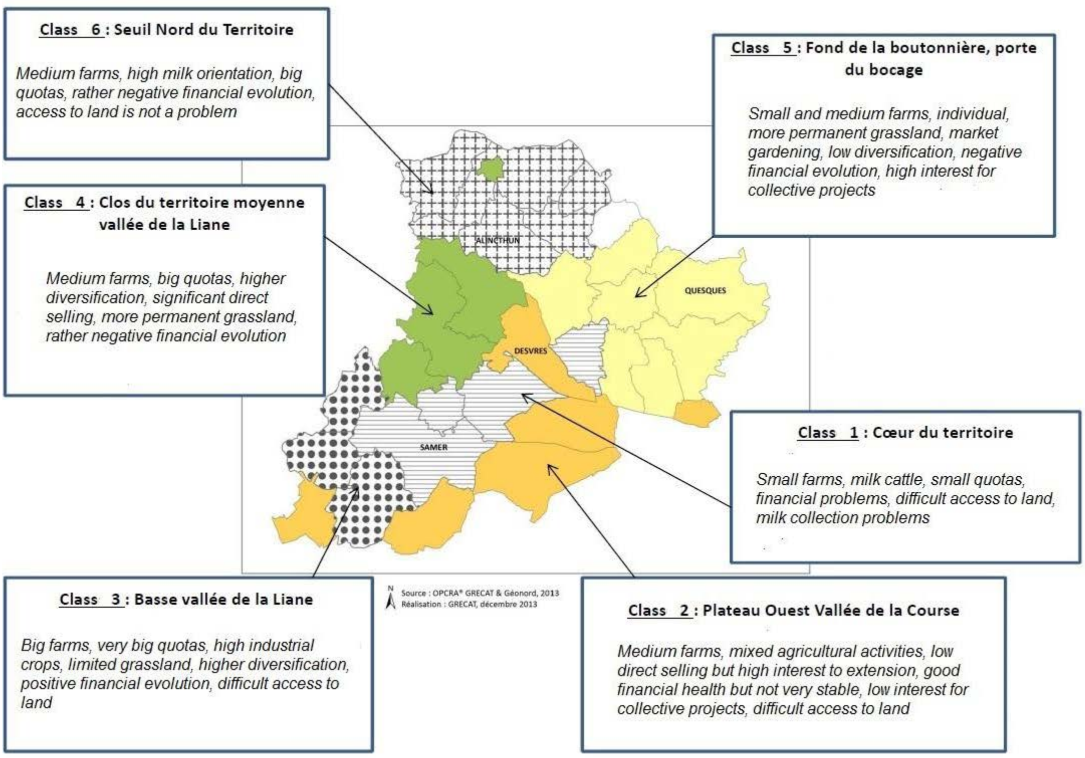


Table 3: Obtained classes characteristics

Criteria	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6
size	43	80	25	63	78	59
Farming	Milk cattle	Milk cattle, mixed culture	Milk cattle, milk or meat + aboveground	Milk cattle, mixed culture	Milk cattle, mixed culture	Milk cattle, milk or meat + aboveground
Landscape type (in french)	CT	POVC	BVL	CTMVL	FBPB	SNT
Status	Individual	Societary - individual	Societary	Societary - individual	Individual	Individual
UAA	Small	Medium	Large	Medium	Medium	Medium
Direct selling (DS)	Medium	Low	Medium	High	Low	Medium
Diversification activities	Medium	Medium	More frequent	Less frequent	Less frequent	Medium
Land access problems	Yes	Yes	Yes	Medium	Medium	No
Agricultural work unit (AWU)	Medium	Medium	High	Medium	Medium	Medium
% Woodland area	High	Low	Medium	Medium	Medium	Medium
% cereals, oilseeds and protein crops	Medium	High	High	Medium	Medium	Medium
% Grassland area	Medium	Low	Low	Medium	Medium	Medium
% industrial crops	Low	Low	High	None	None	Low
% fruit, market gardening	Low	None	Low	Low	High	None
Dairy livestock	Low	Medium	High	High	Medium	High
Milk quota	Low	Medium	High	High	Medium	High
% Vegetal farm turnover	Low	Medium	High	Low	Low	Low
% Animal farm turnover	High	Medium	Low	High	High	High
Financial health	Medium	Good	Good	Medium	Medium	Medium
Financial evolution	Stable	Stable	Improved	Degraded	Degraded	Degraded
Collective projects interest	Maybe	No	No	Maybe	Yes	Maybe
Succession	Yes	Not concerned	Not concerned	Not concerned	Yes	Not concerned

Following this classification, it was possible to extract the most significant features of each class. The mapping of Figure 2 summarizes the most important indicators of the obtained typology.

Figure 2 – Significant characteristics of obtained typology classes



For example, class 5 has a weakened farms structure (compared to Class 3) with a large dependence on livestock farming. Thereby, grasslands are very important for agriculture and landscape identity. Moreover, these farms are rather "isolated" from the rest of CCDS (very rural area with few farmers' market).

Therefore, solutions that could be developed through an action plan supported by CCDS, could be the following (some measures could also be applied for other classes):

- Regulate afforestation (in progress in some communes);

- Assist farmers in the development of local agricultural production valuation, which could be part of existing procedures (collective points of sale or local farm networks);

- Discuss with farmers about workforce sharing strategies;

- Promote the use of "non-agricultural" products such as hedgerows to establish local wood energy industry.

4. Conclusion

Performed according to the specific requirements of the used statistical methods, this obtained statistical territorial typology provides an innovative vision for the studied territory. Indeed, it highlighted six agricultural geographic areas, which finely describe the similarities and differences within CCDS. Moreover, the similarity between the obtained typology and landscape categories consolidates the former CCDS' work, which were primarily based on empirical criteria. The statistical approach being more rigorous, it helped to enhance the contours of this territory by marking a link between landscape entity and agricultural type.

However, the undertaken work should go on as this typology will be only meaningful if it is facing the territory reality. Based on the obtained results and following a "decision support tool" methodology, an operational approach based on targeted actions will validate conclusions of this study. It will also open the way for further reflection on the possible extension of this work in other geographical areas, with as a possible outcome, obtaining a real statistical agro-territorial modeling tool.

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A02

Living in the countryside of Tuscany: are they really better off?

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ABSTRACT

Rural Tuscany is commonly considered as a delightful place characterized by natural and cultural amenities and widespread wellbeing. However, the possible differences at sub-regional level in terms of socio-economic conditions, available opportunities and access to services have not been enough investigated so far. Moreover, the changing picture of the countryside in Tuscany – decreasing agricultural areas and number of farms, depopulation, ageing – might have affected the standards of living of population and the motivations for staying there. This paper is a first attempt to assess the state of wellbeing in the different rural areas of Tuscany from a multidimensional perspective. The results of this study show that large differences still persist among different areas of the same region. First of all, a process of convergence between rural and urban areas is still far to come. In some rural areas, in particular the more agriculturalintensive, the rates of growth of income are positive and the distribution is fair; however, there are other rural areas where incomes have been decreasing over time together with a deterioration of the distribution. Moreover, job opportunities are scarce and the provision of public services is still insufficient. This further fuels dynamics of social exclusion, which might be triggered by the possible process of re-centralization of public services because of budget constraints.

Keywords: wellbeing, rural development, small areas, Tuscany

PAPER

1. Introduction

Rural Tuscany is commonly considered as a delightful place characterized by natural and cultural amenities and widespread wellbeing. Per-capita income in Tuscany is above the national average, the same as the per-capita expenditure on social services (ISTAT, 2012). However, the possible differences at sub-regional level in terms of socio-economic conditions, available opportunities and access to services – in other words, in terms of wellbeing - have not been enough investigated so far. Moreover, the changing picture of the countryside in Tuscany – decreasing agricultural areas and number of farms, depopulation, ageing – might have affected the standards of living of population and the motivations for staying there.

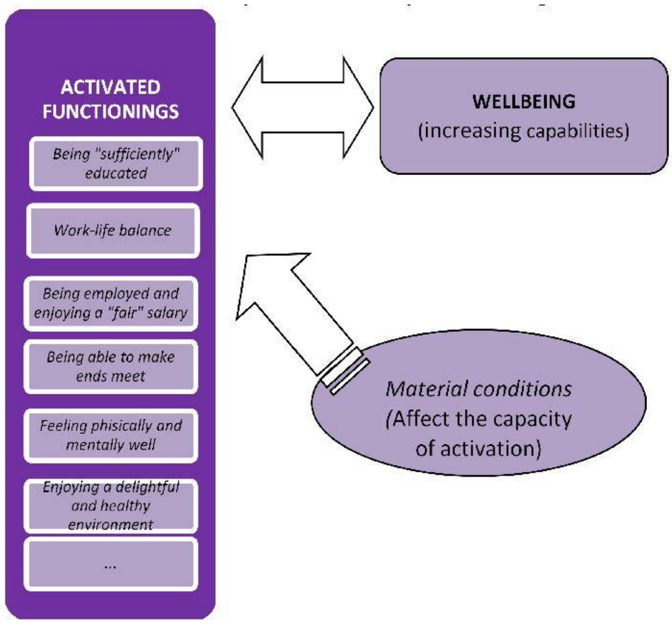
The definition and evaluation of wellbeing is the subject of a large debate among the social scientists (CNEL-ISTAT, 2012; Giovannini e Rondinella, 2011; Stiglitz et al., 2009; Alkire, 2008; Atkinson et al., 2008) and policy makers. Since 2012 the Italian National Institute of Statistics (ISTAT) issued the report about the conditions of fair and sustainable wellbeing in Italy, with the aim of combining the traditional economic measures, based on income and consumption, with some social and environmental indicators (ISTAT-CNEL, 2013). Traditionally, economists have measured the overall level of the standard of living in terms of accumulation of either resources or the utility that can be drawn from it. As stressed by Sabine Alkire (2008), "Many resources are not intrinsically valuable; they are instrumental to other objectives, yet the quality of life arguably depends not on the mere existence of resources but on what they enable people to do and be".

Therefore, the potentials for the conversion of these resources into wellbeing differ across individuals, their own personal characteristics and history and they are inevitably affected by the institutional surrounding. As shown by Stiglitz, Sen, & Fitoussi (2009), the factors shaping the wellbeing of people often depend on circumstances and they are not the product of a rational process based on individual preferences. As a result, perceptions about his or her state of living might be very different from an objective evaluation of it.

The aim of this paper is to assess the state of wellbeing in Tuscany from a multidimensional perspective. Wellbeing is conceived in terms of increasing capabilities, which can be defined as the ability of a person to widen its own available opportunities (functionings) depending on the socio- economic and political conditions of the context (see Sen 1998). Since the political dimension is excluded from the overall analysis[1], the paper focuses on the activated functionings, which are the set of life conditions truly achieved and observable.

As shown in fig. 1, a definitive list of the activated functionings cannot be easily defined and it is widely data-driven. However, the figure reports some examples and highlights that material conditions (as might be described using the standard economic indicators on incomes, inequality and poverty) positively affect the ability of activation of a person or a household but per se they do not improve wellbeing.

Figure 1 – Theoretical framework of wellbeing



Source: Author's own elaboration

In the following paragraphs, wellbeing in the rural Tuscany will be described in terms of both material conditions (section 3) and quality of life aspects (section 4). The latter refer to employment opportunities, with a focus on gender-driven asymmetries (section 4.1), education (section 4.2) and health and environmental conditions (section 4.3).

The analysis is carried out at the small area level (municipality), comparing five groups of municipalities with different level of urbanisation and variable features of the rural context (section 2). The empirical analysis is mainly based on the European Union Statistics on Income and Living Conditions (EU-SILC), which is a database of both cross-sectional and longitudinal multidimensional microdata on income, poverty, social exclusion and living conditions. It replaced the European Community Household Panel (ECHP) in 2004, because of the need for a more harmonized sample design among the Member States. The sub-regional focus adopted in the present study is supported by the use of proper statistical methodologies (section 2) yielding results which show an acceptable degree of reliability. Furthermore, with the aim of extending and supporting the results of our analysis, the evidence from the EU-SILC dataset has been compared with other primary and secondary sources of information on well-being available at the sub-regional level (e.g. administrative records on provision of education and health services, section 4).

The combination of the use of microeconomic information on wellbeing with the small territorial scale of the analysis is the main contribution of this study from a methodological point of view. Indeed, the smaller the territorial scale of the analysis, the greater the relevance of a multidimensional concept of wellbeing for policy design. The link between the features of rurality and the level of wellbeing is a further original aspect of the study. The practical relevance of the analysis is closely connected to the next 2014-2020 European Rural Development Policy, which, among other things, should provide measures to support "social inclusion, poverty reduction and economic development in rural areas". By extension, the study suggests a possible research path in applied socio-economic analysis supporting policy decision making at the small area level.

1 The political dimension has to do with the degree of available freedom, which allows for a larger set of capabilities. Since the territorial level of analysis is sub-regional, it would be very difficult to assess the differences in terms of freedom, which is reasonable to say that mostly depend on the socio-economic conditions of the territories rather than different political ones.

2. Data and methods

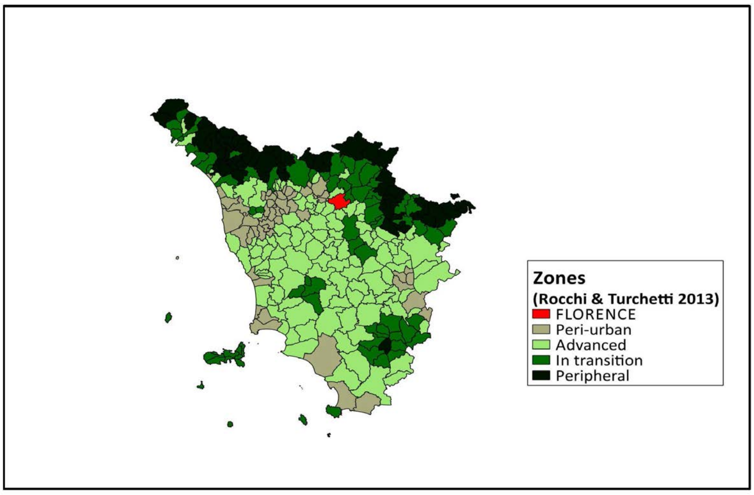
Measuring wellbeing at sub-regional level involves several methodological problems relating to data availability, characterization of territories on the basis of cross-cutting factors (zoning) and identification of relevant variables for quasi-symbiotic small areas. In this study rural and urban areas have been previously classified in a study carried out at the level of municipality (Rocchi & Turchetti, 2013) and clustered on the basis of four main dimensions:

- Urban function, which refers to the relative importance of residential vs. productive use of space.
- Territorial vocation, which highlights the role played by the agricultural sector and the limits imposed by the natural and human constraints;
- Demographic dynamics and commuting, which have an impact upon the use of space and, at the same time, are affected by the economic activities carried out on a territory;
- Productive specialization, which refers to the distribution of productive activities by sector of both employment and produced value added.

The classification of 287 Tuscan municipalities has been done by implementing a cluster k-means analysis, which allowed to a-priori choose the number of areas.[2] As shown in the map below, there are five different zones. Florence and the peri-urban areas are concentrated at north, along the route which carries to the sea. They are characterised by high urban functions and widespread tertiarization. The characteristic attractiveness of peri-urban areas, because of the cheaper housing especially for younger households, and the resulting widespread ageing and depopulation of Florence, are the main differences between Florence and the peri-urban areas.

The other three zones are characterised by low urban functions and, in general, widespread ageing. However, the advanced rural, which accounts for the highest number of municipalities, shows a more modern and stable agricultural sector, with a higher level of entrepreneurship[3]. The high level of entrepreneurship in agriculture depicts the rural in transition too, which is also characterised by a pervasive non-agricultural use of non-urban soil, the presence of several industrial districts and touristic and cultural amenities. Finally, the municipalities of the peripheral area are characterised mainly by natural constraints and high environmental protection (natural parks and protected areas) since they are located nearby the Apennine Mountains. Because of the shortage of productive activities and employment opportunities, apart from some well-developed rural touristic activities and traditional agriculture, ageing and depopulation are widespread.

Figure 2 – Classification of municipalities



Source: Rocchi & Turchetti 2013

Even if the classification satisfactorily discriminates for the functions of each territory, it does not say anything about the wellbeing of people. In order to evaluate it, we use as the main data source EU-SILC. EU-SILC survey is composed of four questionnaires, two at household's level (so called "primary sampling units", PSU) and two at individual level (so called "secondary sampling units", SSU). The units are selected on the basis of a national representative design, which assigns them "a known and non-zero probability of selection" (Eurostat, 2009, p. 22) for both the cross-sectional and the longitudinal data. For Italy the minimum effective sample size is 7250 households (5500 for the longitudinal component) and 15550 individuals (11750 for the longitudinal component).

[2] The number of areas has been a-priori chosen because the mentioned study updates and develops a previous analysis carried out by Rocchi and Caselli (2006).

[3] The entrepreneurship index used in the analysis is an updated and simplified version of the index proposed in (Rocchi and Stefani, 2005).

EU-SILC sample is designed for comparisons between states or administrative regions and not between areas at sub-regional level. However, the sub-regional focus might suggest valuable uses of data whether measures of interest are estimated by using proper weights and they vary within acceptable ranges.

There have been attempts of oversampling at the sub-regional level (Province of Pisa) with the aim of estimating more reliable indices of wellbeing (Pratesi & Coli, 2009) as well as attempts of estimating the variables of interest from covariate information from census of population (Giusti, Pratesi, & Salvati, 2009). Given the limited number of areas considered in this study and the difficult search for reliable covariates, we followed a different approach, based on the direct estimation of the measures of interest by post-stratifying the observations into the areas. In order to report the sample units to the universe, a proper weight has been calculated as:

$$Wnew = \frac{db090}{\sum_{i=1}^{5} db090} \sum_{i=1}^{5} HH$$

Whereas db090 is the EU-SILC household cross-sectional weight (db090) and $\sum_{i=1}^{5}$ HH is the total number of households by area (source: *Demostat*). As shown in the

Tab. 1, some areas are overrepresented –the rural and peripheral and in-transition areas – while Florence is underrepresented. Despite these differences, the distribution of the sample along the five zones is quite similar to the actual one:

Table 1: Total number of households by area, 2009

	Total number of households	%	Total number of households sampled	%
Florence	181944	11,36	135	9,32
Peri-urban	428852	26,78	369	25,48
Advanced	636961	39,78	547	37,78
In transition	283324	17,69	287	19,82
Peripheral	70312	4,39	110	7,60
TUSCANY	1601393	100	1448	100

Source: Author's own elaboration from Demostat and EU-SILC

The Tab. 2 reports the number of households sampled by area over the available years of the survey:

Table 2: Number of households sampled by areas, 2004-2009

	2004	2005	2006	2007	2008	2009
Florence	178	116	125	119	140	135
Peri-urban	477	414	409	381	389	369
Advanced	701	648	636	626	556	547
In transition	333	318	293	279	307	287
Peripheral	62	64	62	84	103	110
TUSCANY	1751	1560	1525	1489	1495	1448

Source: Author's own elaboration from EU-SILC

In order to assess the reliability of results, we have calculated the standard error of estimates through a bootstrap procedure. This procedure allows to "resample" with replacement from the sample data at hand thus "artificially" broadening the represented population in order to better approximate the distribution of a statistic and obtain proper standard errors (bootstrap SE; see Singh & Xie, 2009). Some of the estimated bootstrap SE are reported in the following sections, showing an acceptable degree of reliability of results.

3. The material conditions of rural areas

As shown by Amartya Sen, the economic dimension of wellbeing is not a goal per se but it should be assumed as a mean to enlarge the available set of opportunities (see fig. 1). The exploitation of these opportunities and the increase in the level of wellbeing depend on both exogenous (environmental factors) and endogenous conditions (personal characteristics and choices) affecting the more general quality of life. In a market-based economy the importance of the income level is supposed to be higher given the relevance of the private sector in providing goods and services.

The 2009 EU-SILC data show that, overall, more than two thirds of people say to difficultly meet their monthly needs. The situation is considerably worse in both the peripheral and the rural advanced areas, where the share of people in trouble amounts, respectively, to 81% and 78%. Conversely, in Florence they are only half of the total population. The Tab. 3 somehow confirms these picture but with some variations when considering different kind of purchases. For example, people living in both the advanced rural and the peripheral areas show major difficulties to pay for basic services such as school and health, which might suggest that the provision of public services to marginal areas is somehow troublesome.

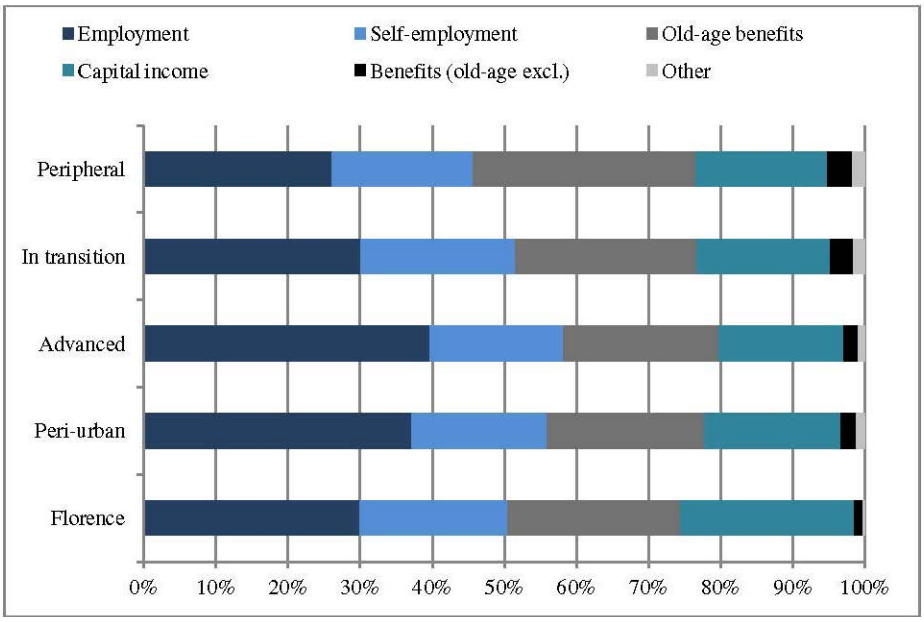
Table 3: Share of households who responded not to have enough money for the listed expenses, 2009

In the last 12 months, there have been any moments when your family did not have enough money to purchase:	Florence	Periurban	Advanced	In transition	Peripheral
CLOTHES	11,09	11,15	14,20	11,30	15,36
FOOD	6,54	4,33	6,02	4,71	1,88
HEALTH	9,14	8,97	10,30	7,11	4,39
SCHOOL	2,85	4,93	4,30	5,72	11,18
TRANSPORTS	8,50	6,47	8,06	5,08	3,63
TAXES	9,08	11,73	9,77	7,43	3,63

Source: Author's own elaboration from EU-SILC

The main sources of income in each area in 2009 are reported in Figure 3. As expected, income from employment is the first source of income almost everywhere, except for the peripheral area where about one third of the overall income is represented by the old-age benefits. The situation is similar in the rural in transition, where 30% of income comes from employment and 25% of income from old-age benefits. At the opposite side, there are the cases of both the peri-urban area and the rural advanced, where income from employment is almost 40% of the total income, while the oldage benefits are remarkably low (about 21%). Capital income is a relevant source of income only in Florence, where it represents about one-fourth of the total income.

Figure 3 – Main sources of income, 2009



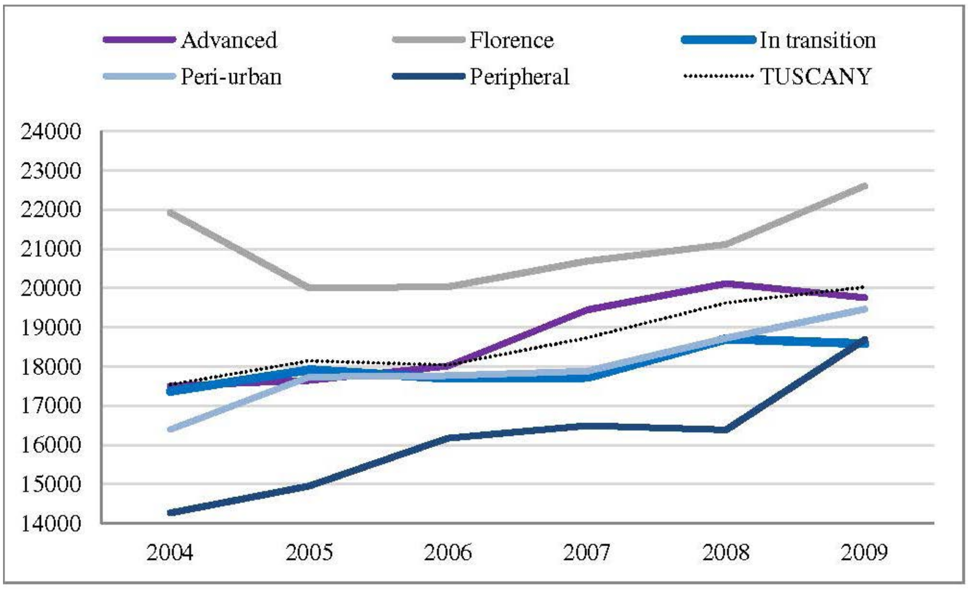
Source: Author's own elaboration from EU-SILC

The EU-SILC survey reports the disposable incomes of households including employee and self-employee incomes, pensions, social benefits and other cash transfers and any kind of other incomes, such as capital incomes (Atkinson & Marlier, 2010). The disposable income is indeed corrected by a within household non-response inflation factor and the household size[4] thus returning the equalized disposable income (EDI) which has been used for the next analysis:

EDI= (total disposable HH income* within HH non-response inflation factor)/HH size

The trend of EDI by area over the years 2004-2009 is shown in the Figure . On absolute terms, the municipality of Florence is the richest ever, even if over time the slope of the curve tends to flat. Both the peripheral and the peri-urban areas show the highest rates of growth (31% and 19%, respectively); while the trend of the rural in transition is almost steady, with no relevant increase over the years. As a consequence, in 2009 the rural in transition turns to be the poorest area of the region.

Figure 4 – Trend of EDI, 2004/2009



Source: Author's own elaboration from EU-SILC

In general, the bootstrap SE of estimates is always higher in Florence and in the peripheral area, because they are, respectively, under and over-represented. However, in the case of Florence this must be due also to the large variability of income because of a more uneven distribution.

Table 4: Average EDI and bootstrap SE, 2004/2009

	Florence	Peri-urban	Advanced	In transition	Peripheral	TUSCANY
2009	22609	19462	19757	18584	18687	20025
Bootstrap SE	1310,08	693,79	585,69	765,26	927,44	404,32
2008	21111	18728	20114	18701	16384	19625
Bootstrap SE	1420,36	547,70	580,32	646,59	957,40	382,99
2007	20689	17881	19443	17721	16489	18729
Bootstrap SE	1342,61	558,97	532,63	555,62	836,58	317,85
2006	20036	17763	18014	17695	16174	18040
Bootstrap SE	1137,74	638,98	498,56	734,77	1333,18	324,44
2005	20000	17736	17647	17915	14946	18143
Bootstrap SE	1158,27	576,10	407,09	730,60	1170,07	334,94
2004	21927	16393	17505	17366	14266	17538
Bootstrap SE	1194,13	467,86	773,42	690,31	1061,96	384,16

Source: Author's own elaboration from EU-SILC

The best combination between a good level of income and a fair distribution occurs in the rural advanced, where the mean EDI is on the regional average and the distribution of income is quite even. On the contrary, the rural in transition and Florence show the highest levels of inequality (Gini index =

[4] In term of equivalent adult members, according to a proper equivalence scale. Both household size and non-response inflation factor are provided by Istat together with the sample.

0.31, above the value of the index calculated for the whole region)[5].

Finally, we set the same poverty line[6] for all areas (60% of the median EDI of Tuscany: 10692č) in order to estimate some poverty indicators. As shown in the Tab. 5, the rural in transition is by far the poorest area with 21% of people below the poverty line, followed by the peripheral area (19%)[7] and the peri-urban area (18%). The poverty gap index (FGT1) measures the distance between the incomes of the poor and the poverty line and it is the minimum cost of eliminating poverty (as a share of the poverty line). This index is particularly useful from a policy perspective because it returns the exact amount of benefits which should be provided on average to each households lying below the poverty line. Therefore, in Tuscany each household should receive about 444čin order to fill the poverty gap, even if they ought to be differently distributed among areas. Since the rural in transition accounts for the largest share of the poor, each household should receive about 637č, followed by those living in the peri-urban area (514č).

As stressed by the World Bank (2005), the design of the policy targeting is the preliminary condition to any strategy of poverty reduction. The main problem with the poverty gap index is that it does not account for the inequality level among the poor; therefore, if the income of a household with a small poverty gap improves, then the poverty gap index improves proportionally even if inequality among the poor has increased. The poverty severity gap index (FGT2) weights more the incomes falling far below the poverty line so as to account for the inequality among the poor. Once again, the rural in transition shows the most severe gap, thus confirming that most of inequality is concentrated in the lower-middle tail of the income distribution; conversely, the rural advanced still shows the best condition (low incidence of poverty and low inequality).

Table 5: Poverty indexes, 2009 (%)

	Florence	Peri-urban	Advanced	In transition	Peripheral	TUSCANY
Headcount index (FGT0)	15.716	18.443	14.550	21.119	19.417	16.888
Bootstrap SE	1.834	2.385	1.939	2.487	4.674	1.220
Poverty gap index (FGT1)	3.814	5.143	3.517	6.367	4.773	4.444
Bootstrap SE	1.025	0.926	0.567	1.025	1.313	0.397
Poverty severity index (FGT2)	1.208	2.571	1.344	3.099	2.003	1.854
Bootstrap SE	0.384	0.656	0.320	0.683	0.790	0.239

Source: Author's own elaboration from EU-SILC

3.1. The quality of life in the rural areas

In this section the focus moves from material conditions to some "activated functionings". Social scientists and institutions often disagree upon what qualitative dimensions should be chosen, especially because they are always context and time-specific; moreover, the set of indicators measuring them are very often data-driven.

The next analysis is largely descriptive and tries to introduce further inputs to complete the analysis of the economic dimension of wellbeing. In particular, the following quality of life dimensions have been considered:

- Employment and gender perspective

- Education

- Health and Environment

3.2. Employment and gender perspective

Employment is a major component of wellbeing not only as a source of income but also as a central factor of psychological health and overall satisfaction with life. Conversely, it can be also a source of uncertainty and stress, especially whether temporary and almost unpaid. Eventually, even in case of permanent, satisfactory and well-paid job, it might turn to be difficult to reconcile the labour time with other life activities. This is particularly true for women, who are generally the main household's caretakers. Their unpaid work is often a substitution for an inefficient public provision of social services targeted to children and elderly people. Hence, the gender perspective is a crucial and cross-cutting

[5] The Gini index expresses the distance from a perfectly even distribution of income of the actual one. The index varies from 0 (corresponding to perfect equity, i.e., equal per capita income throughout the whole population) to 1.

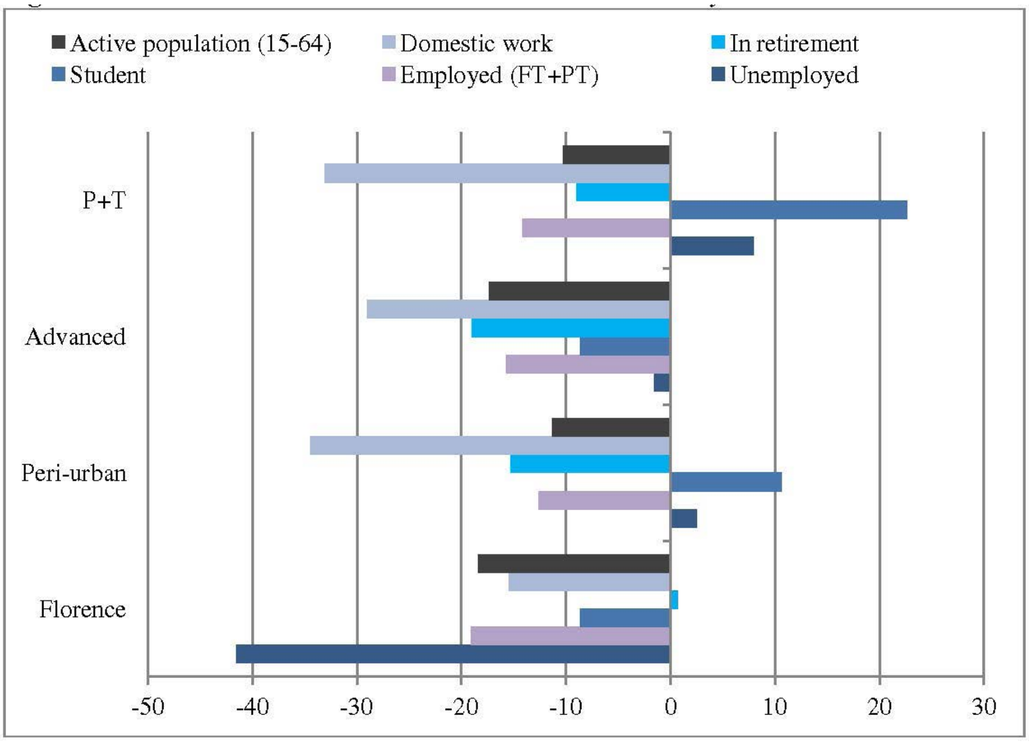
[6] Poverty line can be defined as the threshold which identifies the group of people "in poverty", thus not having enough command over resources, in terms of either income or consumption (World Bank, 2005).

[7] It must be noted that the standard error for the peripheral area is particularly high, so that the reliability of the estimation is quite low.

dimension for the description of the state of wellbeing relating to employment.

The Figure shows the percentage variations in the employment status.[8] Overall, the number of people employed decreases everywhere, with no significant differences by area. Unemployed people, instead, decline only in Florence and in the advanced rural, while increasing in both the peri-urban and the other rural areas. Such negative variations can be explained not only by improved conditions of the labour market but also by the decreasing share of economically active population. From this point of view, the situation in the rural areas is quite clear, since the number of both employed and active population decrease. Moreover, the increase in the number of students in both the peri-urban and the rural areas might be a further sign of the worsening of the economic conditions inducing young people to delay their exit from home.

Figure 5 – % Triennial variations in basic labor statistics by area, 2004/06-2007/09[9]



Source: Author's own elaboration from EU-SILC

Everywhere domestic work decreased over time. Nonetheless, it is not substituted by an increasing number of women at work and, in general, it remains a female job. In fact, the rate of employment of women decreases everywhere, except in Florence, where probably most of the active female population work (see **Errore. L'origine riferimento non è stata trovata.**6). A further difference with men is represented by one-fifth of women that are part-time employed in front of less than 4% of men. Part-time job may help women to better reconcile family needs and working time. However, it is also the heritage of the traditional division of labour within the households and the result of the lack of an adequate provision of nurseries and working hour's flexibility, factors pushing women outside the labour markets.

Table 6: Rate of employment of women by area (%), 2004/06-2007/09

	2004/06	2007/09
Florence	60,82	60,43
Peri-urban	61,32	56,55
Advanced	63,59	57,29
T+P	64,74	50,50

Source: Author's own elaboration from EU-SILC

[8] In order to obtain more robust statistics, the variations have been calculated between the mean values of two three- year periods.
[9] Because of the limited number of observations in the peripheral area, due to the large share of people in retirement, in this section the rural in transition and the peripheral area are considered together (T+P).

Hence, part-time jobs cannot be the univocal response of policy to increase the participation of women to the labour market. In Tuscany the number of public provided nurseries slightly decreased over time (-3,2% over the years 2007/11) in front of a large increase of the private services (+46%) (Regione Toscana, 2013). Even if public grants are provided in order to help households to pay for private services, they are strongly dependent on the yearly budget capacity of the local governments and on the political priorities. Moreover, the ability to pay for of each household inevitably affects the trade-off of women between extending the maternity leave (with consequent salary reductions) or further waiting for searching for a new job – thus decreasing the likelihood of re-entering the labour market – and paying for the nursery. In Florence in 2010 about one-third of kids in the 0/2 age class have been enrolled in a nursery in front of 16% laying into the waiting lists. On the other hand, kids enrolled in the peripheral area are only 10% but with a very short waiting list (1%). On average, both the rural in transition, the rural advanced and the peri-urban area show a coverage of more than 20%, but with the peri-urban area presenting a longer waiting list (7,30%).

3.3. Education

Education is one of the most important dimensions of wellbeing since it broadens the set of available opportunities by allowing people to access well-paid and less risky jobs and fostering social mobility. In developed countries the primary education is guaranteed to everybody and the differences at local level are more related to the distribution or quality of services provided and not to different policies. Moreover, in terms of job opportunities, what really makes the difference is the access to higher (secondary and tertiary) education and to what extent it meets the demand for skilled workers on the local job market.

The Tab. 7 shows that people with secondary education in 2009 survey are 40% of the sample, while people with tertiary education are nearly 20%. There are no relevant differences among areas in the distribution of secondary education, while most of graduates live in Florence and only few of them in the countryside. This explains why the largest share of farmers are not graduated (more than 90% of farmers, according with the last census of agriculture) thus highly reducing the development opportunities of the rural areas. Since their number is small, the share of graduate people in the 30/40 age class who define themselves as employed is quite higher in the rural areas.

Table 7: Secondary and post-secondary education by area (%)

	Florence	Peri-urban	Advanced	P+T	TOS
Share of active population with diploma	37,27	38,49	43,22	42,45	41,32
Share of active population with post-secondary and tertiary education	39,75	18,42	18,19	15,63	19,22
Share of people 30/40 with post-secondary and tertiary education employed	68,42	67,74	74,63	86,67	74,83

Source: Author's own elaboration from EU-SILC

The capacity of people to access higher education depends on the supply side too. While it is common that most of the universities are concentrated in urban centers and it might be desirable that people move from the place of origin to attend their courses elsewhere, when secondary schools at the territorial level are poorly supplied it is less likely that people will continue to study. For example, the number of classes out of 1000 people of the 14/20 age class is much lower in the rural areas, especially in the advanced rural and the periphery.

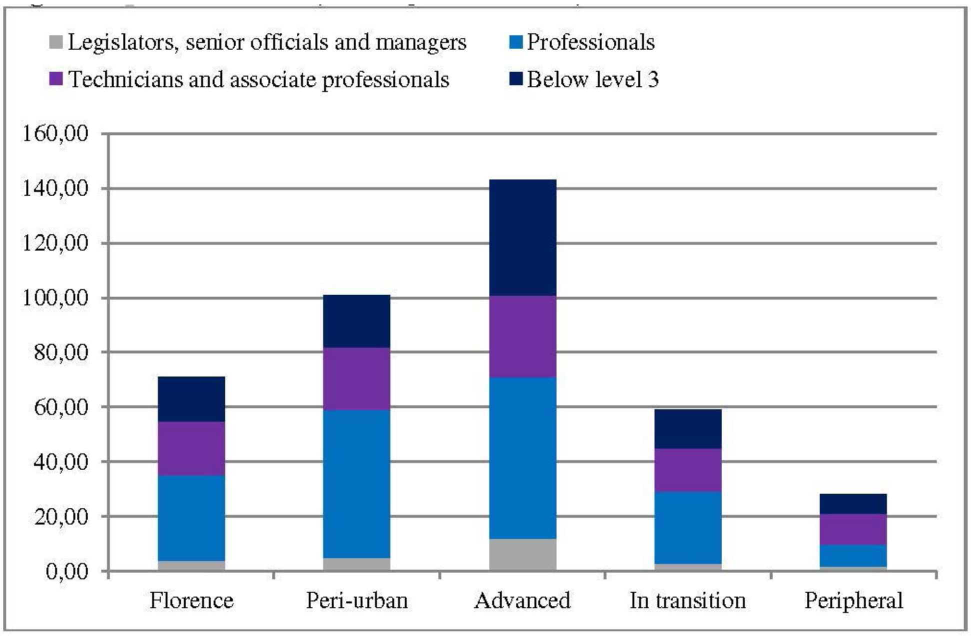
Finally, to what extent graduates find a job fitting with their educational qualifications? First (Fig. 6), one out of five of graduates claim to be unemployed. Among employed graduates, most of them are professionals (44%), followed by technicians (25%) and legislators, senior officials and managers (7%); the rest of them (about 25%) is hired as more unskilled workers fitting also undergraduates' profiles. Summing up, almost half of graduates do not find a suitable position, although there are significant differences by area. The share of professionals living in rural areas is very low since most of the services are provided in urban areas, so it is reasonable that they choose to live there. At the same time, it seems that graduates living in rural areas tend to accept more easily jobs not fitting their level of education: in rural areas the share of people doing a job which requires a lower degree of qualification (below-level 3) is higher with respect to urban areas.

3.4. Feeling good, the access to health services and the environmental conditions

A good state of health is the pre-condition to the overall wellbeing and the ability to live an active life. In 2007[10] more than two third of the sample declare to enjoy a very good or good state of health even

[10] Since 2008 the EU-SILC health module is no longer available.

Figure 6 – ISCO*ISCED by area (post-secondary education)



Source: Author's own elaboration from EU-SILC

if men are more satisfied than women; this datum is almost the same in any area, while most of the differences concern the share of people not feeling good. Overall, approximately 10% of people claim to be in a very bad or bad state of health. The largest share of them lives in Florence (16%), followed by the advanced rural (10%) and the peripheral area (9%), while both the residential area and the rural in transition show the lower shares (8% and 7%, respectively). However, the distribution of responses by sex is more uneven in all the rural areas: for instance, in the rural in transition 10% of women claim not to feel good in front of 4% of men.

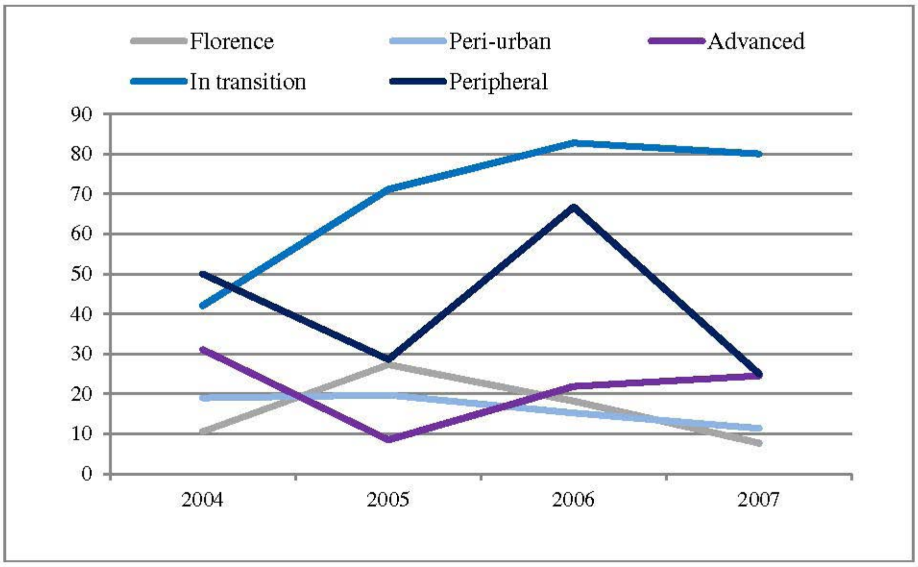
The state of health of a person depends on personal characteristics, especially age, so it is not surprising that areas with younger population claim to feel better. However, there are some other factors affecting health, namely the access to health services and the conditions of the environment where people live. Available data about health services (data source: Minister of Economic Development) confirm that both the peripheral area and the rural advanced have more difficult access to health services because of the limited number of places into the hospital with respect to the population. While in Florence they are 8,38/1000 inhabitants, in the peripheral area they are only 1,74 and in the advanced rural they are 2,86. Both the rural in transition and the peri-urban areas are in the middle. Moreover, the access to more advanced health services might be further hindered by poor infrastructures.

In order to understand to what extent people are really bounded in accessing health services, we provide some trends from the 2004-2007 EU-SILC health modules (Fig. 7). In 2007 people who responded not to have met the need for a medical examination or treatment are 198, about 5% of the whole sample; this share remains quite stable along the yearly surveys. 38% of them live in the rural in transition, followed by the peri-urban area (27%) and the rural advanced (25%). The main reasons why they did not meet the medical examinations or treatments concern either the long waiting lists (41%) or the inability to afford it (31%). Figure 7 shows the trend of the shares of people not meeting their medical needs because of the long waiting lists. In 2007 the number of people reporting this answer in the rural in transition is three times higher than 2004; elsewhere, it remains quite steady, except for the peripheral area where the trend is rough, with slight decreases in both the urban areas.

The picture changes when it comes to consider the ability to pay, which seems to be perceived as a problem especially in the urban areas, where about half of the total urban population report this answer (Fig. 8). However, since waiting lists are not reported as a problem, as well as the supply of health services, it is suggested that these answers have more to do with much specialized treatments not covered by public health services.

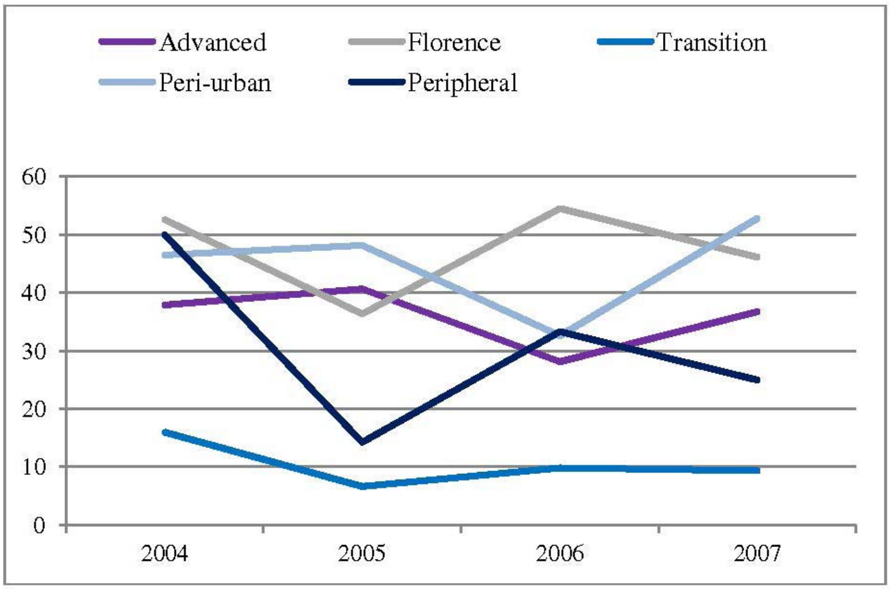
This suggestion would need further studies to be confirmed. We show some data about the distribution of the Avoidable Mortality Rate (AMR) by area, provided by the Regional Agency for Health of Tuscany (Agenzia Regionale di Sanità della Toscana – ARS). The AMR can be defined as the share of "unnecessary, untimely deaths" (Rutstein et al.,1976) which can be avoided through primary prevention, early diagnosis and hygiene & health care. While there are no significant differences in terms of diagnosis and only limited differences for hygiene and health care, the AMR due to scant prevention is higher in both peripheral and peri-urban areas and less in the rural in transition (Fig. 9). Differences by sex

Figure 7 – Share of people not meeting medical examination/treatment because of the LONG WAITING LISTS



Source: Author's own elaboration from EU-SILC

Figure 8 – Share of people not meeting medical examination/treatment because of the LONG WAITING LISTS



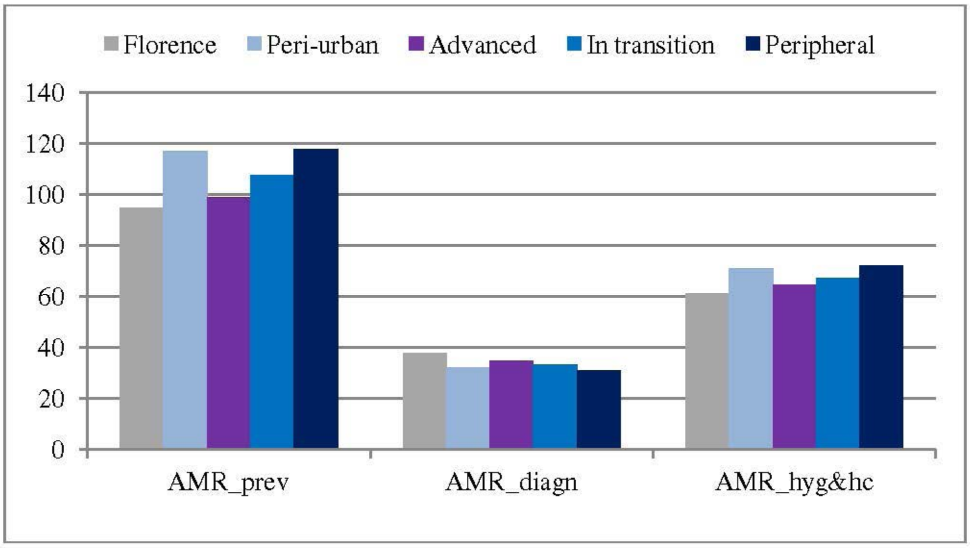
Source: Author's own elaboration from EU-SILC

are even more remarkable, since especially the feminine AMR due to both prevention and hygiene and health care are much higher in all the rural and peri- urban areas.

Hence, it can be suggested that while people living in the peri-urban area are more unable to pay for prevention, the difficult access to health services in the rural in transition is not specific but it is related to all the three aspects. With respect to the peripheral area, even if the number of health services is limited, probably they are well-targeted or in any case sufficient to respond to the needs of the residents.

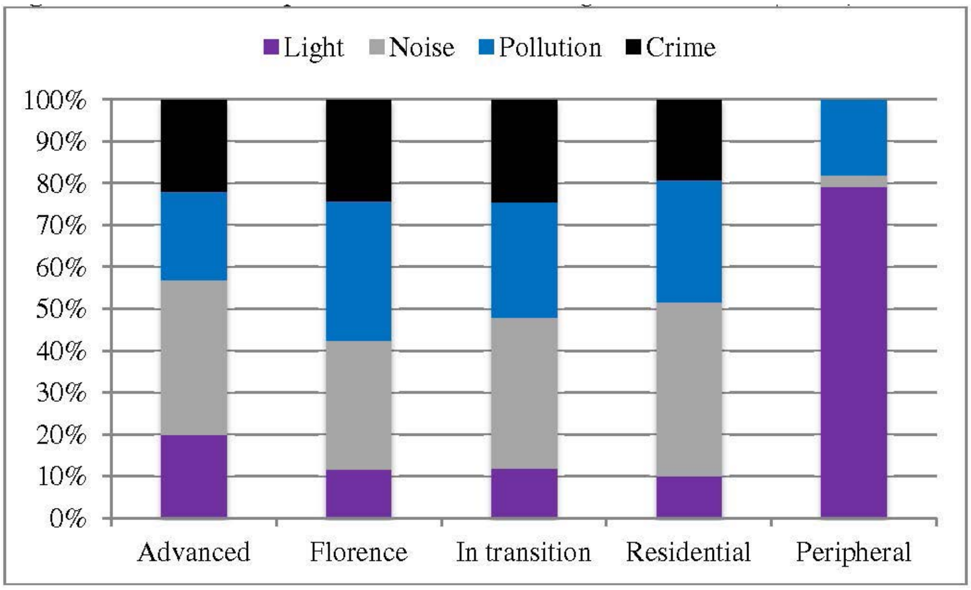
Another factor affecting the state of health is the quality of surrounding environment (Fig. 10). Even if environmental data at municipal level are not available, we show some data from the EU- SILC survey about the perceived main problems reported by the respondents. Not surprisingly, the lack of sufficient light is troublesome especially in the peripheral area, where this is the most remarkable problem, but also in the advanced rural. Crime and pollution are perceived as more troublesome in Florence, while noise in both the peri-urban and in the rural in transition.

Figure 9 – Avoidable mortality rates by area, 2006/2009 (average)



Source: Author's own elaboration from EU-SILC

Figure 10 – Perceived problems with the living environment (2009)



Source: Author's own elaboration from EU-SILC

4. Concluding remarks

This paper is an attempt to assess of the state of wellbeing in the rural areas of Tuscany from a multidimensional perspective. Following the capability approach proposed by Sen, the concept of wellbeing adopted in this study goes beyond economic grounds, including subjective and objective indicators of people's activated functionings in a set of wellbeing dimensions (labor, gender equality, education, health, quality of surrounding environment). The results show that large differences still persist at territorial sub-regional level. The Tab. 8 recaps the main differences among five sub-regional areas which have been identified in the earlier sections.

Even if Tuscany is a region of a developed country where the standards of living are quite high, the results of this study highlight that large differences at sub-regional level still persist. First of all, a process of economic convergence between rural and urban areas is still far to come. In some rural areas, in particular the more agricultural-intensive, the rates of growth of income are positive and the distribution is fair; however, there are other rural areas where income decreased over time together with a deterioration of the distribution. For example, the municipalities included in the "rural advanced" group show positive growth rates over time and a fair distribution of income; moreover, this area can enjoy a good milieu for entrepreneurship, including a modern and well- developed agricultural sector (Rocchi & Turchetti, 2013). However, when it comes to consider other dimensions of wellbeing, the picture changes because job opportunities are scarce and the provision of services still insufficient.

Table 8: Differences by area along the dimensions

	Florence	Peri-urban	Advanced rural	Rural in transition	Peripheral Rural
Material conditions	Highest income but steady growth and unfair distribution	Stagnant trend of income growth but fair distribution	Balance between income growth and fair distribution	Low income growth and unfair distribution	Positive growth of income and fair distribution
Employment and gender	Both unemployment and employment decrease	Unemployment increases and employment decreases, especially among women. Long waiting lists for nurseries	Both unemployment and employment decrease, especially among women	Unemployment increases and employment decreases, especially among women. Scarce demand for the provision of nurseries	
Education			Poor provision of secondary schools. Tendency to more easily accept unskilled jobs with respect to qualification	Lower share of people in the 30/40 age class with post-secondary/tertiary education. A large share of them is employed. Tendency to more easily accept more unskilled jobs with respect to qualification.	
Health	Large share of people saying not feeling good, although the best provision of services in the region	Inability to pay, especially for prevention	Poor provision of services	Poor provision of services, long waiting lists	Poor provision of services, but well-targeted

Source: Author's own elaboration

The situation is even worse in the "rural in transition" and the "rural peripheral" areas, where incomes are lower and, in the case of the former, poverty and inequality are widespread and increasing. Differences in the quantity and quality of public services for education and health likely affect the well-being of people living in areas with prevalent rural features. In the rural areas "in transition" and "peripheral" this disadvantage is combined with controversial trends in economic conditions, resulting in an increasing lag from the rest of Tuscany.

From a methodological point of view, this study shows the relevance of EU-SILC Survey for the analysis of well-being and the opportunity to adopt it for sub-regional studies by using proper techniques of post-stratification. The results show an acceptable degree of statistical reliability, suggesting a wide range of possible analysis based on available micro-economic information. We also attempted to gather some concluding remarks by comparing information about both subjective and objective wellbeing from EU-SILC database with information from other primary and secondary data sources about the supply of local public services. We are convinced that this research path should be further pursued. Indeed, the relevance of a multidimensional concept of well-being, such as the one adopted in this study, for policy design increases moving from larger to smaller territorial scales. Empirical evidence on territory-specific lags in one or more dimensions of well-being might suggest a better targeting of policy measures, improving the efficiency in the use of public resources.

This is the case of regional rural development policy. The ongoing revision of the Rural Development Programme in Tuscany is an opportunity to address some of the issues highlighted above. The case of rural Tuscany shows how "social inclusion, poverty reduction and economic development" should be more clearly considered as a fundamental part of the policy design for rural areas, also in terms of budget allocation. Indeed, the thread for a re-orientation of policy towards the consideration of regional differences turns to be extremely urgent whether also well-developed regions like Tuscany cannot grant to everyone the same access to well-being because of the diverse provision of public services and/or economic opportunities.

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THEMATIC SET

A03

MEASURING THE SOCIAL DIMENSION OF AGRICULTURE

Session Organizer
B. Davis | FAO | Rome | Italy

ABSTRACT

Within the context of the development of the SDGs and the most recent generation of integrated household surveys, the importance and relevance of the interconnectedness of the social and economic dimensions of agricultural households is gaining prominence. While a recognition of the role in influencing behavior of the inseparability of the agricultural household in the context of market failure is well established in the literature, more generalized collection of the necessary broad types of data is more recent. This session will focus on the measurement and analysis of social topics within the context of agricultural households and the particular environment and constraints in which they live. Papers can focus on such diverse topics as the multi-dimensional nature of resilience, the implications of social protection for agriculture, the role of human capital in agricultural productivity, the role of agriculture in youth un- and under employment, etc. Papers can focus on an application to a specific topic in a given country, or focus on methodological issues.

LIST OF PAPERS

Economic growth and poverty reduction: the role of the agricultural sector in rural Indonesia
K. Kadir | BPS | Statistics Indonesia | Jakarta | Indonesia
A. Ratna Rizki | BPS | Statistics Indonesia | Jakarta | Indonesia
DOI: 10.1481/icasVII.2016.a03

Growth and inequality in Sub-Saharan Africa: insight from a linked ABG method and CGE modeling
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Socioeconomic dynamics resulting from structural transformation and agriculture transition in Ghana
F. Alfani | FAO | Rome | Italy
A. Carraro | FAO | Rome | Italy
P. Karfakis | FAO | Rome | Italy
DOI: 10.1481/icasVII.2016.a03d

A03

Economic growth and poverty reduction: the role of the agricultural sector in rural Indonesia

K. Kadir | BPS | Statistics Indonesia | Jakarta | Indonesia
A. Ratna Rizki | BPS | Statistics Indonesia | Jakarta | Indonesia

DOI: 10.1481/icasVII.2016.a03

ABSTRACT

Agricultural sector has emerged as the engine of economic growth in Indonesia. The sector is expected to contribute to poverty reduction in rural areas which is the largest contributor to poverty in Indonesia. Growth in the agricultural sector can induce the growth of the non-agricultural sector through linkages between the two sectors. Thus, the growth of the agricultural sector is not only a positive impact on poverty reduction through the rising of incomes in the sector, but it can also encourage non-agricultural activities in rural areas. This study aims to determine how much the growth of the agricultural sector impacts on the non-agricultural sector in rural areas and how much the growth of these two sectors impacts on poverty reduction in rural areas. Data used in this research is panel data from 2002 to 2008. Data are analyzed using simultaneous equations model estimation and the estimation of panel data regression model. The results of simultaneous equations model analysis show that growth in the rural agricultural sector by 1 percent will induce the growth of the rural non-agricultural sector at 1.35 percent. Meanwhile, the results of estimation of panel data regression model reveal that productivity growth in both the agricultural and the non-agricultural sectors in rural areas by 1 percent will reduce the rural poverty rate by 3.91 percent and 3.97 percent, respectively. Both these findings affirm that the agricultural sector is still the driving force of economic growth and is critical to the success of poverty alleviation in rural areas. In addition, the government also needs to develop the non-agricultural sector to support poverty alleviation efforts.

Keywords: sectoral linkages, growth multiplier, panel data regression

PAPER

1. Introduction

During the last five decades, Indonesia has experienced a massive economics structural transformation from a country that mostly relied on the agricultural sector to a country whose economy is dominated by industry and service sectors. Over the period, the share of the agricultural sector to the total Gross Domestic Product (GDP) has declined dramatically from 45 percent in 1970 to 14 percent in 2016. This change, in turn, triggers a question: Is the sector still important for Indonesia's economic development?

Although the structural transformation has reduced the role of the agricultural sector in the country's economy, the sector clearly still plays a very important role in terms of its contribution to the output of Indonesia's economy as measured by GDP. In 2015, the sector accounted for 13.52 percent of the country's GDP, the second largest after manufacturing sector. The agricultural sector also has a significant contribution to labor absorption, especially in rural areas. BPS estimated that approximately 32.88 percent of the total labor force in August 2015 work in the sector. With these important roles, the agricultural sector is expected to be the engine of economic growth, especially in rural areas.

Until recently, poverty was still one of the main development challenges that must be addressed by the government. Although the number of poor people generally has decreased during last five decades, the number of Indonesians living below the poverty line is relatively high. In March 2016, for instance, the BPS estimated that the number of poor people was 28.01 million or approximately 10.86 percent of the total number of population.

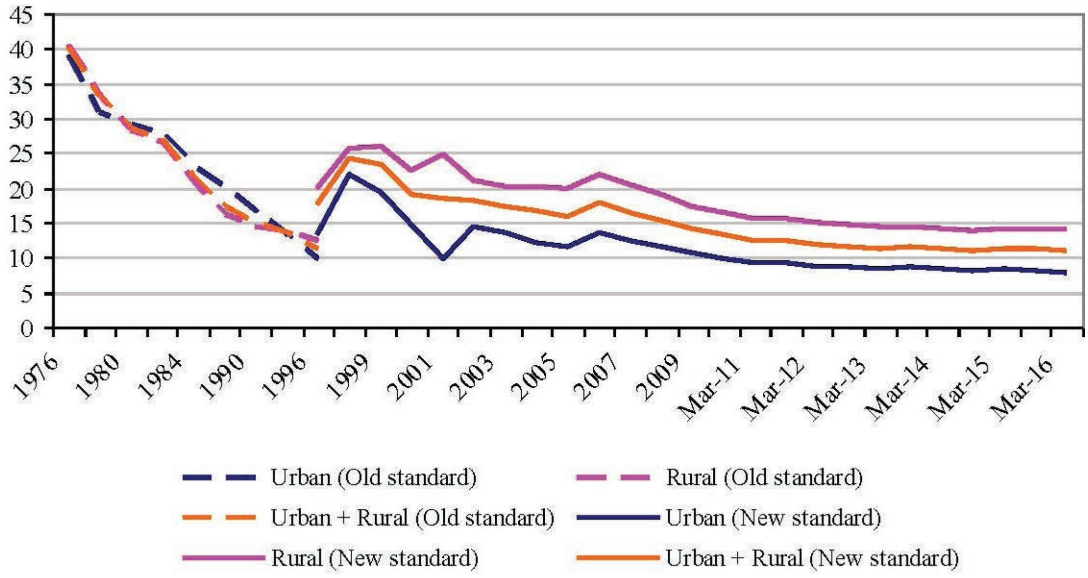
As such, it is clear that poverty is basically a rural-agricultural phenomenon because around 63 percent of the poor people live in rural areas, and most of them rely on the agricultural sector as their livelihood. BPS estimated that in 2014 approximately 67.26 percent of poor households in rural areas were agricultural households. Therefore, the success of poverty reduction measures in Indonesia has a strong connection with the performance of the agricultural sector. In other words, the agricultural sector is the key factor in reducing the number of poor people in the country, especially in rural areas. The growth of the sector definitely gives impacts on poverty reduction not only by increasing the income level of rural people working in it, but also by stimulating the growth of the non-agricultural sector in rural areas.

The focus of our study is to examine the role of the agricultural sector growth as the main driving machine in rural economy, notably in stimulating the growth of the non-agricultural sector in rural Indonesia. In addition, the study aims to assess the role of the rural agricultural growth in reducing poverty in rural Indonesia.

2. Poverty and Agricultural Sector in Indonesia

Indonesia has an impressive experience in curtailing the poverty rates. The success story of the country in poverty alleviation asserts the crucial role of the economic growths in eradicating poverty. It can be traced from 1976 to 1996 when the country experienced a high economic growth period before hit by the Asian Financial Crisis (AFC) in 1997-1998.

Figure 1 - Poverty Rate Trend in Indonesia (%), 1976 - 2016



Source: BPS (various years)
Note: In 1998 BPS revised the method of setting the poverty line. The new method resulted in an increase in the poverty threshold, and the poverty rate in 1996 was adjusted accordingly from 11.3 percent to 17.3 percent

Over the two decades period, through an impressive economic growth performance, reaching around 7 percent per annum on average, Indonesia succeeded in lowering the incidence of poverty from 40.1 percent in 1976 to only 11.3 percent in 1996. Timmer (2008) argued that over the period, there were some main sources of the economic growth in Indonesia, including the growth in the agricultural sector. The dominant contribution of the sector ended up in the 1980s when its role began to be replaced by manufacture industry sector. Although the trend of poverty has been declining after the AFC, its velocity has been relatively slower than the period before the crisis. Even the poverty reduction has experienced a plateau since 2009 due to the low performance of the agricultural sector that has grown below 4 percent on average in recent years.

In fact, from 1976 to 1996, poverty reduction in rural area was faster than that in urban areas. Over the period, the number of poor people in rural areas had plunged approximately 20 million. This impressive trend basically affirms the decisive role of the agricultural sector as the leading sector in the rural economy. The growth of the sector clearly gives a significant contribution to this remarkable poverty reduction because over the period the agricultural sector growth was able to push the level of income and jobs creation in rural areas, not only in the agricultural sector itself but also in the non-agricultural one. This is because the agricultural growth also had stimulated other non-agricultural activities in rural areas that had vigorous connection with agriculture such as trade, agro-industry, transportation and services.

At the same time, the structure of Indonesia's economy experienced a substantial change. Economic structural transformation over the last five decades has eroded the role of the agricultural sector gradually. It was marked by a decrease in the share of the sector on GDP from around 45 percent in 1971 to only 14 percent in 2015.

Unfortunately, although the contribution of the agricultural sector to GDP has been declining, until recently most of the workforce still rely on the agricultural sector as their livelihood. The share of the sector on labor absorption remains the highest compared to other sectors in the economy. It happens because the expansion of the industry sector has failed to absorb more workforce. In other words, the shifting of the labor force from agriculture to industry has not happened in an ideal way. As a result, productivity of the agricultural sector has been declining consistently. For Indonesia, it is a critical problem in the context of pro-poor development because poverty in the country basically a rural agriculture phenomenon.

3. Sectoral Linkages and Poverty Reduction in Rural Areas

The agricultural sector has strong linkages to the non-agricultural sector in rural areas. Through the linkages, the growth of the agricultural sector not only pushes the increase of income in the agricultural activities but also stimulates the growth of the non-agricultural sector in rural areas. Therefore, the agricultural sector has a significant growth multiplier in the areas. The growth multiplier of the sector in an economy dominated by agricultural activities always more than one percent (Hazell and Haggblade in Timmer 2008). Hazell, Haggblade, and Brown (1989) estimated that the growth multiplier of the agricultural sector in Asia was 1.80 percent. Moreover, Suryahadi, Sumarto, and Molyneux (2006) estimated that from 1989 to 2002 one percent growth in the rural agricultural sector in Indonesia would induce the growth of the rural non-agricultural sector by 1.20 percent on average.

The sectoral linkages between the agricultural and the non-agricultural sectors that usually happen in rural areas are in the form of demand linkages that cover both production and consumption linkages. From the production side, the growth of the agricultural sector needs inputs provided by the non-agricultural sector. In addition, the growth of the agricultural sector can also boost the development of economic activities using its outputs as the intermediate inputs. From consumption side, the rising of income in the agricultural sector can enhance agricultural households consumption that, at the end, will raise the demand for goods and services produced by the non-agricultural sector in rural areas (Harianto 2006).

A significant number of empirical studies show that the economic growth that relies on the agricultural sector expansion benefits the poor. The compilation of the empirical studies that affirm the impressive contributions of the agricultural sector growth on poverty reduction in developing countries can be found in Mellor (1999). In the context of Indonesia, many studies also confirm that the growth of the agricultural sector has noticeable impacts on poverty reduction, notably in rural areas. They include among others Sumarto and Suryahadi (2003), Suryahadi, Suryadarma, and Sumarto (2006), and Tambunan (2006).

Enriquez and Stamoulis (2007) argued that the channels through which the growth of the agricultural sector lowers poverty in rural areas consist of two ways. Firstly, the growth of the agricultural sector directly raises the income/consumption level of small farmers that are commonly poor farmers. Secondly, the growth of the sector can indirectly reduce poverty by lowering the price of unprocessed foods, pushing the level of income generated by the non-farm rural economy activities, and raising the jobs creation and the level of wages, particularly for unskilled labors.

4. Methodology

4.1. The Model

Most studies used in estimating the growth multiplier of the agricultural sector are roughly classified into three types: (1) studies using micro-econometrics approach; (2) studies using macro-econometrics; and (3) studies using input-output table, social accounting matrix, and computable general equilibrium model (Suryahadi, Suryadarma, Sumarto, and Mlyneaux 2006). In this study, we apply macro-econometrics approach to examine sectoral linkages in rural Indonesia.

Considering the interdependence relationship between the agricultural sector and the non-agricultural sector in rural areas, we use simultaneous equation model to examine the impacts of the agricultural sector growth on the non-agricultural sector growth in rural areas.We use double log-linear regression, so the estimation of regression coefficient can be interpreted as elasticity. The specification of system of equations that we estimate is presented below:

$$ln(ragdp)_{it} = \alpha_1 + \beta_{11}\, ln(rnagdp)_{it} + \beta_{12}\, ln(land)_{it} + \gamma z'_i + \varepsilon_{1it} \quad (1)$$

$$ln(rnagdp)_{it} = \alpha_2 + \beta_{21}\, ln(ragdp)_{it} + \beta_{22}\, ln(ugdp)_{it} + \gamma z'_i + \varepsilon_{2it} \quad (2)$$

$$ln(awage)_{it} = \alpha_3 + \beta_{31}\, ln(ragdp)_{it} + \beta_{32}\, ln(pmw)_{it} + \beta_{33}\, ln(rlf)_{it} + \gamma z'_i + \varepsilon_{3it} \quad (3)$$

$$ln(awork)_{it} = \alpha_4 + \beta_{41}\, ln(ragdp)_{it} + \beta_{42}\, ln(rnagdp)_{it} + \gamma z'_i + \varepsilon_{4it} \quad (4)$$

$$ln(nawage)_{it} = \alpha_5 + \beta_{51}\, ln(rnagdp)_{it} + \beta_{52}\, ln(pmw)_{it} + \beta_{53}\, ln(rlf)_{it} + \gamma z'_i + \varepsilon_{5it} \quad (5)$$

$$ln(nawork)_{it} = \alpha_6 + \beta_{61}\, ln(rnagdp)_{it} + \beta_{62}\, ln(pmw)_{it} + \gamma z'_i + \varepsilon_{6it} \quad (6)$$

The variables in the system consist of Gross Regional Domestic Product (GRDP) of the agricultural sector in rural areas (*ragdp*), non-agricultural GRDP in rural areas (*rnagdp*), urban sectors GRDP (*ugdp*), wages in the agricultural sector in rural areas (*awage*), agricultural labor—defined as the number of 15+ years old population working in the agricultural sector—in rural areas (*awork*), wages in the rural non-agricultural sector (*nawage*), non-agricultural labor in rural areas (*nawork*), labor force in rural areas (*rlf*), area of agricultural land (*land*), provincial minimum wages (*pmw*), vector of initial variables (e.i. poverty rate in rural areas in 2002 and proportion of 15+ years old rural population who did not complete nine years education in 2002 as a proxy of education level).

By using the order condition, the result of identification process shows that all of the structural equations in the system are overidentified, so they could be estimated. Our focus of estimation is the value of B_{21} that shows the percent growth of the rural non-agricultural sector due to the growth in the rural agricultural sector by one percent. The coefficient also represents the strength of the linkages between the agricultural sector and the non-agricultural sector in rural areas. Meanwhile, in scrutinizing the impacts of the agricultural growth on poverty in rural areas we use panel data regression model. As in equation (1) to (6), we also use the double log regression model. The model that we estimate is:

$$RP_{it} = \alpha + \beta_1 \, ln(aproductivity)_{it} + \beta_2 \, ln(naproductivity)_{it} + \beta_3 \, ln(awage)_{it} + \beta_4 \, ln(nawage)_{it} + \beta_5 \, ln(rcpi)_{it} + (u_i + \varepsilon_{it}) \qquad (7)$$

The model asses the impact of the rural agricultural sector productivity (aproductivity) growth and the rural non-agricultural sector productivity (naproductivity) growth on the incidence of poverty in rural areas.The term of productivity is defined as the output per worker of each sector.We also investigate the impact of other related variables on poverty in rural areas such as the growth in agricultural and non-agricultural wages as well as inflation rates in rural areas (*rcpi*).

4.2. The Data

All data used in our study are from BPS-Statistics Indonesia. We use panel data consisting of 23 provinces that were observed for the period of 2002-2008. We only observed those provinces instead of the total 33 provinces because of the limitation of data availability for certain variables in some provinces. In estimating the growth multiplier of the agricultural sector in rural areas, we use Gross Regional Domestic Product (GRDP) at the provincial level. Because BPS does not disaggregate the GRDP data by rural and urban areas, we have to estimate the proportion of GRDP by sector in every province that goes to rural areas. As the solution, we use the share of the agricultural sector labor in rural areas as the allocator. The share is the proportion of the agricultural labor living in rural area of the total number of labor in every province. We consider that the distribution of the GRDP data by area could be explained very well by the distribution of labor in rural and urban areas. Moreover, the poverty rate data used in our research is derived from The Foster–Greer–Thorbecke (FGT) index estimated by BPS.

5. Results

We use the three stages least square (3SLS) method to estimate all of the structural equations. The estimation results of equations (1) to (6) are shown in Table 1. The results show that the growth of the rural agricultural sector has positive and significant impacts on the growth of the rural non-agricultural sector. The impacts are considered relatively high. One percent growth of the rural agricultural sector will induce growth of the rural non-agricultural sector by 1.35 percent.

Our findings basically confirm that there are strong linkages between the agricultural sector and the non-agricultural sector in rural areas. The linkages include both production linkages and consumption linkages. The strong linkages between the two sectors mean that an increase of income in the rural agricultural sector will stimulate the increase of income in the rural non-agricultural sector through the rising of demand for goods and services produced by the non-agricultural sector in rural areas. At the end, such mechanism will boost the non-agricultural activities in rural areas and create more opportunities for rural people including the poor to gain more income. In addition, the growth of the rural non-agricultural sector also has positive and significant impacts on the rural agricultural sector although it is relatively lower than the impacts of the rural agricultural growth on the rural non-agricultural growth. This study finds that one percent growth of the non-agricultural sector will induce 0.41 percent growth in the agricultural sector in rural areas. It confirms that an increase of income in the rural non-agricultural sector will also stimulate the demand for the agricultural products in rural areas.

The interdependence relationship between the agricultural sector and the non-agricultural sector in rural areas has the implication that the development of the two sectors in rural areas must be conducted simultaneously through an integrated policy. In other words, the development of the agricultural sector in rural areas should not only focused on food production but also should be directed to produce agricultural commodities needed by the non-agricultural sector in rural areas. Moreover, the development of the non-agricultural sector in rural areas must support the rural agricultural sector and creates more opportunities

Table 1: Results of Estimation of Simultaneous Equations Model

Dependent Variables	Independent Variables	3SLS	Dependent Variables	Independent Variables	3SLS
Log of rural agricultural GDP	Log of rural non-agricultural GDP	0.406** (19.29)	Log of rural non-agricultural GDP	Log of rural agricultural GDP	1.353** (16.50)
	Log of gricultural land area	0.254** (6.50)		Log of urban GDP	0.279** (10.42)
	Education level in 2002	0.252** (8.42)		Education level in 2002	-0.406** (-7.48)
	Rural poverty rate in 2002	-0.051 (-1.24)		Rural poverty rate in 2002	0.127* (2.06)
	Constant	10.451** (22.90)		Constant	-12.567** (-9.25)
	Number of observations = 161; R2 = 0.936; P(Chi-stat) = 0.000			Number of observations = 161; R2 = 0.908; P(Chi-stat) = 0.000	
Log of rural agricultural wage	Log of rural agricultural GDP	0.717** (8.79)	Log of rural non-agricultural wage	Log of rural non-agricultural GDP	0.153** (4.01)
	Log of provincial minimum wages	0.442** (5.76)		Log of provincial minimum wages	0.376** (5.37)
	Log of labor force in rural areas	-0.882** (-4.65)		Log of labor force in rural areas	-0.141 (-0.17)
	Education level in 2002	0.072 (0.52)		Education level in 2002	-0.028 (-0.18)
	Rural poverty rate in 2002	-0.150** (-2.84)		Rural poverty rate in 2002	-0.158** (-3.42)
	Constant	-2.618 (-1.89)		Constant	6.099** (6.23)
	Number of observations = 161; R2 = 0.679; P(Chi-stat) = 0.000			Number of observations = 161; R2 = 0.454; P(Chi-stat) = 0.000	
Log of rural agricultural labor	Log of rural agricultural GDP	0.481** (5.86)	Log of rural non-agricultural labor	Log of rural non-agricultural GDP	0.283** (8.16)
	Log of rural non-agricultural GDP	-0.142** (-3.60)		Log of provincial minimum wages	-0.064 (-0.77)
	Education level in 2002	0.610** (17.05)		Education level in 2002	0.740** (17.60)
	Rural poverty rate in 2002	0.182** (5.64)		Rural poverty rate in 2002	-0.223** (-3.41)
	Constant	-4.261** (-4.35)		Constant	-5.288** (-4.37)
	Number of observations = 161; R2 = 0.966; P(Chi-stat) = 0.000			Number of observations = 161; R2 = 0.902; P(Chi-stat) = 0.000	

Notes: Number in parentheses are Z-values. ** Is significant at 1% level.* Is significant at 5 % level

for rural people, especially small farmers, so they do not only rely on the agriculture sector as their source of income. Besides having significant impacts on the growth of the non-agricultural sector in rural areas, the results of estimation also show that the growth of the rural agricultural sector stimulates jobs creation and lift up the level of wage in rural areas, not only in the agricultural sector itself but also in the non-agricultural sector. These facts obviously affirm that the agricultural sector is still the main driver of the rural economy in Indonesia.

Table 1: Results of Estimation of Simultaneous Equations Model

Independent Variables	Fixed Effect (GLS)
Log of rural agricultural productivity	-3.909** (-3.721)
Log of rural non-agricultural productivity	-3.971** (-3.441)
Log of rural agricultural wage	-1.077* (-2.560)
Log of rural non-agricultural wage	-0.594 (-1.773
Log of rural consumer price indix	0.528** (4.484)
Constant	168.694** (10.112)
Number of observations	161
Adjusted R-squared	0.9832
F-statistics	347.571**

Notes: Number in parentheses are t-values. ** Is significant at 1% level.* Is significant at 5 % level

Meanwhile, for the model of the agricultural productivity growth impacts on poverty in rural areas we use the Generalized Least Squares (GLS) method for the panel data. We estimate equation (7) using fixed effect model. The estimation results show that both an increase in the productivity of the rural agricultural sector and the productivity of the rural non-agricultural sector have a significant contribution in reducing the incidence of poverty in rural areas. One percent growth in both sectors productivity will reduce the number of poor people in rural areas by 3.9 percent and 4.0 percent respectively. These findings basically give a clear evidence for two things. First, the agricultural sector still plays a very crucial role in the eradication of poverty in rural Indonesia, which for a long time has been the center of poverty in the country. Second, the role of the non-agricultural sector in rural areas becomes more essential in boosting the welfare of rural poor people.

6. Conclusion

Although the economic structural transformation has occured massively over the last five decades, our study firmly proves that the agricultural sector still plays a very significant role in the Indonesia's economy, particularly in rural areas, where approximately 47 percent of the Indonesian population live. We found out that the sector is still the driving engine of the rural economy that can stimulate the growth of the non-agricultural sector in rural areas in many ways as well as enhance the jobs creation and the level of wage in the areas.

Our study also asserts the powerful impacts of the rural agricultural sector growth together with the rural non-agricultural growth on poverty reduction in rural areas, the home for 63 percent of Indonesian poor people. It means that the rural sector is the key to success in poverty eradication measures in Indonesia, and the role of the rural non-agricultural sector becomes more decisive in the context of rural development in the country. As a consequence, besides enhancing the growth of the agricultural sector productivity, Indonesia also must pay more attention to the development of the rural non-agricultural sector to support poverty reduction in rural areas.

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A03

Growth and inequality in Sub-Saharan Africa: insight from a linked ABG method and CGE modeling

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ABSTRACT

This paper uses survey data from a sample of Sub-Saharan African countries and showsthe heterogeneity in the shape and the structure of inequality between countries and over time.Based on the new Alpha Beta Gamma method (ABG), inequality is considered as an anisotropicdimension along the income scale.In the second part of the paper, we show that the growth-inequality relationship is defined in local domains. Different sector-led growth profiles are found to have heterogeneous effects on inequality at the median, the top and bottom ends of the income distribution.

Keywords: Growth, Inequality, Income, Africa

PAPER

1. Introduction

Africahas the highest poverty rate in the world and is the second most inequitable region after the Latin America. Giving the relation between poverty and inequality, there is timely research question to assess detailed analyses of inequality across and within countries and to find out the growth strategies that lead to more redistribution of wealth.

This paper uses a new representation of inequality developed by (Chauvel, 2014) in order to shed a new light on income distribution in Sub-Africa In this representation, inequality is then considered as anisotropic and varies along the income side. This is contrary to the traditional approachesthat consider inequality as stable and relyingonly onpartial summary statisticslike the Gini coefficient.The study uses survey data from a sample of 10 African countries, especially West African countries[1] to assess the inequality disparities along the income scale, between countries and over time.

The growth realized in the continent did not translate into inequality reduction and an interesting researchquestion could focus on identifying alternative sources of growth that could generate a high poverty reduction and more equal distribution of wealth[2].The second part of the paper tackles this question by using Senegal as a study country. It applies a Quasi-Dynamic Computable General Equilibrium (CGE)model linked to a micro-simulation module to identify the sectors that when driving growth have the highest impact on poverty reduction and inequality. Despite the long debate and the huge literature about growth-inequality linkage no consensus and clear relationship have been found. We contribute to this debate by turning our attention to the possibility that the growth-inequality relationship is defined in local domains along the income scale and by considering the fact that the pattern of growth might be an important factor.We explore the impact on inequality in the different parts of the income distribution in order to better take into account the complex nature of the inequality-growth linkage. This investigation could help to see the conditions in which economic growth impacts on economic inequality and poverty. The analyses of growth-poverty-inequality linkage for Senegal serve as a touchstone for future research including several countries.

Different sector-led growth profiles might have heterogeneous effects on inequality at the median, the top and bottom ends of the income distribution. Moreover, determining the condition under which economic growth impacts inequality requires an in-deep country specific analysis in a general equilibrium framework in order to integrate all the spillover effects in the economy. However, many of the previous studies on poverty-growth-inequality linkage use cross-countries data that often leadto limited and broad conclusions by failing to account for the idiosyncratic factors, and by using samples which include countries at various stages of economic development. A complex and unknown inequality shape combined with an appropriate choice of growth profile might lead to sub-optimal development policies.

The rest of the paper is organized as follows. In section 2, we provide some background knowledge on

[1] Many empirical analyses focused on the Southern African region where we have six countries among the continent's top ten most unequal countries in the world (ADB, 2012).

[2] The GINI coefficient increases from 0.42 to 0.46 over the period 2000 to 2010 (ADB, 2012).

the issue of anisotropic inequality and growth-poverty-inequality linkage.

Section 3 presentsthe methodology we used to address the research questions. Section 4.1 presents the pattern of inequality along the income scale and over time for selected countries in Africa. Section 4.2 identifies the growth profiles that have the highest impacts on poverty and inequality taking into account the heterogeneity along the income scale.

2. Background

2.1 Poverty-inequality-growth linkage

It is widely recognized that Sub-Saharan Africa is one of the most unequal region in the world. The Gini coefficient is estimated at 0.46 and isthe highest, behind Latin America (Table 1). However, beyond this general statistic, there might exist different levels and structures of inequality between countries and between the individuals within each country. This calls for a deep analysis of the structure and the evolution of inequality over the years and along the income scale. Besides, the presented framework allows analyzing how inequality responds to the different economic growth profiles. While there is a consensus that growth is a necessary condition for poverty reduction (Ravaillon and Chen 1997;Deininger and Squire 1997; Fan, Hazell and Thorat,2000; Ravallion, 2004; Fields, 2001; Kraay, 2006), the relationship between inequality and growth was subject to controversial debate in the literaturethat makes the link between the two factors no clear. For instance,a cross-country study by Ravallion (2004) finds that a one percent increase in income level results in a poverty reduction of between 0.6 and 4.3 percent. Likewise, Kraay (2006) found that growth in average incomes can explain 70 and 97 percent of changes in poverty headcounts in developing countries in the short and long-run.

Regarding growth-inequality linkage,Kuznets (1955) identifies an inverted U shape of inequalities over time. However, this relationship was criticized by some authors (Ravallion and Chen 1997; Atkinson, 1999; Arjona, Ladaique and Pearson, 2001) that cast doubt on the direction of the causation and the robustness of the relation.Pardo-Beltran (2002) finds a negative and but non-linear effect of growth on inequality.While Hausman and Gavin (1996) showed that the volatility of growth increases income inequality measured as the ratio of the income received by the richest 20 percent of the population to the income received by the poorest 40 percent.

In contrast to the growth-poverty nexus, the literature review shows that there is little consensus regarding growth-inequality linkage. However, our study investigates whether this relationship might depend on the nature of the growth, the parts of the income distribution that is considered and on the shape of inequality.In fact, different growth sources might have heterogeneous effects on inequality at the different parts of the income distribution because they affect household income differently and are not all growth-neutral. The link between inequality and growth can be multidimensional. However, this paper focuses on one direction of the interaction that is how growth might impact income inequality. There have been many indexes used in the literature to measure inequality at the top and bottom of the distribution, such as the quintile ratios, namely Q5/Q3 and Q3/Q1 and the percentile ratios, namely P90/P50 and P50/P1 or P90/P70 and P10/P30. However, the choice of these indexes might be arbitrary and might lead to various results. The Alpha Beta Gamma method (ABG) defined in section 3 allows a straightforward combination of the information along the income scalewithout losing generality. This paper sheds a light on the difference of structure of inequalities between and within selected sub-Saharan Africancountries by taking into account the heterogeneity in the income distribution.In a second step, this contribution investigates if it is not more the sources of growth that is crucial in determining the effects on inequality. Our framework allows identifying the growth profiles that lead to more egalitarian economies.

Table 1: Income Inequalities in the world

REGIONS	GINI	GE(0)*	90TH/10TH PERCENTILE RATIO
MIDDLE EAST AND NORTH AFRICA	0.37	0.25	5.12
SUB-SAHARAN AFRICA	0.46	0.31	6.63
LATIN AMERICA	0.50	0.50	14.42
SOUTH ASIA	0.33	0.18	4.12
EAST ASIA	0.39	0.25	4.92
EUROPE AND CENTRAL ASIA	0.31	0.16	4.17
HIGH-INCOME OCDE	0.31	0.17	4.09

Note *: Mean log deviation.
Source: World Bank, 2005; AFD, 2007

2.2. Agricultural sector in Senegal

Determining the extent to which different growth profiles affects household welfare and anisotropic inequality can be helpful for designing development policies. We use Senegal as our pioneer work for a better understanding of the potentials for inequality reduction, in addition to poverty reduction, by assessing the complex impacts of each specific sector-led growth on inequality along the income scale. The ABG method is used in order efficiently measure inequality.

In Senegal, as in many sub-Saharan countries, there has not been sufficient work in the sense of investigating the linkages between the several household groups and economic sectors and the various economic mechanisms that are specific to the sectors. The study provides insight on the extent different sector-led growth affect local inequality and household welfare. We will show how these effects vary, in the context of the structural transformation and growth promoted by the Senegalese Emergency Plan (PSE). In fact, the Senegalese government has recently started a new challenge that is the one of rapid progress toward successful economic emergence. This latter is the new reference framework for economic and social policy in the medium and long-term. One of the three axes of the new released PSE is growth and the structural transformation of the economy through the consolidation of the actual growth engines and the development of new sectors that are able to create wealth, employment, and social inclusion. The plan also seeks to promote sectors thathave the strongest export capacity and are attractive for investments (Senegal Emergent Plan, 2014). This new development strategy looking ahead to 2035 comes in addition to the large set of initiatives undertaken by the government like the establishment of the SCA (Accelerated Growth Strategy) at broader level or the implementation of agricultural development initiatives such as the Great Offensive for Food and Abundance (GOANA), the program return to Agriculture (REVA), the agro - Sylvo - Pastoral Orientation Law (LOASP) and more recently the National Program of Agricultural Investment (PNIA), within the Comprehensive African Agricultural Development Program (CAADP).

The implication of an agriculture-led growth is not documented so far, nor has been empirical evidence on the impacts of non-farm sectors on the welfare of both non-agricultural households and agricultural households. On one hand, although occupying a high share of employment, Agriculture in Senegal contributes weakly to the national GDP, contrary to Services sector. On the other hand, it is widely recognized that the Services sector drives growth, but poverty and inequality are still persistent and at the current path of the economy, it is difficult to imagine that figures will change much better over the next decades. Therefore, an interesting research question is to identify the growth profiles that have higher contribution to poverty and inequality reductions. The general equilibrium modelling part wants to shed a light on the heterogeneity on the effects of different growth types on anisotropic inequality and poverty. The characteristics of the economic sectors are not identical and the patterns that ensure their linkages to populations are quite different. Therefore, inequality and poverty impacts of various growth strategies deserve to be analyzed by considering the full range of general equilibrium effects. Further, the analyses of the sector-led growth and inequality linkages will be extended to remaining countries once we have built the appropriate micro-

Table2: The general structure of the economy

Sectors	*GDP share*	*Employment share*	*Export share*	*Import share*
Primary sector	16.1	47.4	11.2	7.0
Agriculture	7.0	26.4	3.2	6.1
Food Ag.	5.6	17.2	1.2	5.7
Industrial Ag.	1.4	9.2	2.0	0.3
Livestock	5.1	16.5	0.0	0.3
Forestry	1.1	2.5	0.1	0.1
Fishing	2.8	2.1	7.9	0.6
Secondary sector	23.9	14.7	64.1	85.3
Mining	2.2	0.9	8.9	9.9
Food processing	5.8	5.2	14.8	17.6
Industry	10.0	3.8	34.8	52.3
Other industries	6.0	4.8	5.6	5.5
Tertiary sector	60.0	37.9	24.7	7.7
Trade	16.7	25.8	0.0	0.0
Telecommunication	7.3	0.2	5.4	1.3
Business services	5.3	3.5	6.2	3.1
Health and Education	4.4	2.8	0.7	1.3
Other services	26.4	5.7	12.4	1.9

Note: GDP, employment, export, and import shares from the SAM are presented

Source: Authors

simulated CGE model for each country.

Beyond the macro-economic models that are based on national accounts, it is important to explore growth-poverty-inequality linkage from household surveys. As pointed out by Bourguignon et al. (2008), linked micro-macro can help to deal with the limitations of single and pure micro (respectively macro model) that when taken solely, only provides partial responses of policies at the macro level (respectively the micro level). The Table 2 presents the structure of the Senegalese economy. Agriculture employs the most of the individuals (47.4%) but account for only 16% of the GDP. The agricultural sector is confronted with many difficulties, including an overall yield decline owing to the soil degradation, the dependence to the precipitation, the successions of sub-optimal government policies, and the difficulties facing the main fertilizer provider, the Chemical Industry of Senegal – ICS, etc. Services account for a large share of the GDP (60%), despite the fact that agriculture is the primary source of employment in rural areas. The country's key export sectors are in the Industry (mainly chemical industry that includes fertilizer and phosphate extraction). Besides, the Food processing with 14.8% and primary sector with 11.2% have a significant part in the national export level (for the primary sector, we have especially the fishing sector, the groundnut and the vegetable sectors).

The use of the CGE allows integrating all relevant economic aspects, especially existing spillover effects in the economy and resource re-allocation. The analyses give valuable information on the responsiveness of the inequality and poverty to growth driven by a specific sector, as many policies are formulated by targeting specific sectoral programs.

3. Methodology

3.1 Inequality analyses

To assess inequality we used a new method develop by Chauvel (2014) that relies on the fact that inequality is anisotropic and its intensity is variable along the income scale. This method differs from the traditional one that only considers a constant general inequality index in the population expressed as the Gini index. The Alpha, Beta and Gamma (ABG) method estimates three parameters of inequalities, compatible with the Pareto properties of the tails. These parameters provide the level-specific measures of inequality at the median (alpha), the top (beta) and the bottom (gamma).

Starting from the CF distribution (see Champernowne, 1937; Fisk, 1961; Dagum, 2006), the ABG method is based on the expression of power of income Y_i (measured as the logarithm of the medianized revenuey_i) as a function of the logit of the rank quantile p_i in the distribution, X_i = logit (p_i) = log (p_i /q_i) where q_i is the proportion of individuals (1 - p_i) having income above the income of the individual i.

$$Y_i = ln(y_i) = ISO(X).\ X_i \qquad (1)$$

With $ISO(X)$ expressing the local inequality at level $X_i$through the divergence between the median and log-income y_i and is defined as follows

$$\text{ISO(X)} = \text{alpha} + \text{beta B(X)} + \text{gamma G(X)} \qquad (2)$$

Where $B(X) = (\text{theta1}(X) + \text{theta2}(X))/2$ and $G(X) = (-\text{theta1}(X) + \text{theta2}(X))/2$

And $\text{theta1}(X) = \tanh\ (X/2) = \frac{e^{X/2} - e^{-X/2}}{e^{X/2} + e^{-X/2}}$ and $\text{theta2}(X) = \tanh^2(X/2)$

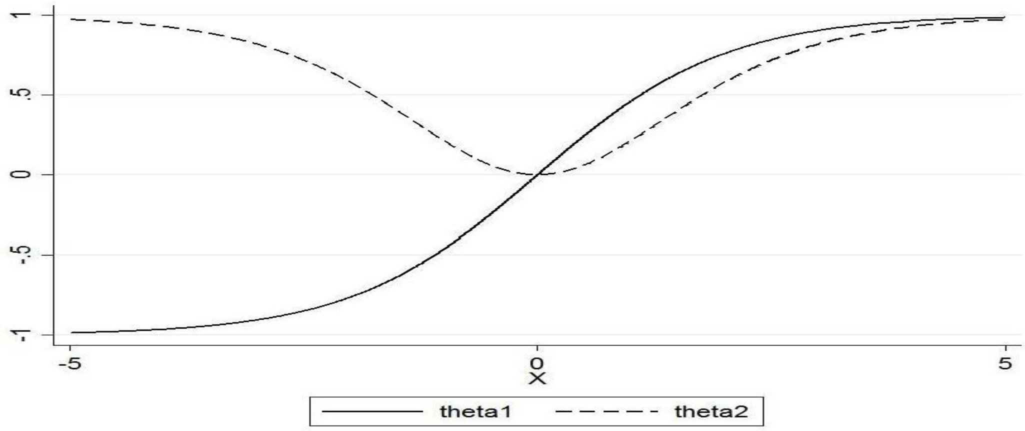
The coefficient alpha of the inequality level near to the median corresponds to the constant term in the equation (2). The uses of the two tangents hyperbolic related functions theta1 and theta2 allow the parameter beta to measure additional inequality at the top and gamma the additional inequality at the bottom. When beta and gamma are equal to zero, the distribution is a CF of coefficient alpha that will correspond to the Gini index. Otherwise the inequality is considered as non-stable along the income scale. The coefficient beta is positive when the rich are richer than in the CF distribution of coefficient alpha and gamma is positive when the poor are poorer than in the CF distribution of coefficient alpha (For more information see Chauvel, 2014).

To assess poverty, the calculated poverty indexes are the Foster-Greer-Thorbecke (FGT) family of poverty measures.

$$FGT = \frac{1}{N}\sum_{i=1}\left(\frac{z-y_i}{z}\right)^{\alpha}.\ I(y_i \leq z) \qquad (3)$$

For $\alpha = 0$ the FGT index collapses to the headcount ratio P_0 that quantifies the proportion of the population that is poor, but does not show how poor the poor are. $\alpha = 1$ gives the poverty gap index (P_1) that measures the extent to which individuals fall below the poverty line as a proportion of the poverty line. The poverty line corresponds to the level of expenditure that allows households to meet nutritional needs and essential non-food consumption.

Figure 1: theta1 and theta2 functions



3.2 CGE modeling and micro-simulation

As explained before, we use Senegal as a case study to see how different sources of growth might have different impacts on both poverty and anisotropic inequality. A dynamic extension of the standard model developed by the International Food Policy Research Institute (IFPRI) is used (see Lofgren and Robinson, 2002 and Thurlow, 2004). The model is constructed for Senegal and calibrated using the 2011 agricultural Social Accounting Matrix (SAM) that we build. The simulations are run over a ten year period from 2011 to 2020 at the midterm of the Sustainable Development Goals(SDGs)[3].

Table A1 and Table A2 in the appendix provide a description of the model, and further explanation can be found in the above-mentioned documents.

Households are disaggregated based on their location, activity, and initial poverty status (Rural agricultural poor, rural agricultural rich, rural non-agricultural poor, rural non-agricultural rich, urban agricultural poor, urban agricultural rich, urban non-agricultural poor, and urban non-agricultural rich). Their consumption levels result from the maximization of a Stone-Geary utility function. The aggregated domestic output is allocated between domestic sales and exports using a constant elasticity of transformation (CET) to reflect the imperfect transformability between these two types of sales. An Armington function (Armington, 1969) is used to model imperfect substitutability between domestic outputs supplied for the domestic market and imports (See Lofgren, 2002 and Thurlow, 2004 for more details on the CGE model)[4]. Labor is disaggregated into four categories: unskilled labor, primary labor, secondary labor, and tertiary labor.

To assess the impact on poverty and inequalities, we use a micro simulation that we calibrated to household survey ESPS II[5]. Endogenous changes in consumption resulting from the CGE model are passed down to the household by mapping each of the household in the micro simulation model to the corresponding household in the CGE[6].

3.3 Data Source

The study relies on data from household surveysavailable forthe different countries. These surveys are representative at the national level and collect detailed information on household characteristics (employment, housing, income, education, health, etc.). The source of these surveys is indicated for each country in Table 3.

4. Results and Discussion

4.1 Inequality and poverty

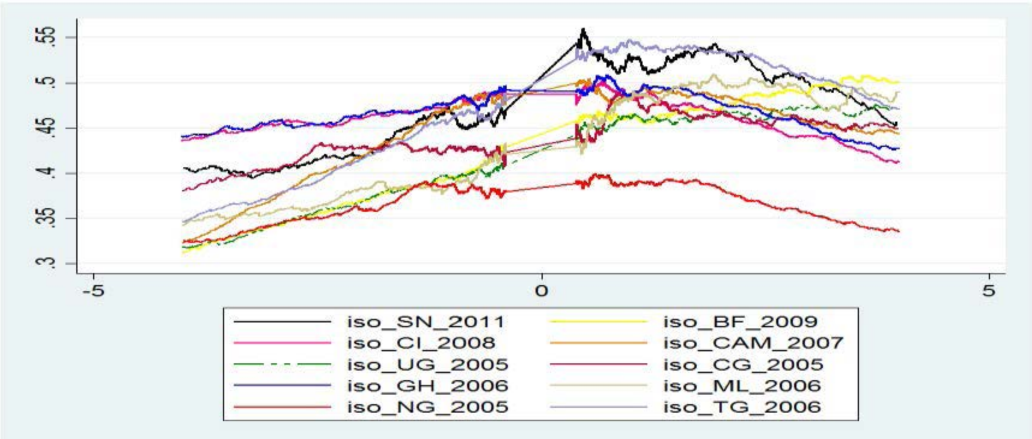
While there are many studies describing poverty, this study primarily focuses on inequality. The analyses of the isographs(Figure 2) and their summary in the ABG parameters (Table 4) show some heterogeneity between countries in both the level and the shape of inequality along the income scale, especially at the top income extremity. The isographs are not flat or constant over the income scale, revealing therefore the existence of local inequality. The difference of the parameters Beta and Gamma from zero indicates the limit of the Gini indicator as pointed out by (Chauvel, 2014).

[3] The new Sustainable Development Goals aim to end poverty by 2030 and are going to replace the Millennium Development Goals from January 2016.
[4] The Armington and CET elasticities are borrowed from the GTAP.
[5] Poverty Monitoring Survey.
[6] See (Colombo, 2010) for explanation of survey data and CGE model linkages.

Table3: Data source for income inequality analyses

Country	Survey Used	Year
Senegal	ESAM I: The Senegalese Household Survey I	1994
	ESPS I : Poverty Monitoring survey I	2005
	ESPS II : Poverty Monitoring survey II	2011
Uganda	UNHS: Uganda National Household Survey	2005
Burkina Faso	EPI: Priority Survey	1994
	ILCS: Integrated Living Conditions Survey	2009
Cameroon	ECAM III : Households Survey	2007
Ghana	GLSS : Living Standards Survey III	1992
	GLSS : Living Standards Survey V	2006
Mali	Household survey	1989
	ELIM: Integrated Household survey	2006
Niger	ECVAM : Vvulnerabilityandhouseholdfood insecurity	2005
Togo	QUIBB	2006
Ivory Coast	Living Standards Survey	1993
	Living Standards Survey	2008
Congo	ECOM: Household poverty monitoring survey	2005

Figure 2: Shape of inequality across the countries



Note: SN = Senegal; BF = Burkina Faso; CI = Ivory Coast; CAM = Cameroon; UG = Uganda; CG= Congo Democratic; GH = Ghana; ML= Mali; NG = Niger; TG = Togo

Source: Authors

Considering the last available household survey, the countries in our study are classified according to the sign of the parameters beta and gamma. Although the years of the different surveys are not the same, it is still insightful to compare the shape of inequality as we believe that inequality structure does not change drastically in the very short term.

All the countries have a negative gamma. However, the coefficient Beta allows the classification of the countries in two groups. Cameroon, Ghana, Niger, and Ivory Coast (Group N) have a negative beta while Senegal, Uganda, Burkina Faso, Mali, Togo, and Congo (Group P) have a positive one. In the first group countries have an isograph in the form of an inverted U with the peak observed around the zero and those in the second group have isograph with a positive slope. A positive Beta reveals more inequality at the top of the income distribution than at the median. The country typology reveals that despite being on the same continent and having similar economic structure, there are significant variations across countries in the structure of the inequality. Senegal and Togo have the highest inequality at the median of the distribution, Ghana and Ivory Coast have the highest inequality among the poor households, while Burkina Faso and Mali tend to have the highest level of inequality whenconsidering the richest households.

4.2 Dynamic inequalities for selected countries

A description of the temporal variation of the shape of inequality for some countries(two countries selected from each group) would allow seeingin detail potential heterogeneity in the change of the

Table4: Parameter valuesfrom the ABG method

Countries	Year	Alpha	Beta	Gamma
Senegal	2011	0.5061	0.0035	-0.1243
		(0.0005)	(0.0022)	(0.0012)
Uganda	2005	0.4289	0.0421	-0.0921
		0.0001)	(0.0003)	(0.0004)
Burkina Faso	2009	0.4401	0.0436	-0.1068
		(0.0001)	(0.0004)	(0.0003)
Cameroon	2007	0.4967	-0.0517	-0.1290
		(0.0002)	(0.0005)	(0.0009)
Ghana	2006	0.4946	-0.0372	-0.0564
		(0.0001)	(0.0006)	(0.0003)
Mali	2006	0.4306	0.0827	-0.0769
		(0.0003)	(0.0011)	(0.0007)
Niger	2005	0.3913	-0.0322	-0.0523
		(0.0002)	(0.0006)	(0.0005)
Togo	2006	0.5101	0.0063	-0.1523
		(0.0002)	(0.0008)	(0.0005)
Ivory Coast	2008	0.4921	-0.0520	-0.0564
		(0.0001)	(0.0005)	(0.0003)
Congo	2005	0.4399	0.0347	-0.0283
		(0.0003)	(0.0008)	(0.0009)

Note: Standard errors in parentheses.

Source: Authors

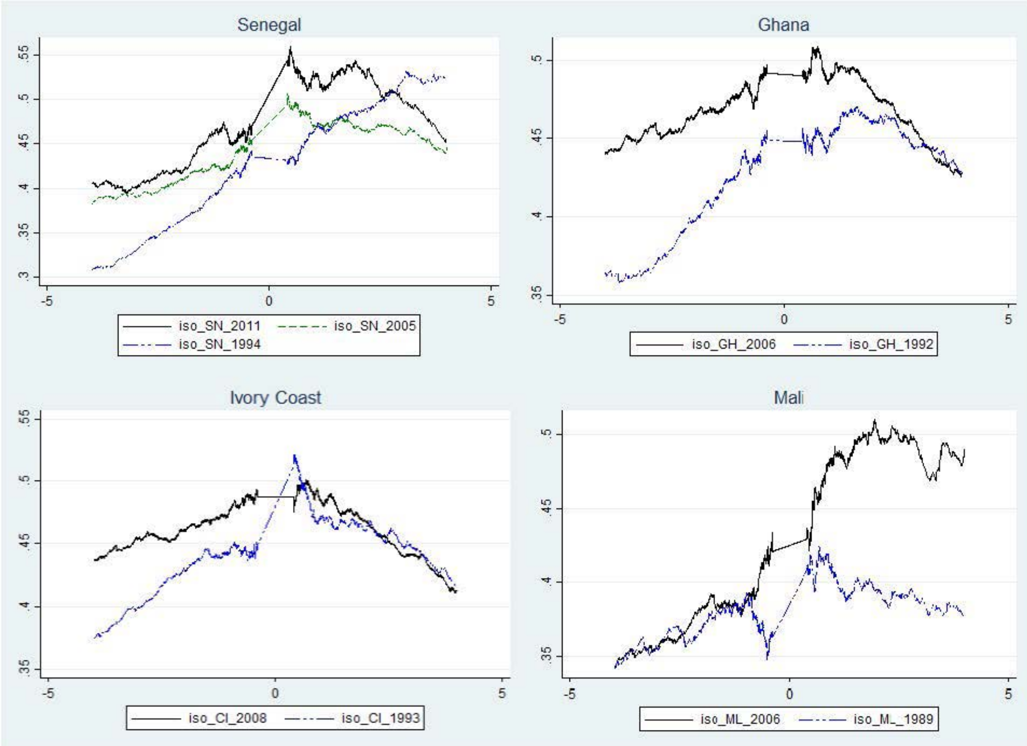
Table5: Classification of the countries following the shape of their isograph

	Beta Negative	**Beta Positive**
Gamma negative	***Group N*** Cameroon Ghana Niger Ivory Cost	**Group P** Senegal Uganda Burkina Faso Mali Togo Congo

Source: Authors

structure of inequality between the two last decades. The figure 3 shows the change and the persistent problem of inequality along the income scale over the years for the selected countries. The shape of inequality has changed less in Ivory Coast between the 1990's and the 2000's. In Senegal the inequality has increased over the years at the lower and middle level of income while the isograph decrease at the top. Senegal has observed a change in its shape of inequality that appears to be increasing throughout the mid-nighties and started charting an inverted U shaped type in the mid-twenties. Ghana and Mali show opposite patterns with either an observed widening or compression of inequality at the ends of the distribution over the years. Income inequality in Ghana has substantially increased at the low level of the income and has not changed much at the top while in Mali only inequality at the upper tail has

Figure 3: Dynamic of inequality



Source: Authors

changed drastically. Therefore, in Mali the increase of overall inequality is due to the diverging effect at the upper tail from the 1900's to the 2000's while in Ghana it comes from the diverging effect at the lower tail between the two periods. The differences of the inequality structures indicate that there should be no blueprints of the development policies' looking at the issue of inequality in Africa, each country deserves to be treated separately.

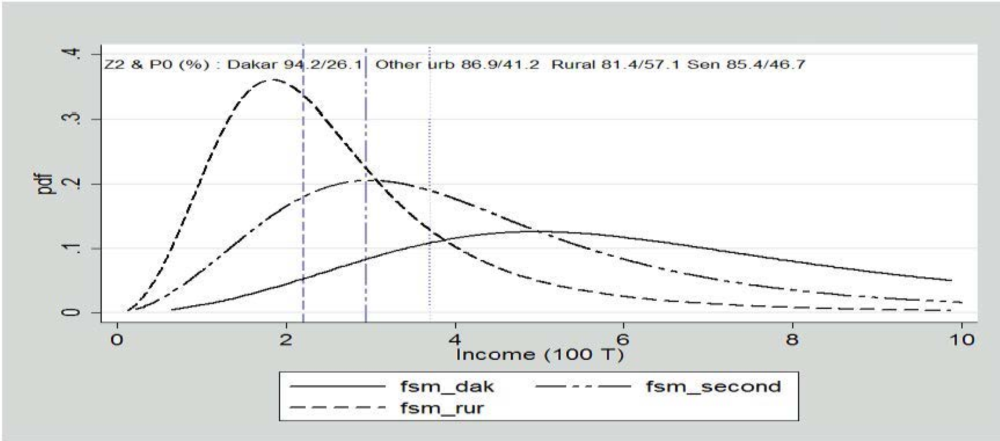
4.3 The engines for poverty and inequality reduction: Application to Senegal

A prominent debate is to identify the sectors and corresponding growth profiles that have the potential to be panaceas for both poverty reduction and income inequalities. This question is discussed in what follows by using Senegal as a case study country. The analysis will be extended to cover other countries in our future research, as there are no universal policy prescriptions and because of idiosyncratic characteristics of the growth-poverty-inequality linkage in each country. Moreover, the previous section has shown significant differences in the structure of inequality between African countries showing potential limitations of cross-countries studies analyzing the issue of inequality in Africa. The evidence from this analysis has the potential to contribute to development policy making and designing an optimal policy strategy in order to realize development targets in terms of poverty alleviation and inclusive growth. Using the quasi-dynamic CGE modeling framework linked to the ABG method, we simulate an additional slight growth of the GDP from the baseline (Business As Usual – BAU) value of 3.7 % to 4% through different scenarios where we assume that this additional growth is led by a specific sector. The size of the simulation here is not crucial as different shifts will generate the same mechanisms in the economy.

The figure 4 shows the initial income distribution in 2011 in Senegal assuming that the income generating process follows a Singh-Maddala distribution. The latter is a generalized Pareto distribution and is considered as providing a better fit for income distribution than distributions like Gamma or Log-normal (Singh and Maddala, 1976; Mac Donald and Ransom, 1979). Poverty headcount is estimated at 46.7% at the national level and is heterogeneous across locations with a widespread rural poverty (57.1%). The capital Dakar shows highest income variance compared to the rural areas and other urban locations. In the rural areas, poverty is not a marginal phenomenon as poor individuals are clustered around the poverty line. This indicates a difficulty in promoting policies that try to directly identify and target these poor individuals due to the concentration of individuals around the poverty line. There are many non-poor individuals that are closer to the poverty line as well as many poor individuals are not severely affected by poverty. These two groups might have the same characteristics.

The impact on poverty and inequality in each sector-led growth depends on the income and price effects. For each household, the significant part of the change in income can be expressed as a weighted sum of the factor earning from different sources. The importance of the direct income effect on poverty and inequality changes for a given household type following a production shift in each single sector *f*, will depend on the propensity of the sector to use a given factor *f* and on the share of this factor income

Figure 4: Income distribution across strata in 2011

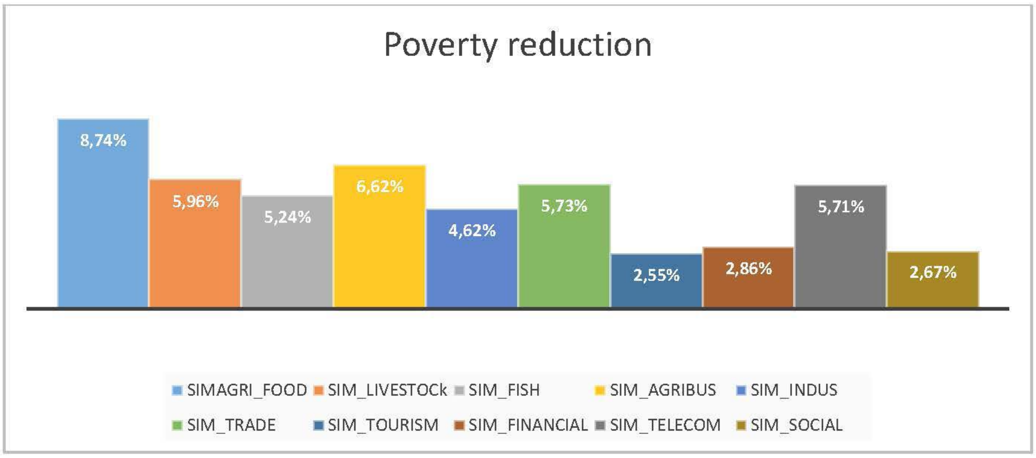


Note: Z2 = 100 − P_1 measures the intensity of poverty reduction.dak = Dakar; rur = rural areas; second = other urban centers.

Source: Authors

distributed to the household. The importance of the price effect for the households depends on the weight of the good that is produced by the sector driving growth in the composition of the household consumption basket. Furthermore, poverty and inequality tend to decrease more if the experienced growth is inclusive and associated with an equitable income distribution in the population. In addition to these effects that are directly related to the sector that is assumed to be affected by growth generated through sectoral productivity improvement, we have indirect effects that will determine the final size of the changes. These indirect effects depend on both production and consumption linkages between the targeted sector and the rest of the economy. A sector with important backward and forward linkage might have larger spillover effects.Agriculture-led growth has the largest impact on poverty with 8.74% reduction of the poverty rate in 2020 compared to its initial level. Agribusiness and Livestock follow with (respectively) poverty change of 6.62% and 5.96%. However, simulations where growth is led by non-agricultural sectors show also significant impacts on poverty reduction, especially for trade and telecommunication.

Figure 5: Change in poverty across the sector specific led growth$(P_{0\,2020}^{SIM} - P_{0\,2011})/\,P_{0\,2011}$



Source: Authors

Likewise, the evolution of the inequality in 2020 is displayed in Figure A1 in the appendix. Inequality achieved in 2020 and resulting from each sector-led growth can be compared to the initial inequality level. Figure A1 shows that agriculture-led growth (green line) generate the highest reduction of the inequality level compared to the case where growth is led by non-agricultural sectors. While some non-agricultural sectors might increase the level of inequality. The observed poverty reduction effects of the different sources of growth are partly related to the resulting income distribution. Figure 6 summarizes quantitatively the results by giving the change in the inequality level in the median, upper tail and bottom side of the income distribution. For the different simulations (SIM), the reduction of inequality along the income scale is calculated as follows:

- Reduction of inequality at the median: $(alpha\ _{2020}^{SIM} - alpha\ _{2011})/\ alpha\ _{2011}$
- Reduction of inequality at the top: $[(alpha + beta)\ _{2020}^{SIM} - (alpha + beta)_{2011}]/ (alpha\ + beta)\ _{2011}$
- Reduction of inequality at the bottom: $[(alpha + gamma)\ _{2020}^{SIM} - (alpha + gamma2011]/\ (alpha+gamma)\ 2011$

Considering inequality at the median, only growth led by the primary sector (namely Agriculture, Livestock, Fish), Agribusiness and Trade have reducing effects. Promoting growth profile led by these sectors can help to remedy inequalities instead of empowering relatively a certain class of individuals and impoverishing the weaker population. For the remaining sectors, the simulations show the potential trade-off between growth and inequality. Results also show that only agriculture and agribusiness tend to overcome inequality along all the income scale (median, upper tail and lower tail). The livestock, fishing sector, industry andfinancial sectorstend to reduce inequality at the top of the income distribution, but increase the one at the bottom while trade, tourism, telecommunication, and social services have the opposite effect by reducing inequality at the bottom and increasing the one among the richest households. The difference observed in inequality reduction between the growth profiles is due to the difference in income source between households and on the extent to which some sectors are linked to the household groups and to the poorest within each household group.

The simulations assume the same level of government payments to household compared to the baseline simulation. Therefore, the changes in household income will come from other sources. Household income is affected following the changes in wage and quantity of the different labor categories, on agricultural and non-agricultural capital, on land, the variation of intra-household transfers, and the

Table 6: Distribution of the household labor income across the labor categories (%)

Households	*Unskilled labor*	*Primary labor*	*Secondary labor*	*Tertiary labor*
Rural agricultural poor	70.1	9.8	5.8	14.3
Rural agricultural rich	76.4	5.2	2.7	15.8
Rural non-agricultural poor	50.0	17.2	4.8	28.0
Rural non-agricultural rich	55.2	7.6	6.1	31.1
Urban agricultural poor	45.7	15.5	4.8	34.0
Urban agricultural rich	41.8	14.4	3.3	40.5
Urban non-agricultural poor	25.5	19.4	12.7	42.3
Urban non-agricultural rich	13.6	11.6	16.4	58.4

Source: Authors

variation of transfer from the rest of the word. Wage and employment variation in the productive sector induces changes in the salaries of the workers associated with the concerned sectors and in turn change of household income. For example professionals are more represented in the urban non-agricultural households, while unskilled labor is predominant in the other household groups, especially for in rural and agricultural households (see Table 6). Secondary labor is the second more represented in the urban non-agricultural household. Thus, variation in the quantity and wage of this type of labor tends to have repercussions on the income of urban non-agricultural household compared to the other household groups andcompared to unskilled and primary labor.

For a better understanding of these linkages between sectors and households we compute an interdependence index through the different factors č These relationships help to understand the direct effects of sector-led growth scenarios. To take into account the heterogeneity with the agriculture sector, we consider the disaggregation into different crops which are further subdivided into 14 regions to cover heterogeneity in resource endowments, crop patterns, and farming activities.

$$Inter(h, s, f) = Inter(h, f).\ Inter(f, s)$$

Where $Inter(h, f) = \frac{YIF_{h\ f}}{\sum_{f\ \epsilon\ F} YIF_{h\ f}}$

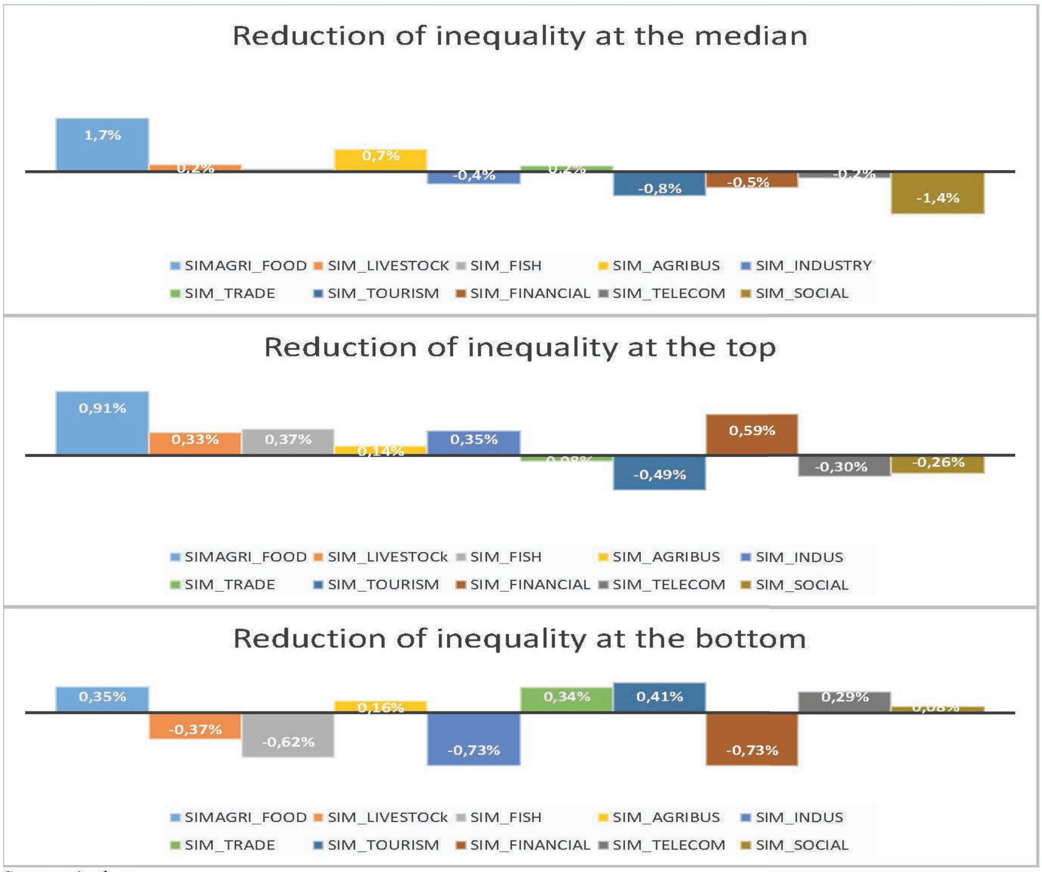
$Inter(h, f)$Indicates the extent to which the household groups are linked to the factors. This index evaluates the importance of the income from factor f in the total factor income of the householdh.

And $Inter(f, s)$=$\frac{WF_f \overline{WFDIST}_{f\ a} QF_{f\ a}}{\sum_{a\ \epsilon\ A} WF_f \overline{WFDIST}_{f\ a} QF_{f\ a}}$

$Inter(f, s)$considers the intensity of the sector in the use of f.

The calculated interdependence coefficients show the interdependence coefficients between households and sectors that occur through factors. In general, rural agricultural households are linked to agricultural sector and the degree of this relationship is higher for the poor households. Unskilled labor and agricultural capital are mainly at the base of this relation and allow the differentiation from the other sectors. Particularly through the capital factor, the rural and agricultural households are more linked to the fishing sector and through unskilled labor to the livestock sector. Rural and non-agricultural households are linked to the Agriculture sector through income from unskilled workers and slightly to services through professional labor and capital with a weaker linkage for the poor. Urban and non-agricultural households are more linked to the services mainly through professional workers and capital. This latter is more related to the richest than to the poor. The interdependence metrics also show that the non-agricultural and the richest households in urban areas are less linked to agriculture than the poor ones. In both urban and rural area rich households are more associated with land. Trade that is associated with transaction costs is linked to rural households and urban poor households, mainly through unskilled labor. For urban and rich households this occurs through professional labor and capital. These various linkages will determine the way growth profiles affect poverty reduction and inequality along the income scale. Growth in labor intensive sectors has more impact on poverty and inequality than growth in the capital intensive sectors. Results show that to reduce inequality along the income scale, future growth should be driven by Agriculture and Agribusiness. In addition, productivity growth in Staple crop and Livestock sub-sectors might lead to the highest impacts on poverty and

Figure 6: Reduction of inequality at the median, the top and the bottom



Source: Authors

inequality given theirrelative strong linkages with the poorest households, as shown by the calculated interdependence metrics.

Besides, we calculate a difference in difference indexes to see how the gap between inequalitie at the top (respectively inequality at the bottom) is reduced between the additional growtl scenarios and the initial situation. These differences are expressed as follows:

- Reduction in the difference between inequality at the top and inequality at the median:

$$(beta_{2020}^{SIM} - beta_{2011}) / beta_{2011}$$

- Reduction in the difference between inequality at the bottom and inequality at the mediar

$$(gamma_{2020}^{SIM} - gamma_{2011}) / gamma_{2011}$$

Agriculture is likely to create more homogenous and constant inequality profile along the income as agriculture-led growth close the gap between inequality at the top and bottom ends and the inequality

Figure 7: Reduction in the difference between inequality at the top (respectively at the bottom) and inequality at the median

Source: Author

level evaluated at the median. It is insightful to identify how the different growth profiles impact on inequality by controlling for all the scale of income. Effort to reach a specific level of targeted growth within formulated policy goals might be insufficient if they do not consider income asymmetries. The findings suggest that examining the level of growth and not its profile, and conducting analyses by using a single non-elastic measurement of inequality might be inappropriate when capturing the effect of growth on inequality. The majority of the results shows evidence that policies that aim to boost agricultural policies are the most egalitarian.

5. Conclusion

Africa's remarkable economic growth in recent years did not automatically translate into considerable welfare improvement andnegatively affected the equal distribution of wealth. This poor performanceleads inequality at the forefront of public debate.Yet there is still much to be learned about inequality in Africa and the complex relationship between growth-poverty-inequality. The paper uses a sample on Sub-African countries and show heterogeneity in the temporal change of the structure of inequality and in the shape with strong variations at the different level of the income scale. The use of the Alpha Beta Gamma method shows that there is a limitation to focus on the summary statistics. Policies that attempt to reduce inequality should not only lies on broad measurement indexes generally expressed at the median of the income distribution, but should also look atthe income distribution at the extremes. Based on the pattern of the isographs and structure of inequality we classify the countries in two different groups. Further, using Senegal as a case study the paper identifies Agriculture and Agribusiness-led growth as having reducing effect on poverty and on inequality along the income scale. Growth driven by these key sectors can make the majority of the people not be disconnected from income growth. As for Senegal, similar study will be conducted in other countries based on the same anisotropic concepts of inequality.

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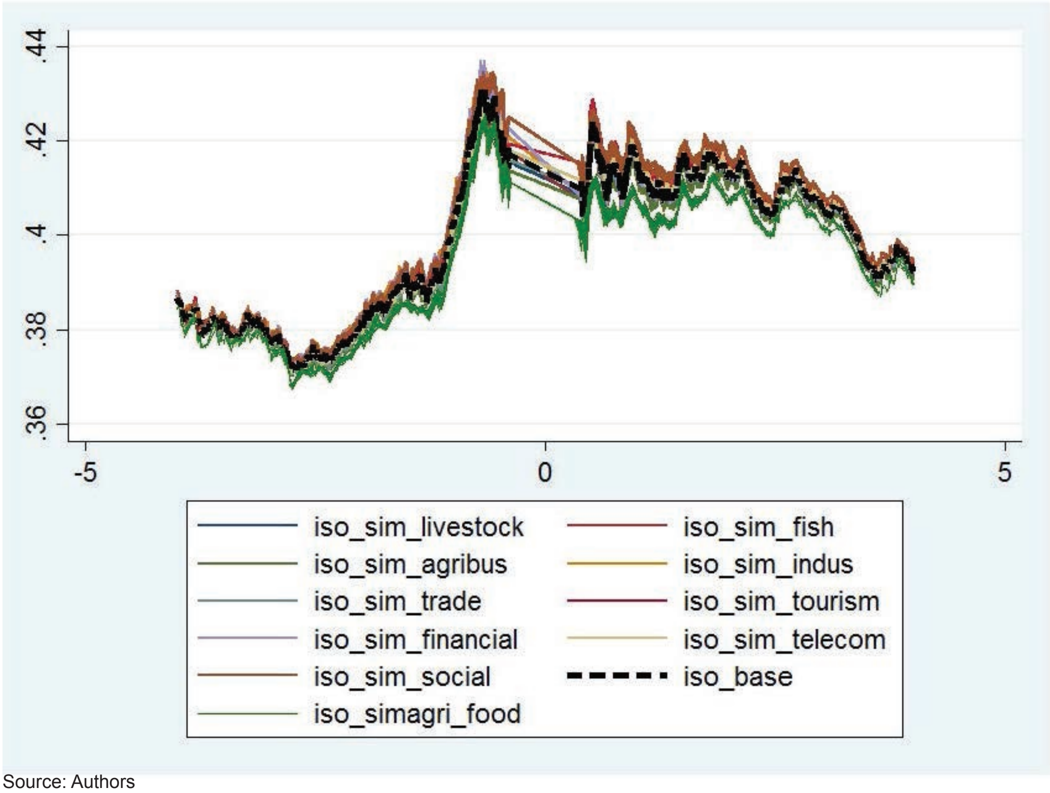
Figure A1 - Shift in the inequality level across growth scenarios



Source: Authors

A03

Land inheritance and youth employment and migration decisions: evidence from rural Ethiopia

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ABSTRACT

How does the amount of land youth expect to inherit affect their migration and em- ployment decisions? We explore this question in the context of rural Ethiopia using panel data from 2010 and 2014. We estimate a household fixed effects model and ex- ploit exogenous variation in the timing of land redistributions to overcome endogenous household decisions about how much land to bequeath to descendants. We find that larger expected land inheritances significantly lower the likelihood of long-distance permanent migration and of permanent migration to urban areas during this time. Inheriting more land is also associated with a significantly higher likelihood of em- ployment in agriculture and a lower likelihood of employment in the non-agricultural sector. Conversely, the decision to study is unaffected. These results are most heavily driven by males and by the older half of our youth sample. We also find that several mediating factors matter. Land inheritance plays a much more pronounced role in pre- dicting rural-to-urban permanent migration and non-agricultural sector employment in areas with less-vibrant land markets and in relatively remote areas (far from major urban centers). Overall, the results suggest that inheritance strongly influences the spatial location and strategic employment decisions of youth.

Keywords: Agriculture, employment, land inheritance, migration, youth

It's the youth bulge that stands to put greater pressure on the global economy, sow political unrest, spur mass migration and have profound consequences for everything from marriage to Internet access to the growth of cities (Sengupta, 2015).

PAPER

1. Introduction

How does the amount of land youth expect to inherit affect their migration and employ- ment decisions? In rural Africa, youth typically rely on inheritance (or on small land rental markets) to access parcels under usufruct land rights systems[1]. However, popula- tion pressures—including a youth bulge in many developing countries—are reducing land availability (Jayne et al., 2010; Muyanga and Jayne, 2014) and potentially opportunities for youth to work in agriculture. Further, as farms intensify agricultural production to overcome land constraints (Ali and Deininger, 2015; Barrett et al., 2010; Bellemare, 2013; Carletto et al., 2013; Headey et al., 2014; Larson et al., 2014; Sheahan and Barrett, 2014), labor saving technologies may consequentially substitute youth farm labor (Bustos et al.,

2016). Pessimistic views on inheritance prospects may push some youth to delay entering the labor force by seeking a secondary or tertiary education. Alternatively, youth may be en- couraged to transition from low-return agricultural to high-return non-agricultural activities (Bezu and Barrett, 2012; Nagler and Naude, 2014). Understanding how land inheritance size impacts youths' subsequent migration and employment decisions is thus critical for understanding the likely impacts of these artifacts of development.

Our main objective is to examine if perceptions of land inheritance prospects (as a proxy for individual land access) affect youth migration and employment decisions in the context of rural Ethiopia. We use a unique dataset on all descendants (children and other close relatives, living in or out of the home, who might stand to inherit land) of household heads and their spouses in 27 woredas (districts) of the Amhara and Oromia regions of Ethiopia.

Our analysis utilizes a measure of individual expected land inheritance based on detailed information provided by household heads on inheritances granted and expected to be granted to each of their descendants. As in Bezu and Holden (2014), we analyze multiple youth employment outcomes simultaneously (permanent migration, long-distance permanent migration, rural- to-urban permanent migration, agricultural employment, non-agricultural employment, and propensity to seek education)

[1] We adopt the World Bank definition of youth employment, encompassing individuals between ages 15 and 34 (Filmer et al., 2014).

to understand whether land constraints drive human capital investment and transitions into potentially high-return occupations. We consider how these relationships vary with gender and youth age. Lastly, we examine the role of mediating factors, to inform policy: the quality of land rental markets and travel time to a major urban center. Such factors may influence the costs of migration, opportunity costs, and barriers into non-agricultural labor.

One of the main empirical challenges confronting analysis of this question is the endo- geneity of individual land inheritance. The size of youth land inheritances is likely shaped by numerous factors unobservable to the econometrician yet correlated with individual labor activities. We estimate a household fixed effects model and appeal to historical land reforms in Ethiopia to develop an instrumental variable for expected individual land inheritance. Specifically, since the installation of Ethiopia's current government in 1991 following the col- lapse of the communist "Derg" dictatorship, 20 of our 27 sample woredas have experienced a large-scale land redistribution. Under such redistributions, the local government allocates land to households based on household size at the time (with particular attention to adult males), with variation over space and time. Using a complete list of descendants of the head and their spouse, provided by the head, and using kebele (or sub-district) official surveys to identify the most recent year of redistribution, we construct an instrumental variable for individual expected inheritance. This instrument is the share of an individual's male co-descendants that were at least 18 years old at the time of the redistribution, interacted with a dummy for having more than one male descendant immediately below one's self in the birth order. This interaction flexibly allows the impact of having a greater share of male descendants be over age 18 at the time of the redistribution to vary according to whether or not the head will face pressures to provide multiple male inheritances immediately after providing an inheritance to a given descendant. Allowing for this is important given that males in our dataset tend to receive larger inheritances than do females (about 60 percent larger, at the median)[2]. Any given youth has a greater likelihood of inheriting land if he has a higher proportion of his male co-descendants aged 18 or higher prior to the redistribution, but the impact should be especially large for youth faced with an acute threat to the size of their inheritance: multiple males immediately following them in the birth order. We show that this instrument is strong, and in a placebo analysis we demonstrate that its strength quickly deteriorates if we use any year other than the actual year of redistribution.

We find that larger expected land inheritances significantly lower the likelihood of long- distance permanent migration and of rural-to-urban permanent migration during this time, despite overall null impacts on permanent migration. Inheriting more land does not signif- icantly reduce permanent migration, but it leads permanent migrants to form households nearby rather than in other districts or urban areas. Inheriting more land is also associated with a significantly higher likelihood of employment in agriculture and a lower likelihood of employment in the non-agricultural sector. Conversely, the decision to study is not robustly impacted by one's expected land inheritance.

These effects are largely driven by men; inheriting more land does not significantly im- pact the migration of women. Further, while inheriting more land predicts significantly greater employment in agriculture and lower employment in the non-agricultural sector for men, the impacts are significantly smaller in magnitude and—in the case of non-agricultural employment—statistically insignificant for women. Impacts on long-distance permanent mi- gration and employment in the non-agricultural sector are also significantly larger for youth aged 20–34 (above median for the sample) than for those in the 15–19 age range, reflecting that it is somewhat older youth whose migration and employment decisions are most heavily influenced by the size of their land inheritance. This may be driven by older youth being closer to the time of inheritance, or, for men in particular, closer to the timing of establishing financial independence and marital arrangements (Honwana, 2012). Land inheritance plays a much more pronounced role in predicting rural-to-urban permanent migration and non- agricultural sector employment in areas with less-vibrant land markets than in areas with more vibrant markets. Similarly, it is in relatively remote places (far from a major urban center) that the amount of land inheritance is most important for migration and employment decisions. This suggests the importance of context in studying the effects of inheritance.

Overall, the results suggest that inheritance strongly influences the spatial location and strategic employment decisions of youth. Youth have a strong tendency to remain in the agricultural sector if given the opportunity to access land, and they pursue non-agricultural labor opportunities in large part as a response to land shortages.

The paper is organized as follows. Section 2 presents our overarching conceptual frame- work, reviewing existing literature and the knowledge gaps that our paper seeks to address. Section 3 outlines access to land in Ethiopia, the norms that governance inheritance of land in Ethiopia, and the current state—and related drivers—of migration and youth employ- ment in rural Ethiopia. Section 4 outlines our primary data source and how we measure inheritance, migration, and employment outcomes. Section 5 outlines our empirical strategy, including our main econometric specification and identification strategy. Section 6 presents our main results as well as result by gender, age, depth of

[2] This is despite legal provisions in our study regions stating that women have equal rights as men to access, use, and manage land (ANRS, 2006, 2007; ONRS, 2007).

land rental markets, and proximity to a major urban center. Finally, Section 7 concludes.

2. Conceptual Framework

There are two formative complementary or substitutionary relationships between factor in- puts (labor, land capital, and non-land capital) in agricultural production that influence the demand for youth labor. The first is the complementarity between land and family labor.

These relationships can be quite complex in sub-Saharan Africa (SSA), depending on land and labor constraints (Headey et al., 2014). Consider the case where land is constrained as in Ethiopia, but labor and land are perfect complements. If the household has excess labor, then the demand for youth farm employment will be relatively low. However, the relationship between labor and non-land capital is another integral determinant of labor demand in this case. The adoption of labor-intensive technologies would shift upward the demand for youth labor. This is what one might expect to occur in SSA, given smallholder farmers' intensification of fertilizer use, high yield varieties, and other input-intensive prac- tices to increase production (Barrett et al., 2010; Headey et al., 2014; Headey and Jayne, 2014; Larson et al., 2014; Muyanga and Jayne, 2014; Sheahan and Barrett, 2014). Else- where, farmers have shifted their adoption toward labor saving technologies, causing an exodus of labor from the agricultural sector (Bustos et al., 2016).

Of course, the presence of local non-agricultural employment and income opportuni- ties may draw youth out of agriculture (de Brauw and Mueller, 2012). Opportunity costs of working on the family farm put pressure on youth employment decisions. Recent work suggests the opportunity costs posed by the agricultural wage (Dillon and Barrett, 2014) and non-agricultural self-employment sectors may be low (Bezu and Barrett, 2012; Nagler and Naude, 2014), the latter being driven by high barriers to youth starting their own non-agricultural enterprises. Thus, among households with rudimentary production technologies or excess labor, youth may be pushed to take advantage of the monetary re- turns to migration, traveling to destinations with higher wages (de Brauw et al., 2013a).

Existing literature has not come to firm conclusions about the impacts of land access on subsequent youth migration and employment decisions. An important recent study links individual access to land with youth aspirations of exiting the agricultural sector in southern Ethiopia (Bezu and Holden, 2014). The authors find robust negative relationships between farm size per child and off-farm employment, with weaker evidence on migration. But esti- mated effects of land access on migration and off-farm employment may be attenuated by at least two factors. First, using the ratio between farm size and children of the household head may result in a biased measure of individual inheritance. Eligible candidates for inherited land include migrant children of the head and spouse, as well as extended family members (Holden and Bezabih, 2008). Second, even a measure of lagged household farm size may fail to account for land transfers that occurred prior to the initial interview. If an individual's expectation of additional land inheritance in the future is negatively correlated with what they received prior to the initial interview, and pre-initial interview transfers increase migra- tion and non-agricultural employment, then estimates of the impacts of expected individual inheritance in the future on migration and employment may be downward biased. This mo- tivates our analysis of the impacts of land access that takes into account the full history of descendants of the household head or their spouse—regardless of whether or not they still live at home—and which further takes into account all inheritances already granted as well as those expected to be granted in the future.

We also account for how recent developments in migrant labor and land rental markets might influence youth employment-land relationships. First, we examine how expected land inheritance differentially predicts employment decisions depending on whether the individual is in close proximity of a major urban center. The expected returns to migrant labor will be higher if moving costs are lower—either due to proximity or due to knowledge of the local language increasing the probability of securing employment at destination (Sjaastad, 1962). Yet, the wage gap between one's origin and destination may be much smaller in areas close to cities, reducing youth migration (Harris and Todaro, 1970). A less pronounced inverse relationship between access to land and youth migration (push factor) may thus be observed in areas closer to towns due to these countervailing effects. This is an empirical question meriting analysis. Second, we consider whether the presence of more robust local land rental markets reduces youth tendencies to migrate or work in the non-agricultural sector. Local rental markets provide youth opportunities to establish their own farms outside of inheritance. For this reason, youth are one of the most prominent groups engaging in these markets in SSA (Deininger et al., 2015). In areas with robust rental markets, youth migration and employment decisions may be less responsive to expectations on inherited land. Although rental markets provide youth access to land, we do not expect the presence of rental markets to perfectly offset responses we might observe between expected land inheritance and employment; there is likely a premium to having ownership or longer-term usage rights to the land youth cultivate. This premium may be due in part to inheritance conferring more secure property rights than does rental.

3. Background and Context

3.1 Access to land in Ethiopia

Ethiopia has long faced severe problems of land scarcity. Population density is growing rapidly, leading average household farm sizes to dwindle. In 2011–12, more than half of the rural farm households in Ethiopia cultivated less than one hectare of land (CSA, 2012). Further, a youth bulge in Africa[3] promises to intensify these problems for youth in partic- ular (CSA, 2015). In such land-constrained countries under usufruct land rights systems, like Ethiopia, youth rely on periodic land redistributions, inheritance, and/or small rental markets for any access to land.

The communist "Derg" dictatorship ruled Ethiopia from 1974–1987; land was formally owned by the government, which aimed to maintain social equity by ensuring at least some degree of equality in household access to land. The current regime has been in place since 1991, following the collapse of the Derg dictatorship. Land continues to be formally owned by the government, with formal land markets (sales) outlawed. However, several land redis- tributions have occurred since 1991, usually based on household size at the time (with extra weight placed on adult males). In our study regions of Amhara and Oromia, 20 of our 27 sample woredas experienced such a land redistribution, though there is substantial variation in the timing of the redistributions, as shown in Table 1[4]. The median year of redistribution is 2003, but these range in time from 1992 to 2013. Post-Derg era land redistributions have mostly involved land which had been previously utilized by state farms (Bruce et al., 1994)[5].

Individual land users in our study regions have the legal right to transfer their land use rights to their children or other family members (ANRS, 2006, 2007; ONRS, 2007). Individuals also have the right to rent their land use rights to any person—with some region- specific restrictions on size and duration of the land transactions[6]. Land inheritances in Ethiopia are not uniform across descendants of the head—both due to cultural factors like norms associated with gender and age and due to restrictions on land fragmentation[7].

3.2 Norms of Inheritance

Although statutory land tenure and inheritance laws in Ethiopia allow all rural citizens wishing to engage in agriculture to access land, customary norms and practices tend to favor men (Fafchamps and Quisumbing, 2005)[8]. First, marriage is primarily patrilocal whereby the wife resides with or near the husband's parents. Second, sons (especially the first born) traditionally care for their parents in old age (Kumar and Quisumbing, 2012). Finally, cus- tomary beliefs limit the type of agricultural labor in which females can engage (plowing, sowing seeds and threshing are exclusively male activities), necessitating male labor partici- pation on any plot.

Existing research has explored sibling competition and its effects on parental and youth decision-making in a variety of contexts[9]. Fafchamps and Quisumbing (2005) suggest that a groom's number of brothers (but not sisters) has a strong negative effect on land inheritance at marriage. Gibson and Gurmu (2011) find that having a greater number of elder brothers decreases a sibling's agricultural productivity (younger male siblings receive less productive land) and diminishes marriage opportunities (via less assets brought to the marriage).

Finally, previous research contends that not only older brothers, but also younger sib- lings may affect a youth's decision to seek an alternative livelihood outside of agriculture. Gibson and Gurmu (2012) analyzed sibling out-migration in a district of Ethiopia close to the capital of Addis Ababa (in Oromia region) and found that the birth of a younger sibling doubled the odds of out-migration over time. The primary reason for migration was to seek high school education or non-agricultural employment opportunities.

3.3 Migration and employment in rural Ethiopia

Recent analysis of migration in Ethiopia suggests that migrants are predominantly 'pushed' from their homes rather than attracted by an urban 'pull' of higher returns on human capital investments. For example, the Ethiopian Urban Migration Study (World Bank, 2010) reports that more than 42 percent

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[3] As of 2015, 37 percent of the population of Ethiopia was between the ages of 15 and 34 (CSA, 2015).

[4] In the survey, we asked about the latest redistribution so as to ensure that respondents recall the period of redistribution post-Derg dictatorship.

[5] While communal grazing land and woodland continues to be distributed to new claimants as need arises, such reallocations are not nearly at the scale of the land redistributions that occurred during the post-Derg era (Demeke, 1999).

[6] For example, while the restrictions are more relaxed in Amhara, the Oromia land proclamation decrees that individuals have the right to rent out only up to half of their total land holding, limiting the duration of the land rental to a maximum of 3 years for those who employ traditional farming and 15 years for modern/mechanized farming (ONRS, 2007).

[7] Farm fragmentation is a key challenge in Ethiopia—partly induced by intra-household land transfers over the last 20–25 years. In response, many regions (including our study regions) have introduced restrictive regulations regarding the size of a plot. Oromia land law sets a floor size per plot of 0.5 hectares for annual crops and 0.25 hectares for perennial crops (ONRS, 2007), while the minimum plot size in Amhara is 0.25 and 0.11 hectares for plots under rain-fed agriculture and irrigation, respectively (ANRS, 2006, 2007).

[8] For further discussion of customary law and inheritance, see North (1990), Fafchamps and Quisumbing (2002), and Mekonnen and Worku (2011).

[9] See, for example, research on sibling composition and rivalry on: health outcomes (Kumar and Quisumbing, 2012; Mekonnen and Worku, 2011; Kushnick, 2010; Garg and Morduch, 1998; Morduch, 2000), education outcomes (Congdon Fors et al., 2015; Gibson and Sear, 2010; Lloyd et al., 2009; Butcher and Case, 1994), and inheritable wealth (Grawe, 2010; Keister, 2003).

of migrants stated that they would not have migrated if they would have been able to make a living in their original home. Zeleke et al. (2008) reports that young men are the most likely to migrate in Amhara region and respondents cite a lack of sufficient means of subsistence, shortage of land, and shortage of employment opportunities in the rural areas as primary reasons for migrating. Likewise, Dorosh et al. (2012) find that households with less agricultural land were more likely to send out migrants, as were poorer households and households afflicted by a community-wide drought shock. Similar relationships between migration and land are reported in de Brauw (2014) and Lee and Mueller (2016).

According to the National Labor Force Survey in 2013 (NLFS), rural-rural and rural- urban migration shares are almost equivalent at 35 and 33 percent respectively of total migrants (authors' calculations using NLFS, 2013). Of course, there is substantial regional variation in these numbers, with greater rural-rural migration in Amhara, Oromiya and SNNP regions than in Tigray, for example[10].

Although migration in Ethiopia occurs for a variety of reasons (education, risk insurance, employment diversification), research on non-agricultural labor activities suggests that there are few opportunities for rural laborers to obtain employment outside of agriculture. Among rural-urban migrants aged 15–65, only 35.5 percent are motivated to migrate in search of work (Mueller et al., 2015). Education is the strongest determinant of rural-urban migration (de Brauw et al., 2013b; Mueller et al., 2015), following large national education investments during the last decade of about 4 percent of GDP (World Bank, 2016).

Schmidt and Bekele (2016) use the NLFS 2013 to show that only 23 percent of the economically active population identifies their primary occupation as being in the non- agricultural sector. Among non-agricultural sector workers, the largest share (30 percent) is engaged in sales work, of which street vendors and local market sales comprise 42 percent. Informal alcohol vendors make up another 20 percent of sales work, while formal shopkeepers comprise 22 percent. The majority of the remaining non-agricultural laborers are divided among construction and mining (11 percent), food processing and craftwork (8 percent), teaching (6 percent), and a variety of other jobs such as refuse and personal service work- ers. These are by and large low-skilled occupations with limited labor demand, possibly explaining why youth are often pushed rather than pulled into them.

Both employment diversification (via non-agricultural employment and/or migration) and the pursuit of educational opportunities represent potential strategies of risk diversifica- tion. A variety of factors including sibling competition for inheritable assets like agricultural plots, agricultural shocks (e.g., droughts or floods), and declining agricultural productivity may lead youth to pursue these strategies. Given that agricultural land in Ethiopia is predominantly accessed via inheritance or share-cropping[11], we hypothesize that access to land (via inheritance) affects youth decisions to stay in agriculture or seek other livelihood opportunities. We explore this hypothesis using a unique panel dataset that collects data over a variety of agro-ecological zones and farming systems.

4. Data

Ethiopia provides an ideal environment in which to examine how access to land affects individuals' decisions to diversify out of agriculture for several reasons. First, it is a pri- marily agrarian economy where land is accordingly central to livelihoods—as in much of the developing world. Second, geographic and topographic characteristics, as well as farm- ing systems and the value of farming, differ significantly over short distances—providing useful variation in our explanatory variables. Finally, land tenure policies and inheritance customs, described in Section 3, provide a natural experiment for understanding the effects of sibling (and co-descendant) configuration on land inheritance perceptions and ultimately employment diversification choices.

We take advantage of a panel survey conducted in 2010 (round 1) and 2014 (round 2)[12]. Round 2 was purposefully designed to address the research questions outlined above; it collects detailed information on not only household members (that live in the household and comprise the household roster), but also direct descendants of the household head or their spouse that are non-resident. This permits us to analyze the expected inheritances as well as the migration and employment decisions of all descendants.

The round 1 survey encompassed 1,810 households and was completed in July 2010 in order to evaluate the impact of the Sustainable Land Management Program (SLMP) in Amhara and Oromia regions. The sample was drawn from a list of kebeles (sub-districts) within the Blue Nile Basin in Amhara and Oromia[13]. The final sample consisted of 27 kebeles located in 9 woredas, with approximately 200

[10] de Brauw and Mueller (2012) also note differences in regional migration trends, findings that greater land transferability is associated with decreased migration.

[11] Although sharecropping provides access to agricultural land, tenuous contracts require sharecroppers to continuously change contracts and work different agricultural plots (see Deininger et al. (2003, 2011)).

[12] Both rounds were conducted by the International Food Policy Research Institute (IFPRI) in collaboration with the Ethiopian Development Research Institute (EDRI).

[13] Based on the list of SLMP kebeles in Amhara and Oromia, a random sample of woredas (districts) were selected whereby a woreda must contain one SLMP kebele.

households surveyed per woreda[14]. In round 2, 1,748 of the households interviewed in round 1 were located and interviewed again, representing a household attrition rate of 3.4 percent over 4 years.

Our analysis uses a cross-sectional dataset. We include in our estimation sample all direct descendants of the household head[15] or their spouse who lived in the household in round 1. Our dataset records whether or not they left the household (permanently migrated) by round 2, and their sector of employment in round 2. We describe our specific measures in Section 4.1. Our controls are from round 1 to reduce concerns of reverse causality.

4.1 Variable Measurement

We measure youths' expected land inheritance by asking heads about each of their direct descendants: how much land they have already received[16] and how much land they expect to provide in the future. Summing the two gives the total expected inheritance. This is a meaningful quantity as heads are generally the prime decision-maker over inheritances. In the text, we refer to individuals' expected land inheritance; in all cases this should be understood as the sum of what they have inherited and what the head expects to provide.

We measure migration in three ways. First, we code a dummy variable for permanent migration that takes on a value of 1 for any youth who was a household member in 2010 but is no longer a household member by 2014. For this definition of permanent migration, individuals may have migrated anywhere in Ethiopia or elsewhere. However, they cannot simply be temporarily absent; they must no longer be considered a household member. Second, we code a dummy variable for long-distance permanent migration, which takes on a value of 1 provided that the individual permanently migrated since 2010 and by 2014 lives outside of the woreda (district) in which they resided in 2010. Finally, we code a dummy variable for permanent migration to an urban area, which takes on a value of 1 provided that the individual permanently migrated since 2010 and by 2014 lives in an urban area.

We are predominately interested in whether individuals work in the agricultural or in the non-agricultural sector. We accordingly consider two employment outcomes: agriculture is the individual's primary occupation, and the non-agricultural sector is the individual's primary occupation. We further examine whether or not the individual is currently studying as their primary occupation—indicating the choice to acquire human capital[17].

4.2 Descriptive statistics

Table 2 summarizes the outcomes, land access measures, and individual and household characteristics for the full sample as well as for the sub-sample of those who expect to inherit land (71 percent of the full sample). We focus most of the analysis on those who expect to inherit land; this encompasses the vast majority of all individuals, and is also the estimation sample driving our slope coefficients when we consider the logged value of land inheritance as our key explanatory variable. We apply a natural logarithmic transformation to reduce the tendency for extreme outliers to drive inferences in our regression analysis.

Panel A summarizes the outcomes of interest. Nearly half of individuals (45 percent) permanently migrated between survey rounds. Of those permanent migrations, nearly half were to locations outside of the woreda in which they lived in 2010 and 62 percent were to an urban area[18][19]. The primary occupation is most often in agriculture (37 percent) or in school (29 percent); but 16 percent work in the non-agricultural sector and 13 percent do domestic work. Only 4 percent of the sample reports being unemployed. The average individual expects to inherit 0.34 hectares of land (Panel B).

Panel C shows that the sample is tilted towards males (67 percent). The descendants' average age in round 1 is about 20 years, most (98 percent) are children of the head[20], 68 percent have finished the first education cycle (grades 1-4), and few (5 percent) are married. A quarter of the descendants have more than one male descendant directly following them in birth order. On average, descendants have 1.4 older male descendants and 1.2 older female descendants; 17 percent were at least 18 years old at the time of the last land redistribution. Household characteristics[21] are summarized in Panel D. While about two-thirds of households have a metal roof, only 3 percent have an improved floor. The

[14] For more information on sample selection and site location, see Schmidt and Tadesse (2014).

[15] We use the round 2 household head since data on the complete list of descendants of the head and their spouse—as well as inheritance amounts—was completed in round 2.

[16] We ask how much land they have received from either the household or the peasant association (PA).

[17] There are two other possibilities for primary occupation: domestic employee and unemployed. These are summarized in Table 2, alongside our main employment outcomes of interest.

[18] These numbers come from the following calculations: 0.21/0.45 = 0.47 and 0.28/0.45 = 0.62. Note that moving out of woreda and moving to an urban area are not mutually exclusive.

[19] Our sample implies an annual out-of-woreda (district) migration rate of 5 percent. This is slightly larger than the rate computed using 2007 Census data, 1.1 percent (Mueller et al., 2015), perhaps due to the focus on youth who have greater rates of mobility (Lee and Mueller, 2016) and increasing migration trends.

[20] The sample is restricted to direct descendants of the head or their spouse, but this can include stepchildren or grandchildren (though it rarely does).

[21] Household characteristics are not included because they are collinear with household fixed effects.

household head was, on average, 53 years old, male (83 percent) and had no education (58 percent). 71 percent were Orthodox Christians and 25 percent were Protestant.

5. Empirical Strategy

We investigate the effect of land inheritance on youths' migration and sector of primary employment decisions. If all variation in youths' expected land inheritance were exogenous to employment and migration decisions, we could recover causal estimates of the impact of expected inheritance by estimating the following linear probability model:

$$E_i = \beta_0 + \beta_1 L_i + \gamma \mathbf{X}_i + \alpha_j + \epsilon_i \quad (1)$$

where i indexes individuals. We denote by E_i migration and employment outcomes, by L_i expected land inheritance, by $\mathbf{X}_i$ a vector of control variables, described below, and by α_j household fixed effects. Standard errors are clustered at the kebele level, the relevant administrative unit in which land redistribution policies are executed.

5.1 Identification

A concern of our analysis is that the anticipated amount of land inheritance is likely to be endogenous to migration, employment, and educational decisions. There are several possible sources of omitted variable bias likely to bias ordinary least squares (OLS) estimates of β_1.

First, in a model without household fixed effects, one would worry that a household's land endowment, wealth, and income levels would heavily influence both migration and employment decisions and expected inheritance. Migration is costly and requires the payment of up-front costs to finance it (Carrington et al., 1996). Further, employment in agriculture is more likely in a family with ample experience in this sector due to their own larger land en- dowments and knowledge (Bezu and Barrett, 2012). Indeed, this source of omitted variable bias is a compelling reason to include household fixed effects in all regressions; through their inclusion, our regression results use within-household variation in expected land inheritances to explain within-household variation in migration and sector of employment decisions.

Second, within a household, parents may select descendants with particular characteristics—such as a physical aptitude for, or a keen interest in, agriculture—for larger inheritances. This would be problematic for identification if such physical and mental traits also drive employment and migration decisions. Similarly, within a household, parents may prioritize children with good marriage prospects in the village (Fafchamps and Quisumbing, 2005). As such children face lower search costs in finding a partner, they may find higher- quality partners and marry at an earlier age, thus reducing the likelihood of long-distance and rural-to-urban permanent migration. Parents could also prioritize children most likely to help them in old age (Bernheim et al., 1985). Such children may be more or less likely to migrate or to work in agriculture; helpful children may be those who are helpful due to superior physical and mental endowments, but they may also be those who are helpful due to inferior endowments and thus greater willingness to stay behind and serve parents. As these different potential sources of omitted variable bias may skew OLS estimates in different directions, it is not possible to sign the direction of bias.

We address such sources of omitted variable bias in two main ways. First, we control for a number of factors that may influence the land allocations that youth receive and which are also likely to influence migration, employment, and educational opportunities and decisions. All of our specifications include household fixed effects to capture all characteristics of a community (kebele) and a household that may influence youths' decisions. These include the availability of land (community wide as well as within the household), laws and regulations, customs and traditions, the full history of community land redistribution, as well as access to agricultural and non-agricultural employment opportunities and educational institutions.

We additionally allow kebeles to have different impacts on individuals according to their gender, age, and marital status by including interactions of kebele fixed effects with a dummy for being male, with fixed effects for the descendant's age, and with a dummy for being married at baseline. This could capture the fact that, for example, different local governments may preferentially treat males, youth at critical stages such as those just reaching marriage- able age, or the married when redistributing land to individuals.

Our household fixed effects control for the total amount of land available to the house- hold. However, within households, there is a great deal of variation in expected inheritance across descendants. Some of this may be explained by a number of individual characteristics for which we control: being male, being the oldest male, age, marital status, whether the individual is a child of the head, whether they have completed the first cycle of primary school (grade 4), and whether they were themselves at least age 18 at the time of the last land redistribution. The set of older descendants a youth has is also likely to influence both the youth's decision-making and his access to land since older descendants are a) likely to inherit land and other assets before him and b) may provide information or support in identifying and obtaining employment or educational opportunities. Following Vogl (2013), we include fixed effects for the exact permutation of older descendants (mostly comprised of siblings, but also including a small number of grandchildren or step-children of the head) that the youth has above them in the birth order (e.g., no older descendants, Boy (B)-Girl (G)-Boy (B), GB, BG, BBBB, G, etc)[22]. We additionally control for having more than one male descendant immediately below (younger than) one's self in the birth order. Males in Ethiopia generally receive larger land inheritances than do females, and any individual's land inheritance tends to be smaller when they are immediately followed by multiple males.

Second, we implement an instrumental variables (IV) strategy. Specifically, we leverage a unique feature of Ethiopia: given its authoritarian regime, land access in Ethiopia is influ- enced by government efforts to redistribute land. There is significant geographic variation in such redistributions; the median year is 2003, but these range in time from 1992 to 2013[23].

Our in-depth interviews with kebele officials suggest that males over age 18 receive priority at the time of redistribution. This suggests that households with a greater share of their male descendants being over age 18 at the time of the most recent land redistribution should have relatively more land allocated to these descendants. While our fixed effects capture the average impacts of these redistributions (as well as their gender-, age-, and marital status- specific impacts), their impacts may vary in other ways within a household. Specifically, we would expect "marginal" individuals at high risk of receiving a small inheritance to benefit most from having a greater share of their male co-descendants be over age 18 at the time of the land redistribution. Our data reveal one such vulnerable group: those with more than one male descendant immediately below them in the birth order, for whom their household's head will very soon after them have two or more boys reaching the age of inheritance. In our dataset, the median male land inheritance (in terms of land area) is 60 percent greater than that of the median female. As such, brothers pose a larger threat to inheriting land.

We use a single interaction term as an instrumental variable for expected land inheritance: the share of male descendants in the household who were over age 18 at the time of the land redistribution interacted with a dummy for having more than one male descendant immediately follow them in birth order. As we have one excluded instrument (an interaction term) and one endogenous variable, our model is exactly identified. The instrumental variable is summarized in Table 2; its mean is 0.03.

Our first stage equation states that an individual's expected land inheritance, measured as L_i, is a function of the product of the share of male descendants in the household who were over age 18 at the time of the most recent land redistribution, r_i and a dummy for having more than one male descendant immediately follow one's self, m_i:

$$L_i = \delta_0 + \delta_1 r_i \times m_i + \delta_2 m_i + \theta \mathbf{X}_i + \pi_j + \eta_i \tag{2}$$

where π_j are household fixed effects.[24]

The validity of this instrument rests on a single identifying assumption: The difference in the effect of having a larger share of male descendants in the household be over age 18 at the time of land redistribution on those with versus without more than one male descendant immediately below them in birth order only affects migration and employment decisions through its effect on expected land inheritance. Importantly, the individual components of the excluded instrument, m_i and r_i, are included in our main specification of Equation 1 (the latter through our use of household fixed effects). That is, we explicitly allow both of them to directly impact our migration and employment outcomes. We do not claim that either of them only affects such outcomes through their effect on the size of an individual's inheritance. Thus, we need only believe that their interaction is a valid instrument—not that either of the two variables in level form is a valid instrument.

In Table 3, we show that this instrument satisfies the inclusion restriction: it is a strong predictor of the size of individual i's land inheritance. In our baseline specification with our full control set (column 2), a standard deviation (0.11 unit) increase in the excluded instrument makes one's land inheritance 1.3 times greater[25]. The F statistic on the excluded instrument is 26.6, suggesting no problems of

[22] As in Vogl (2013), with this control set, we anticipate that the gender of the next sibling after a descendant, conditional on having such a sibling, can be taken as if random.

[23] In 20 kebeles, a land redistribution occurred after 1991 (in the post-Derg regime era). In 7 kebeles, no such redistribution occurred. In those kebeles in which no redistribution occurred, we code that the share of descendants over 18 at the time of the most recent land redistribution was 0, to reflect that none of the descendants in the household helped the household obtain more land by virtue of their age.

[24] r_i does not appear in the regression in its level form as it is collinear with our household fixed effects.

[25] This comes from taking exp(2.478 × 0.11) = 1.3.

weak instruments[26]. We argue that the exclu- sion restriction holds since the precise timing of land redistributions in a community—and specifically, the difference between its effect on those with versus without multiple male descendants immediately below them in the birth order—should be exogenous to the within- household selection mechanism determining the size of individual land inheritances.

A potential concern with our IV strategy is that kebeles with relatively early (or late) land redistributions may simply be on different time trends with respect to how having younger brothers influences within-household allocations of land. If this were the case, then it might not be the land redistribution itself that explains the strength of our first stage, but rather just the order in which kebeles experienced such a redistribution (with that order potentially being endogenous to factors influencing youth employment and migration decisions)[27]. Our first stage would be just as strong if we were to instead pretend that each kebele's land redistribution occurred in year t + k rather than year t, for k E (−∞, ∞). We carry out this placebo analysis in Figure 1, for integer values of k E (−15, 15), plotting k on the x- axis and the F statistic on the excluded instrument in our main specification (column 2 of Table 3) on the y-axis. We see that the F Statistic is maximized when k = 0 (i.e. when we use for each kebele the actual year, t in which land redistribution occurred). Further, it quickly deteriorates as we move away from k = 0. Indeed, among the 30 years to which we try perturbing the actual year of redistribution, for 26 we obtain an F Statistic indicating problems of weak instruments[28][29]. Overall, these findings are encouraging; they suggest that it is the extra land being made available by redistributions, and not different trends across kebeles with early versus late redistributions, that is driving our strong first stage results.

6. Results

6.1 OLS Estimates

Table 4, Panel A provides ordinary least squares (OLS) results from regressions of permanent migration (columns 1–2), long-distance permanent migration (columns 3–4), and permanent migration to an urban area (columns 5–6) on a youth's logged amount of expected land in- heritance, in hectares. We present specifications with (even-numbered columns) and without (odd-numbered) our full control set; all specifications include household fixed effects.

In our preferred specification with our full set of controls, a 10 percent increase in a youth's land inheritance is associated with a 1.6 percentage point decrease in the incidence of permanent migration[30]. This represents a 3.0 percent decrease relative to the mean rate of permanent migration. Inheriting land is also associated with a lower incidence of long- distance permanent migration, and less permanent migration to urban areas in particular. These findings are present regardless of whether we include our full control set. A 10 per- cent increase in land inheritance is associated with a 2.4 percentage point decrease in the incidence of long-distance permanent migration, and a 2.7 percentage point decrease in the incidence of permanent migration to urban areas. Relative to the means of each of these outcome variables, these indicate an 8.9 percent and a 7.9 percent reduction in long-distance permanent and rural-to-urban permanent migration, respectively. This suggests that receiving a land inheritance is associated with less migration, but that the magnitude of its impacts are particularly large for long-distance and rural-to-urban migration.

Table 4, Panel B presents OLS results from regressions of one's primary sector of employ- ment being agriculture (columns 1–2), non-agriculture (columns 3–4), and being a student (columns 5–6) on a youth's logged amount of expected land inheritance, in hectares. The likelihood of one's primary sector of employment being agriculture is significantly larger for those who have inherited or expect to inherit land, regardless of whether we include our full control set. In our preferred specification with our full set of controls, increasing a youth's land inheritance by 10 percent is associated with a 2.5 percentage point increase in the incidence of one's primary sector of employment being agriculture, which is a 7.8 percent increase relative to the mean incidence of employment in agriculture. The amount of land inheritance is also correlated with a lower incidence of employment in the non-agricultural sector, although this effect is not statistically significant at conventional levels (p-value = 0.16). While land inheritance is negatively correlated with whether or not an individual's primary occupation is being a student, the correlation is not robust to the inclusion of our full control set[31].

[26] If we instead compute the excluded instrument using the share of total descendants that was over age 18 at the time of the land redistribution, rather than the share of male descendants, we obtain a slightly smaller F statistic of 26.2.

[27] Table 1 shows this order, with Tulugura kebele experiencing the first redistribution, followed by Fundisa and Arjo a year later, and Shemagile Giyorigis experiencing the latest land redistribution.

[28] In our main specification, the Stock-Yogo critical value for 10 percent maximal IV size for a Cragg-Donald F Statistic is 16.38.

[29] Further, the four other "sufficiently high" F Statistics occur at t − 5, t − 4, t − 3, and t − 2; this may be due to redistribution policies in some kebeles favoring not those over age 18, but rather those over age 23 (or age 22, or age 21, or age 20)—that is, youths slightly older than 18.

[30] Given our level–log model, here and elsewhere, the effect of a 10 percent increase in land inheritance is obtained by taking the coefficient on expected land inheritance × ln(1.1).

[31] We obtain similar results (available upon request)—for both our migration and employment outcomes—when we instead measure land access using a dummy for whether or not an individual has inherited or expects to inherit land.

6.2 IV Estimates

The OLS estimates presented thus far may fail to account for important, within-household variation in factors that influence both land inheritance as well as migration and employment decisions. To address this endogeneity problem, we next turn to IV estimates. Section 5.1 outlined our IV identification strategy and described our excluded instrument: the share of male descendants in the household who were over age 18 at the time of the most recent land redistribution interacted with a dummy for having more than one male descendant immediately follow one's self.

Table 5, Panel A compares our earlier OLS estimates of the impacts of the size of land inheritance on migration outcomes (columns 1–3) with IV estimates that account for the endogeneity of land inheritance to migration (columns 4–6). Compared to the OLS estimates, the IV estimates are larger—though, for the case of permanent migration to any area, the effect is no longer statistically significant. However, we still find strong impacts on long-distance permanent migration and rural-to-urban permanent migration. A 10 percent increase in a youth's land inheritance is associated with an 8.1 percentage point decrease in the incidence of long-distance permanent migration and a 4.8 percentage point decrease in the incidence of rural-to-urban permanent migration. Relative to the means of each of these outcome variables, these indicate a 30.0 percent, and a 14.1 percent reduction in long- distance permanent migration and rural-to-urban migration, respectively.

In Panel B of Table 5, we compare OLS estimates of the impacts of the size of land inheritance on employment outcomes (columns 1–3) with IV estimates (columns 4–6). The significant, positive impact of inheriting more land on employment in agriculture is now even larger in magnitude and more statistically significant; the IV results show that a 10 percent increase in expected land inheritance increases the incidence of employment in agriculture by 6.2 percentage points, which is a 19.4 percent increase relative to the mean incidence of employment in agriculture (significant at the 0.01 level). The impact of the amount of land inherited on employment in the non-agricultural sector is also larger in the IV results, and also significant at the 0.01 level; a 10 percent increase in land inherited leads to a 4.1 percentage point increase in employment in the non-agricultural sector, which is a 21.6 percent increase relative to the variable's mean. As in the OLS results, however, we find no impact of receiving a larger land inheritance on the probability of being a student. Inheriting land seems to powerfully impact one's sector of employment, but not one's choice of whether or not to study.

6.3 Impacts by Gender and Age

While we have thus far identified average impacts of the size of land inheritance on youth migration and employment outcomes, we have not examined how these impacts differ across youth with different characteristics. However, from a policy perspective, it is important to understand which individuals in our sample are most driving these results. Of special importance are the differential impacts on men versus women, and on youth at different ages— specifically, above versus below median for our sample, which involves separately considering 15–19 year olds and 20-34 year olds. Given cultural and social norms that often disfavor women in land inheritance (Fafchamps and Quisumbing, 2002) and in educational and employment opportunities (Croppenstedt et al., 2013), one might expect land inheritance to have a significantly different impact on young women than on their male co-descendants. In addition, a lack of financial independence can delay other social and political milestones in youths' lives (Honwana, 2012). Thus, the very young may not be poised to take large migration and employment decisions in response to an inheritance, while older youth may be at critical junctures in which land strongly influences decision-making.

Table 6, Panel A estimates a model in which we interact our full set of individual-level controls with gender; this allows us to compare how well land inheritance predicts migration and employment outcomes for men versus women, and to test for any statistically significant differences. Given problems of weak instruments for this interacted model, we estimate by OLS[32]. This is less of a concern given the consistent story—in terms of sign and statistical significance—told by our OLS and IV results for our key outcomes. Also, to the extent that the bias in our OLS estimates is uncorrelated with gender, the relative size of the coefficients on land inheritance for men versus for women is informative.

What is immediately apparent is that men are driving our results for migration. Land inheritance is not a significant predictor of permanent migration by women, but it predicts a significantly lower likelihood of long distance permanent migration and rural-to-urban permanent migration for men. Further, these differences are both significant at the 0.01 level. We also find that larger inheritances predict a greater likelihood of working in the agricultural sector for both genders, though this finding is statistically significantly larger in magnitude for men than it is for women. That is, increasing a man's inheritance increases his likelihood of working in agriculture more than it increases a woman's chances. While inheriting more land predicts a lower probability of working in the non-agricultural sector for both genders, this finding is only statistically significant for men. A small land inheritance may drive men

[32] Due to degrees of freedom considerations in these analyses by gender and youth age group, we estimate a slightly modified specification that uses gender, marital status, and age fixed effects instead of fixed effects for kebele × gender, kebele × marital status, and kebele × age fixed effects.

to the non-agricultural sector, but women do not take up these non-farm opportunities—possibly due to the above-hypothesized higher barriers to entry that they face. This difference between the findings for men and women is statistically significant at the 0.05 level. Finally, inheriting more land does not predict a higher probability of being a student for either gender.

In Panel B of Table 6, we estimate a model in which we interact our full set of individual- level controls with a dummy for being 20 years old or older—the median age in our sample, allowing us to compare how well land inheritance predicts migration and employment out- comes for each group. Once again, we estimate using OLS in response to problems of weak instruments. We see that our migration results are mostly driven by those aged 20–34 (older youth), as are reductions in employment in the non-agricultural sector. This is consistent with older youth being those most vulnerable to having decisions impacted by land inher- itance, while the relatively young are not yet taking major life decisions in response to an expected inheritance. However, land inheritance predicts similar increases in employment in agriculture for both groups. As for men and women individually, neither below-median nor above-median aged youth are more likely to be students as a result of inheriting more land. Overall, it seems that land inheritance does not matter much for whether or not one studies—either in the aggregate, or for a particular gender or age group. This is consistent with the overall low prioritization of education among rural households in Ethiopia relative to other countries (Dillon and Barrett, 2014).

6.4 Impacts by Rental Markets and Proximity to Urban Center

It is also critical to examine the role of mediating factors that may heavily influence youths' costs of migration, opportunity costs, and barriers to entry into non-farm labor. We consider two such mediating factors: the quality of land rental markets and travel time to a major urban center. We differentiate kebeles with relatively low land rental activity from those with relatively high land rental activity by examining if a kebele is below- or above-median in terms of the share of households renting out land. We distinguish kebeles that are relatively close and relatively far from a major urban center by again dividing our sample kebeles into those that are below- and above-median in terms of travel times, respectively. Following the Ethiopia Central Statistical Agency, we define major urban centers as all regional capitals plus any other cities with a population of 100,000 or more in 2007 (CSA, 2014). The 26 cities range in size from 20,824 to 3,156,057, and have a median population of 110,086; they are listed in Appendix Table A1. Once again, we estimate a model by OLS in which we interact our full set of individual-level controls with one of these two dummies—either a dummy for having below-median land rental market activity, or a dummy for having an above-median travel time to a major urban center[33].

As shown in Table 7, the size of land inheritance is a more powerful predictor of spatial and sectoral location decisions in areas with more vibrant land rental markets and those close to major urban centers. Where land rental market activity is low (below median), a reduction in one's land inheritance predicts a significantly greater tendency to migrate to an urban area and be employed in the non-agricultural sector than we see in areas with richer rental markets. Rental may be a viable alternative to inheritance, but where such markets are weak, youth not inheriting land will tend to migrate and enter the non-agricultural sector in higher numbers. This provides evidence of the partial substitutability of land access via inheritance versus land rental markets. Similarly, travel time to a major urban center matters as well; for those far away (above median travel time), a reduction in one's land inheritance is a significantly greater predictor of long-distance and rural-to-urban permanent migration, and of employment in the non-agricultural sector, then it is for those nearby. When an urban center is nearby, youth employment in the non-agricultural sector is largely unaffected by the size of land inheritance, and we see little impact on long-distance or rural-to-urban migration, reflecting greater off-farm employment opportunities close to home.

7. Discussion

We find strong relationships between expected land inheritance and youths' (ages 15–34) likelihoods of engaging in long-distance permanent migration, rural-to-urban permanent mi- gration, and non-agricultural sector employment in rural Ethiopia. Our empirical model— which exploits exogenous variation in the timing of land redistributions to overcome the endogeneity of the size of land inheritance—predicts that a 10 percent increase in inheri- tance size reduces rural-to-urban migration and employment in the non-agricultural sector by 4.8 and 4.1 percentage points, respectively. These findings are largely driven by the male and 20-34 year old sub-populations. The period of 20 to 34 years of age is crucial because it is the stage of the life cycle where individuals typically form new households. The fact that the employment decisions of older youth are most susceptible to expected land inheritance evokes a common trend, the African concept of waithood (Honwana, 2012), whereby older youth postpone major employment decisions until they attain financial independence.

We examine two prominent features of land and labor markets to measure the extent to which youth

[33] These regressions further include fixed effects for kebele × gender, kebele × marital status, and kebele × age fixed effects, as well as their interactions with one the two dummies (for rental market activity or for travel time to a major urban center).

employment decisions are constrained by land inheritance. First, we consider the role of access to land rental markets, which could provide an alternative to inherited land and facilitate youth self-employment in agriculture. The relationship between land inheritance and rural-urban migration appears to weaken, and that between land inheritance and non- agricultural employment is entirely eliminated, in areas of high rental market activity. This reaffirms the notion that push factors dominate pull factors in dictating migratory decisions in Ethiopia (World Bank, 2010). Our results highlight youth preferences to use migration or non-agricultural employment as a last resort after exhausting all means of access to land (such as temporary arrangements via land rental markets). It also supports the notion that rural inhabitants tend to diversify sectorally (Schmidt and Bekele, 2016), particularly in areas constrained by land availability, rather than exit agriculture altogether.

Second, we assess whether a reduction in either moving costs or search costs, captured by being closer to an urban area, mediates the effect expected inheritance has on employ-ment and relocation. There is no apparent relationship between land inheritance and either migration or non-agricultural sector employment in areas closest to urban areas (those with below-median travel times). The wage gap between rural and urban areas is likely negli- gible in such settings, disincentivizing migration. Moreover, employment in places close to urban areas is likely driven by labor demand. In contrast, in remote areas, youth are most likely pushed to diversify through non-agricultural sector employment or migration when subject to liquidity constraints, as under periods of income variability (Gray and Mueller, 2012) or land scarcity (Bezu and Holden, 2014; Deininger et al., 2007). We show that by relaxing youth constraints on land in remote areas, the proclivity to engage in long-distance migration or rural non-farm employment is greatly reduced.

Our findings have broader implications for the development strategies available to Ethiopia. Absent government intervention, the decline in arable land over time may increase youth unemployment and urbanization. In this regard, relaxing policy-induced frictions in the land rental market in the country (Holden and Ghebru, 2016), or otherwise freeing up land for individual use, can result in far-reaching impacts in reducing youth unemployment. Educational campaigns, starting at a young age, in conjunction with investments in the ser- vice and manufacturing sectors will be crucial to absorb the fraction of youth with limited opportunities for landownership. The government has signaled its commitment to the latter under its 5-year Growth and Transformation Plan (2015/16-2019/20) (Schmidt and Bekele, 2016). Finally, there is growing need to initiate a modernization in the agricultural sector, by increasing access to extension and encouraging widespread adoption of agricultural tech- nologies. Agricultural growth will increase rural household welfare, generating the demand for auxiliary services and goods which landless rural youth can provide

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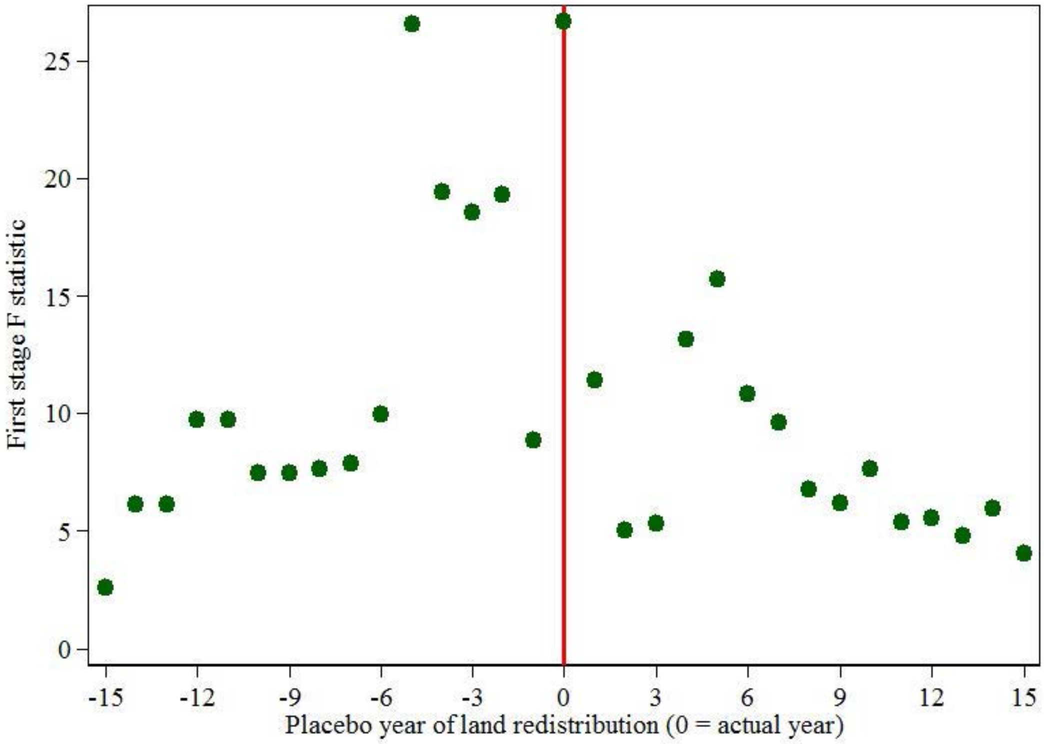
Figure 1 – Placebo analysis: First Stage F statistics if land redistribution is assumed to occur before or after the actual year



Source: Authors' calculations based on IFPRI's Watershed Surveys of 2010 and 2014
Notes: The x-axis indicates the number of years after the actual year of land redistribution that we assume land redistribution occurred; positive numbers indicate that we pretend it occurred in later years than the actual, while negative numbers indicate that we pretend it occurred in earlier years. The y-axis displays the First Stage F Statistic on our excluded instrument (from estimating column 3 of Table ??). The vertical line at x = 0 highlights the value of the F Statistic when we use the actual year of land redistribution

Table 1 – Observations by years of last land redistribution

Panel A: Year of Most Recent Post-Derg Era Land Redistribution

Kebele	Year
Tulugura	1992
Fundisa	1993
Arjo	1993
Agemi Nijar	1997
Kaka	1997
Gesges Shibirime	1997
Wajarba	1997
Taime Abekidan	1997
Esey Debr Ganba Gubiya Jantega	1997
Yetijan Shebelima	2003
Kenge Abo Amesha	2003
Atsed Mariya	2004
Leklekitaq	2005
Cholmana Mntura	2005
Disbasfilira	2005
Kersa Wolega	2006
Gombo Kiltu Jale	2006
Belita Amijye	2010
Dat Giyorgis	2012
Shemagile Giyorigis	2013
Kologelan	none
Wanesha Dabus	none
Aintodele	none
Hadaresa Bila	none
Kolba Anchabi	none
Meksaleku	none
Kela Beroda	none

Panel B: Distribution of Year of Most Recent Land Redistribution within estimation sample

Year	Share of observations
1992	3.4
1993	9.5
1997	21.8
2003	6.5
2004	4.4
2005	9.5
2006	9.2
2010	4.0
2012	1.7
2013	3.6
none	26.6

Source: Authors' calculations based on IFPRI's Watershed Surveys of 2010 and 2014
Notes: Number of observations, 1,989, is based on the sample used for estimation

Table 2 – Descriptive statistics

	Full Sample			Sample With Non-0 Expected Land Inheritance		
	Mean	SD	N	Mean	SD	N
Panel A: Outcomes						
Dummy - permanent migrant	0.53	0.5	1717	0.45	0.50	1170
Dummy - permanent migrant out of woreda	0.27	0.44	1709	0.21	0.41	1167
Dummy - permanent migrant to urban area	0.34	0.47	1709	0.28	0.45	1167
Primary occupation is in ...						
Agriculture	0.32	0.47	1713	0.37	0.48	1167
Non-agriculture	0.19	0.4	1713	0.16	0.36	1167
Student	0.30	0.46	1713	0.29	0.45	1167
Domestic	0.13	0.34	1713	0.13	0.34	1167
Unemployed	0.04	0.19	1713	0.04	0.19	1167
Panel B: Land access						
Dummy - inherited or expects to inherit land	0.71	0.45	1717	1.00	0.00	1170
Land inheritance (hectares)	0.34	2.14	1671	0.48	2.54	1170
Log land inheritance	-1.36	0.92	1170	-1.36	0.92	1170
Panel C: Individual Controls						
Dummy - male	0.64	0.48	1717	0.67	0.47	1170
Age	19.9	4.05	1717	19.9	4.09	1170
Dummy - child of head	0.97	0.16	1717	0.98	0.13	1170
Dummy - married	0.05	0.21	1717	0.05	0.23	1170
Dummy - >1 male descendant immediately follows in birth order	0.25	0.44	1717	0.25	0.43	1170
Number of older male direct descendants	1.38	1.49	1717	1.37	1.48	1170
Number of older female direct descendants	1.18	1.38	1717	1.17	1.38	1170
Dummy - Age 18+ at time of land redistribution	0.18	0.38	1717	0.17	0.38	1170
Dummy - completed cycle 1 of primary school (grade 4)	0.70	0.46	1717	0.68	0.47	1170
Panel D: Household Characteristics						
Household size	7.13	2.24	834	7.16	2.28	625
Number of men 18+ in household	1.96	1.08	834	2.00	1.09	625
Number of women 18+ in household	1.65	0.87	834	1.68	0.89	625
Number of direct descendants of household head	7.09	2.62	834	7.11	2.74	625
Dummy - metal roof	0.67	0.47	834	0.67	0.47	625
Dummy - improved floor	0.03	0.17	834	0.03	0.17	625
Dummy - head of household is male	0.84	0.37	834	0.83	0.37	625
Head of household age	52.2	10.92	834	52.8	10.99	625
Dummy - head of household has no education	0.59	0.49	834	0.58	0.49	625
Dummy - Orthodox Christian	0.72	0.45	834	0.71	0.46	625
Dummy - Protestant	0.22	0.41	834	0.25	0.43	625
Dummy - Muslim	0.02	0.14	834	0.01	0.11	625
Share of males 18+ at time of land redistribution	0.17	0.29	834	0.17	0.3	625
Panel E: Instrument						
Excluded instrument*	0.03	0.11	1717	0.02	0.1	1170

Source: Authors' calculations based on IFPRI's Watershed Surveys of 2010 and 2014

Notes: *The share of male descendants who were over age 18 at the time of the redistribution interacted with a dummy for having more than one male descendant immediately follow one's self. Land redistribution always refers to the most recent redistribution.With land refers to those who either have already inheritted land or expect to inherit land. Improved floor refers to being made from concrete, stone, cement, tile, bricks, or wood (not made from earth or cow dung). Households without a descendant in the sample are not included in household characteristics descriptive statistics. Religions are those of the household head

Table 3 – IV first stage results

	Outcome: Log land inheritance	
	(1)	(2)
Excluded instrument: Share of male descendants 18+ at time of land redistribution × Dummy - > 1 male descendant immediately follows in birth order	2.501***	2.478***
	(0.460)	(0.480)
Dummy - >1 male descendant immediately follows in birth order	-0.082	-0.079
	(0.061)	(0.065)
Observations	1,170	1,170
R-squared	0.902	0.902
Number of households	625	625
First stage F stat	29.59	26.63
Full set of individual-level controls?	No	Yes

Source: Authors' calculations based on IFPRI's Watershed Surveys of 2010 and 2014. Notes: Individual-level controls include dummies for being a child of the head of household, for being at least 18 years at the time of the kebele's last land redistribution, for completing cycle 1 of primary school (grades 1-4), and for being the oldest direct descendant and being male. The first stage F stat is the t-statistic on excluded instrument squared. Also included are household fixed effects and fixed effects for exact permutation of older sibling sex, for kebele × age fixed effects, for kebele × marital status, and for kebele × gender. Standard errors are in parentheses and clustered at the kebele level

Table 4 – OLS results showing how the amount of land inheritance predicts migration and employment decisions

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Migration						
	Dummy - migrated ...					
	Anywhere		Out of woreda		To urban area	
Log land inheritance	0.025	-0.165**	-0.085**	-0.252**	-0.128***	-0.283***
	(0.051)	(0.076)	(0.037)	(0.094)	(0.043)	(0.081)
Additional controls	No	Yes	No	Yes	No	Yes
Observations	1,170	1,170	1,167	1,167	1,167	1,167
R-squared	0.001	0.783	0.011	0.788	0.024	0.800
Number of households	625	625	624	624	624	624
Panel B: Occupation						
	Dummy - primarily employed in ...					
	Agriculture		Non-agriculture		Student	
Log land inheritance	0.309***	0.262**	-0.059	-0.180	-0.142***	-0.050
	(0.044)	(0.109)	(0.042)	(0.126)	(0.042)	(0.201)
Additional controls	No	Yes	No	Yes	No	Yes
Observations	1,167	1,167	1,167	1,167	1,167	1,167
R-squared	0.095	0.815	0.006	0.753	0.021	0.778
Number of households	625	625	625	625	625	625

Source: Authors' calculations based on IFPRI's Watershed Surveys of 2010 and 2014

Notes: Migrated is defined as living in the household during round 1, and living elsewhere in round 2. Additional controls include dummies for being a child of the head of household, for being at least 18 years at the time of the kebele's last land redistribution, for completing cycle 1 of primary school (grades 1-4), for being the oldest direct descendant and being male, and for having multiple male descendants immediately following in the birth order. Also included are fixed effects for exact permutation of older sibling sex, for kebele × age fixed effects, for kebele × marital status, and for kebele × gender. Standard errors are in parentheses and clustered at the kebele level

Table 5 – Comparison of OLS and IV results showing how the amount of land inheritance predicts migration and employment decisions

	OLS			IV		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Migration						
	Dummy - migrated ...					
	Anywhere	Out of woreda	To urban area	Anywhere	Out of woreda	To urban area
Log land inheritance	-0.165**	-0.252**	-0.283***	-0.198	-0.855***	-0.508***
	(0.076)	(0.094)	(0.081)	(0.199)	(0.173)	(0.173)
Observations	1,170	1,167	1,167	1,170	1,167	1,167
R-squared	0.783	0.788	0.800	0.783	0.727	0.791
Number of households	625	624	624	625	624	624
First Stage F-Stat				21.73	21.73	21.73
Panel B: Employment						
	Dummy - primarily employed in ...					
	Agriculture	Non-agriculture	Student	Agriculture	Non-agriculture	Student
Log land inheritance	0.262**	-0.180	-0.050	0.655***	-0.427***	-0.171
	(0.109)	(0.126)	(0.201)	(0.168)	(0.095)	(0.140)
Observations	1,167	1,167	1,167	1,167	1,167	1,167
R-squared	0.815	0.753	0.778	0.799	0.742	0.776
Number of households	625	625	625	625	625	625
First Stage F-Stat				22.61	22.61	22.61

Source: Authors' calculations based on IFPRI's Watershed Surveys of 2010 and 2014

Notes: Migrated is defined as living in the household during round 1, and living elsewhere in round 2. All specifications include dummies for being a child of the head of household, for being at least 18 years at the time of the kebele's last land redistribution, for completing cycle 1 of primary school (grades 1-4), for being the oldest direct descendant and being male, and for having multiple male descendants immediately following in the birth order. Also included are fixed effects for exact permutation of older sibling sex, for kebele × age fixed effects, for kebele × marital status, and for kebele × gender. Standard errors are in parentheses and clustered at the kebele level

Table 6 – Analysis of impacts of size of land inheritance on migration and employment out- comes by gender and by age (OLS)

	Dummy - migrated ...			Dummy - primarily employed in ...		
	Anywhere	Out of woreda	To urban area	Agriculture	Non-agriculture	Student
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: By gender						
Log land inheritance (women)	0.097	0.024	-0.022	0.154***	-0.078	-0.082
	(0.073)	(0.044)	(0.053)	(0.047)	(0.047)	(0.065)
Log land inheritance (men)	-0.003	-0.155***	-0.188***	0.226***	-0.163***	-0.058
	(0.062)	(0.047)	(0.051)	(0.047)	(0.042)	(0.061)
Observations	1,170	1,167	1,167	1,167	1,167	1,167
R-squared	0.418	0.449	0.415	0.563	0.436	0.525
Number of households	625	624	624	625	625	625
P-value of difference	0.11	0.002	0.004	0.093	0.022	0.614
Panel B: By age						
Log land inheritance (20-34)	-0.010	-0.104*	-0.149**	0.220***	-0.139***	-0.011
	(0.068)	(0.055)	(0.058)	(0.053)	(0.040)	(0.058)
Log land inheritance (15-19)	-0.024	-0.028	-0.107	0.221***	-0.061	-0.082
	(0.09)	(0.056)	(0.066)	(0.046)	(0.048)	(0.077)
Observations	1,170	1,167	1,167	1,167	1,167	1,167
R-squared	0.407	0.425	0.393	0.542	0.424	0.501
Number of households	625	624	624	625	625	625
P-value of difference	0.799	0.096	0.317	0.984	0.069	0.181

Source: Authors' calculations based on IFPRI's Watershed Surveys of 2010 and 2014

Notes: Migrated is defined as living in the household during round 1, and living elsewhere in round 2. Estimates are from completely interacted models where gender and age (15-19 years vs 20-34 years) dummies are interacted with all controls. All specifica- tions include dummies for gender, for age, for marital status, for being a child of the head of household, for being at least 18 years at the time of the kebele's last land redistribution, for completing cycle 1 of primary school (grades 1-4), for being the oldest direct descendant and being male, and for having multiple male descendants immediately following in the birth order. Also included are fixed effects for exact permutation of older sibling sex. P-value of difference refers to the p-value for the interacted log land inheritance variable. Standard errors are in parentheses and clustered at the kebele level

Table 7 – Analysis of impacts of size of land inheritance on migration and employment out- comes by depth of land rental markets and by travel time to a major urban center (OLS)

	Dummy - migrated ...			Dummy - primarily employed in ...		
	Anywhere	Out of woreda	To urban area	Agriculture	Non-agriculture	Student
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: By land rental market activity						
Log land inheritance (low activity)	-0.337***	-0.181*	-0.514***	0.410***	-0.661***	0.418**
	(0.108)	(0.094)	(0.080)	(0.099)	(0.120)	(0.196)
Log land inheritance (high activity)	-0.179	-0.378**	-0.267***	0.443***	0.006	-0.361**
	(0.119)	(0.151)	(0.077)	(0.143)	(0.143)	(0.155)
Observations	1,170	1,167	1,167	1,167	1,167	1,167
R-squared	0.830	0.848	0.850	0.869	0.826	0.850
Number of households	625	624	624	625	625	625
P-value of difference	0.335	0.280	0.035	0.853	0.001	0.004
Panel B: By distance to major urban center						
Log land inheritance (close)	0.430***	0.173	-0.071	0.473**	0.090	-0.610***
	(0.079)	(0.131)	(0.064)	(0.204)	(0.121)	(0.104)
Log land inheritance (far)	-0.126	-0.330**	-0.317***	0.234*	-0.319**	0.116
	(0.100)	(0.158)	(0.073)	(0.125)	(0.148)	(0.289)
Observations	1,170	1,167	1,167	1,167	1,167	1,167
R-squared	0.841	0.849	0.871	0.892	0.828	0.849
Number of households	625	624	624	625	625	625
P-value of difference	0.000	0.021	0.018	0.327	0.042	0.026

Source: Authors' calculations based on IFPRI's Watershed Surveys of 2010 and 2014

Notes: Migrated is defined as living in the household during round 1, and living elsewhere in round 2. We calculate the share of households in each kebele with at least one parcel of land either rented, sharecropped, or temporarily loaned. The median share across the kebeles is 22.5%. Low and high activity refers to being below and above the median share of households, respectively. Close and far refer to a household being below or above (respectively) the median travel time (107 minutes) to a major urban center (regional capital or cities with a population of 100,000 or more in 2007). Estimates are from completely interacted models where rental market activity and distance dummies are interacted with all controls. All specifications include dummies for being a child of the head of household, for being at least 18 years at the time of the kebele's last land redistribution, for completing cycle 1 of primary school (grades 1-4), for being the oldest direct descendant and being male, and for having multiple male descendants immediately following in the birth order. Also included are fixed effects for exact permutation of older sibling sex, for kebele × age fixed effects, for kebele × marital status, and for kebele × gender. P-value of difference refers to the p-value for the interacted log land inheritance variable. Standard errors are in parentheses and clustered at the kebele level

Table A1: Major urban center populations (2007)

Major urban center	Total population
ASAYTA-TOWN	20,824
ASOSA-TOWN	35,752
GAMBELLA-TOWN	52,659
ADIGRAT-TOWN	72,375
KOMBOLCHA-TOWN	77,757
DILA-TOWN	77,856
ASELA-TOWN	83,591
DEBERE MARKOS-TOWN	86,225
DEBRE BREHAN-TOWN	87,204
NEKEMTE-TOWN	94,014
HOSAENA-TOWN	94,208
SODO-TOWN	98,930
ARBA MINCH-TOWN	101,819
HARAR-TOWN	118,353
BISHOFTU-TOWN	127,678
SHASHEMENE-TOWN	133,252
JIJIGA-TOWN	142,408
DESSIE-TOWN	152,568
JIMMA-TOWN	157,432
BAHIR DAR-TOWN	202,157
HAWASSA-TOWN	221,397
DIRE DAWA-TOWN	263,827
GONDER-TOWN	273,157
MEKELE-TOWN	284,652
ADAMA-TOWN	285,611
ADDIS ABABA	3,156,057

Source: CSA (2014)

A03

Socioeconomic dynamics resulting from structural transformation and agriculture transition in Ghana

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ABSTRACT

Since 1990 Ghana's economy has accelerated sharply and the level of overall poverty experienced a significant decrease. Agriculture is still playing an important role but is gradually replaced by the progressive expansion of the non-agricultural economy, in particular the services sector. Using nationally representative data from the Ghana Living Standards Surveys by the World Bank for 1991, 1998 and 2005, we examine recent trends in the reallocation of labour across sectors, agriculture production, input adoption and socio-economic characteristics of the households, both at national and regional levels. We attempt to advance the analysis of structural transformation in Ghana by investigating the determinants of household labour allocation via a micro-econometric approach based on synthetic panels (Dercon, 1985). This analysis shows that structural transformation is occurring at different speeds across the country leading to the development of a "north-south dualism". While northern regions' economies are still relying on low productive agriculture, the "Services revolution" is gradually shaping the southern regions economy. Regression-based results suggest that factors such as households' demographic composition, level of education, poverty status, migration flows, access of infrastructure and financial services are all factors contributing to labourers' occupation choices.

Keywords: Structural Transformation, Synthetic Cohort, Agriculture transition, Regional Development, Ghana

JEL Codes: E24; J62; O11; O40; O55; Q12; R11; R20

PAPER

1. Introduction

The debate on Sub-Saharan Africa's economic growth and poverty alleviation has recently seen a resurgence of interest by policy makers and the academic world on the role of structural transformation (AfDB, 2013, ACET, 2014). The structural transformation process that consists in the reallocation of labour from traditional agriculture sectors to industry and services[2], started in Europe with the industrial revolution (Kim, 2007, Allen, 2009) before spreading out in Africa, Asia and Latin America, where countries started a quicker and more mixed transition with respect to the rest of the world. This process evolved differently throughout the developing countries: while Asian economies rapidly evolved "from flying geese into leading dragons" (Lin, 2012) the African shape of structural transformation was radically different. Many countries experienced substantial amounts of labor reallocation across sectors and the sectoral composition of their economies generally shifted from mostly agrarian to a combination of agriculture, industry and services. A great movement of farmers away from rural areas led to a drop in the agricultural value added and employment since the 1960s. Industries lost ground since the mid-1970s and globalization did not realize the promise of growth. Inter-sectoral mobility of labour went in the wrong direction, shifting from more productive to less productive sectors, with services instead of manufacturing becoming the primary recipient of labour exiting from agriculture. Not much recovery seemed to take place, with African countries remaining under-industrialized at all levels of income (McMillan et al., 2012, Rodrik, 2014).

Since Fisher (1939) and Kuznets (1966), who included structural transformation as one of the six most relevant stylized facts of development, a vast macroeconomic literature stressed this topic in several ways. A useful review of this literature is provided by Herrendorf et al. (2011) who highlighted the importance of multi-sector models to control for the complexities and the two-way causality relationship between economic growth and structural change. Recent literature examined the relationship between structural transformation and productivity gaps (Caselli, 2005; Duarte and Restuccia, 2010), urbanization (Michaels, 2012; Gollin et al. 2013, Christiansen et al., 2013), demographic transitions (Beegle, Weerdt, and Dercon, 2011; de Brauw et al., 2014), land institutions (Deininger et al., 2014), farming systems (Jayne et al, 2014) and environmental externalities (Antoci et al. 2009, 2012). Despite the huge potential for structural change due to the high share of the labour force in agriculture in most

[1] Authors listed in alphabetical order.
[2] See Lewis, 1954, Kuznets, 1966, Maddison, 1980 and Chenery et al., 1986 among others.

of Sub-Saharan Africa (SSA), literature on structural transformation in Africa has been not investigated much. Only recently, contributions on this topic experienced an important improvement. Authors like de Brauw et al. (2014), Christiansen and Todo (2014), McMillan et al. (2014a) and De Vries et al. (2015)[3] started to fill this gap by analysing gains/losses and consequences for economic growth and poverty reduction objectives[4] of structural transformation in Africa.

Experiences from developing countries achieving such targets usually indicate that the drivers of growth and development differ not only between countries, but also within the same country. Labour reallocation itself changes, depending on cultural and environmental factors, often not modeled within macro-level analysis but yet representing the assumption on which these are based. It is thus hard to give a precise insight of the drivers affecting structural transformation and labour movements across sectors without controlling for the host of heterogeneity arising from differences at regional level or - better - at household level (Foster and Rosenzweig, 2007; Fox and Sohnesen, 2012). In this sense, the microeconomic perspective is quite relevant, since it better reflects individuals' occupational choices by looking specifically at their local heterogeneity. The availability of questionnaires on individuals' employment sector, time use, income, wage and other relevant labour-related indicators helps makes the construction of productivity measures easier. These, once paired with other relevant covariates can improve the understanding of labour allocation decisions.

At the moment, research at micro-level on structural transformation is scant, in particular if considering its microeconomic dimensions in a context of labour reallocation. To the best of our knowledge only recently authors like Christiansen and Kaminski (2015) and McCullough (2015) focused on micro-level empirical research on structural transformation. The first looked deeply into the distribution of productivity levels within sectors by proposing a micro-level decomposition approach of consumption growth and poverty reduction in Uganda. The second provided a descriptive overview of the key features of structural transformation in four different African economies.

Country level studies on Ghana's structural transformation (Breisinger et al. 2009; Kolavalli 2010, Jedwab 2011, Jedwab and Osei, 2012) often concentrate on the evolution of demographic, employment and productivity indicators at the national level, leaving very little space for micro-level scale considerations. The contribution of this study lies in filling this gap by providing, on the one hand, a descriptive review of changes in the structure of the workforce and the evolution of agricultural and socio-economic characteristics of households living in rural areas over a period of 20 years; on the other hand, a micro-level empirical assessment using Weighted Least Squares to identify the determinants and the key correlates that can explain the likelihood of households changing the distribution of labour across the different occupational sectors. Ghana is of particular relevance to our purposes for two reasons. The first is related to its enormous structural transformation potential: its average GDP growth rates increased in the last decades, the number of poor reduced, and – most importantly – according to WDI (2014) the number of people employed in agriculture decreased by 18% in the last 20 years, with the sector still employing 44% (in 2013) of the economically active population. The second is the availability of data over a 25 year time span, which is long enough to capture structural variation in the country's economy. We base our analysis on the Ghana Living Standards Surveys from 1991/92, 1998/99 and 2005/06 designed by The World Bank. The GLSS data include detailed information on households' social and economic characteristics, as well as a detailed section on agriculture activity. From this we have drawn variables related to farm activity, agriculture inputs and farming equipment and livestock. However, in both developed and developing countries, long-running panel datasets are rare, whereas cross sectional household surveys are often conducted on a regular basis. Although such surveys do not allow following individuals over time, to overcome the unavailability of panel data, groups of people may be tracked from one wave to another by the use of cohort clusters (Deaton, 1985) rather than observations at the individual or household level in a "pseudo-panel" framework.

The rest of the paper is organized in two parts. The first part begins with section 2 by providing some stylized facts of Ghana's economic growth, poverty reduction and structural transformation, and ends up with a descriptive analysis of the process of structural transformation both at national and regional scales. The second part of the paper focuses on the econometric analysis: section 4 describes the econometric model and section 5 provides the econometric results. A final section concludes.

2. Economic growth and structural transformation in Ghana: aggregate stylized facts

By African standards, Ghana has done reasonably well in recent years, representing a success story of noteworthy poverty reduction and significant economic growth. In relation to poverty reduction, the level of overall poverty among the Ghanaian population fell from 52% in 1991/92 to 29% in 2005/06, and lingered at 24% in 2012/13. The Ghana is one of the few African countries to achieve the first MDG target of halving poverty[5], although four out of its ten regions are lagging behind with people still living in extreme poverty. Regarding economic growth, since 1990 the country's economy expanded, with average GDP growth rates

[3] Among others, we do not report all the literature.
[4] See, for instance, McMillan and Headey (2014) for a comprehensive review in a World Development special issue.
[5] In Africa and Eastern Asia, only 63 countries have reached the MDG-1 hunger target between 1990 and 2015 (FAO, 2014).

ranging between 4% to 5% during the 90s and early 2000s and thereafter increasing to 8% on average (WDI, 2014). This impressive growth performance – which reached a peak of +14% in 2011 – is quite unusual at world level. In fact, in the last 20 years only a few developed and developing countries achieved these levels over such a period.

In the last decades, agriculture has been the backbone of Ghana's economy contributing between 40 and 50% of total GDP between 1965 and 1975 and rising up to 60% in the 80s. Even though it experienced a constant decline, agriculture still plays an important role in ensuring food security by representing the 22% of the GDP in 2014 (Figure 1) with 44% of the economically active population employed in the sector in 2013 (down from 62% in 1992).

During the 80s, the Ghanaian economy underwent an important change with the implementation of the Structural Adjustment Program (SAP)[6]. Since the launch of the SAP, which that rescued Ghana from the economic collapse, the country experienced strong improvements in the industrial sector, whose contribution to total GDP increased to 27% in about 20 years. The same happened to the manufacturing sector, which grew by seven percentage points right after the SAP implementation, but its value added never went beyond the 10% of the total GDP. Looking at Figure 1, between 1981 and 2005 the service sector became increasingly relevant for the entire Ghanaian economy, reaching an average value of about one-third of the total GDP. The "regime switch" registered in 2006 (-10% agriculture, -6% industry, +1% manufacturing, +16% services) is mainly due to the rebasing of the series[7], with the number of subsectors under services being increased from six to eleven in the new series. The reorganization of the services sector led the way accounting for almost half of Ghanaian GDP, overtaking the agricultural sector as the most prominent sector of Ghanaian economy.

3. The Process of Economic and Social Development in Ghana

3.1 The dataset

In the present study we provide a descriptive analysis of change in households' characteristics, the structure of the workforce among agricultural and non-agricultural households and an analytic assessment of the determinants of time allocation using three waves from the Ghana Living Standards Surveys (GLSS), a comprehensive dataset modeled after the Living Standards Measurement Surveys (LSMS) and designed by The World Bank. The surveys were conducted in 1991/92, 1998/99 and 2005/06 (i.e., GLSS3, GLSS4 and GLSS5), adopting almost identical questionnaires with positive synergies in the analysis of economic transformation, agricultural transition and its contribution to poverty and hunger alleviation.

Among the variables included in the sample, we consider household demographic variables, variables related to participation in labor activities, land owning, annual household income and consumption, as well as durables owned by the household and information on access to credit. The entire sample includes 4,523 observations from GLSS3, 5,998 from GLSS4, and 8,688 from GLSS5, representing respectively 3.3, 4.2, and 5.5 millions of households at national level. Furthermore, we define a subgroup of agricultural households as households operating land and earning income from crop sales. For each round, we estimate an amount of agricultural households of around 60% percent out of the total sample. In particular, the sample sizes of agricultural households are 2,958, 3,698, and 4,755, for 1991, 1998 and 2005 respectively. Finally, we define three geographic groups according to the geographic location of the different regions. We group the ten regions in three different clusters, the northern macro-region, characterized by a semi-arid tropical climate (rural savannah), the central macro-region and the southern one, the coastal area[8].

The three clusters consist of 2782, 6098 and 2528 observations respectively. We report the evolution of the different variables over time at national and regional scales for the overall sample and the agricultural households.

3.2 National level

Table 1 in the Appendix reports summary statistics of main variables for the overall sample at national level. Education seems to have expanded during the 1990s in the country, which has resulted in a rise in the average years of school, from 2.7 in 1991/92, to 4.0 in 1998/99, to 5.3 in 2005/06, and an increase in the highest years of education in the household from 4.7 to 8.2 over the whole period. Figures show a decline in the share of household heads employed in agriculture from 53% in 1991 to 45% in 2005 although the agriculture sector is the major source of income in Ghana, whereas the share of household

[6] As reported by Konadu-Agyemang (2000) the most relevant measures behind the SAP implementation (1983) consisted in cuts in social services, devaluation of the cedi, abolishing the domestic price control, broadening the tax base, strengthening the tax administration, divesting state owned enterprises and encouragement of cocoa and other traditional exports.

[7] The rebasing exercise has been performed by the Ghana Statistical service using the International Standard Industrial Classification (ISIC). More information available at: http://www.statsghana.gov.gh/docfiles/news/gdp_newsletter_rebased_gdp_nov_2010.pdf.

[8] North includes: "Northern", "Upper East" and "Upper West" regions; Center includes "Volta", "Eastern", "Ashanti", "Brong Ahafo" regions and finally South includes "Western", "Central", "Gt Accra".

heads employed in transport, storage and communication increases over the whole period. On the other hand, the employment shares in manufacturing, and wholesale and retail trade increase from 1991 to 1998 (i.e., from 7.7 to 8.9 for the former, and from 11.4 to 13 for the latter), and slightly decrease from 1998 to 2006 (i.e., from 8.9 to 8.7 for the former, and from 13 to 12.7 for the latter).

Figures on annual consumption describe an increasing trend over the whole period both for food and non-food expenditure per adult equivalent expressed in 2005 Ghanaian cedis and appropriately deflated for price variation. This kind of variable is commonly used in the literature as a welfare indicator in measuring poverty and inequality (Ravallion and van de Walle, 2008). Figure 2 depicts the distribution of log consumption per adult equivalent for the three rounds of the GLSS showing higher densities towards the right side of the graph for non-farm households, while farmers have more density towards the left side. Following the consumption path, total household income (in 2005 Ghanaian cedis), as well as its sources show an increase over time.

Descriptive statistics show a limited access to credit in the country with higher shares of informal sources with respect to formal ones, and loans mainly allocated for agricultural activities, as well as for business purposes. Some studies highlight that among others, age and gender of the household head and political affiliations are the main determinants of credit demand by farmers (Kimuyu and Omiti, 2000; Akudugu, 2012). On the other hand, other analyses reveal that extension services, education level and saving habits influence household access to formal credit (Dzadze et al., 2012; Hananu et al., 2015), with loans mostly used for agricultural and non-agricultural production, and consumption purposes.

Table 2 (see Appendix 1) provides summary statistics for the subsample of agricultural households only. Descriptive statistics show that among others, the household size, the gender of the head and the level of education are also important components also for the restricted sample of agricultural households. The share of female-headed households as well as the household size decrease (from 26 to 23% in the former and from 4.9 to 4.7% in the latter) in 14 years, whereas the average years of education in the household increase from 2.2 in 1991/92, to 3.1 in 1998/99, to 3.9 in 2005/06.

Figure 3 shows the distribution of the amount of land operated for the three waves of the survey. Operated land is defined as the sum of the agricultural land owned-and-operated by the household plus the difference between the amount of land rented/sharecropped in and rented/sharecropped out. The majority of the distribution falls below two hectares of land, and more than 75% of farmers operating operate less than the average farm size each year. The resulting figures show an expansion from the 1990s with a rise in the average farm size, from 2.3 hectares in 1991/92, to 2.5 in 1998/99, to 3.3 in 2005/06[9]. The increase may also be seen also for land owned, that includes operated land, land sharecropped out and rented out by agricultural households; that grows from 3.1 hectares in GLSS3 to 3.9 hectares in GLSS5. In this regard, Figure 4 presents basic information on land ownership by land size for agricultural households. It is interesting to note that the percentage of households owning less than 0.5 hectares of land shrank by 9% between the first and the last wave. This reduction has been partly compensated by the growth (+6%) of the large landowners (→4 ha). Furthermore, the share of farmers owning land with deed exponentially increases over time from 5.9% in 1991/92, to 16.6% in 2005/06.

Moving towards the variables related to farm activity, Figure 5 depicts the use of agricultural inputs by classes of land endowment per year. Overall, the purchase of seeds and seedlings is the most important agricultural input, with the exception of households owning more than two hectares of land in 2005/06. We find evidence of a negative variation in the share of seeds and an increase of the amount of fertilizer and pesticides adopted over time for all classes of land endowment. Smaller farmers tend to use more seeds rather than other agricultural inputs, whereas households cultivating more than two hectares of land purchase pesticides and fertilizer more frequently, especially in the 2005/06 round.

In this context, among agriculture inputs, it is worth taking into consideration the labour variable, revealing a decreasing but still high share of rural households (namely, 66% in 1991, 73% in 1998, and 57% in 2005) hiring workers during land preparation, weeding and harvest. On the other hand, the value of agricultural assets decreases over time, from 336 Ghanaian cedis in 1991/92, to 149 in 2005/06, with very low shares of households owning different assets, such as tractor, plough, cart, and sprayer.

3.3 Regional dynamics

Development economics literature largely documented the process of structural transformation over time at national level. However, responsiveness to change at national level is the result of different changes at local level. Factors like tradition, different levels of development or environmental and geopolitical acute disparities largely influence households' decision making processes. This is why, in order to assess the phenomenon of structural transformation in Ghana it is also crucial to thoroughly understand the patterns of change also at sub-national level. We proceed by clustering the ten regions in three macro-regions according to their geographic position, namely North, Centre and South, which represent respectively the rural savannah, the centre and the coastal area. For each group we analyse

[9] It is worth noting that these values do not include landholders not selling crops.

the evolution of society, economy, agriculture and technology in a descriptive framework. We place particular emphasis on the reallocation of labour across the different sectors by focusing on the ten regions separately through the adoption of choropleth maps.

Table 3 in the appendix compares the full sample and the agricultural households, featuring their most relevant socio-economic characteristics. Looking at the full sample, the first line shows the share of farmers over the total. Farmers are predominantly located in the northern area, which is less urbanised and where agricultural households are almost the double with respect to the southern macro-region. It is worth noting that the share of agricultural households decreases in all the three macro-regions (-10% in the north, -15% in the centre, -13% in the south). This reduction coincides with a migration from rural to urban areas. In fact, figures on the share of rural households over the total clearly show an important drain out towards urban areas in the centre (-12%) and coastal regions (-7%), while in the rural savannah it is pretty much constant over time.

In northern regions, households are on average slightly bigger and much less educated with respect to the rest of the country. Indeed, if we look at the dynamics, the average number of years of education almost doubles over time in both the centre and southern areas, while in the north it decreases. Even though in some areas education level seems to experience an upward trend, education inequality remains an issue in the north where it is strongly differentiated by gender. Female members' education with respect to the other household members is lower than in the other macro- regions. They benefit less from education with respect to men, particularly in the rural savannah areas, where the percentage of female headed households in 2005 was 13%, approximately one-fifth of the other two regions. Figures from the agricultural households' subsample confirm this trend.

The following rows provide information on the households' participation in labour activities. The first set of indicators represent the percentage rate of households' members of working age declaring to be employed, unemployed, inactive (see Table 3). Figures are in line with the findings at national level. There is a very low spatial diversity across regions with about three out of four adults employed in any working activity, with 1 to 3% of unemployed adults (with higher rates in the coastal area) and an average of 15% of adults declaring to be inactive. No definite pattern can be associated to these dynamics, neither in the full sample, nor for the agricultural households. Labour is the prevailing source of income in Ghana, and is mainly employed in agriculture and services segments because of the endemic characteristics of these sectors, which are both labour intensive. What is really striking is the evolution in the share of labourers, which takes different shapes across sectors and over the years. To get a better idea of the changing patterns in the reallocation of labour within the country we plot in Figure 6 a set of bar charts constructed for the full sample at regional level and reflecting the employment rate in each of the three different segments where households' heads are employed: agriculture, manufacturing and services (wholesale and retail trade, transport, storage and communication and community, social and personal services). It is evident that agriculture still plays a central role in the economy of the northern provinces - the poorest ones. Basically, in 1991 the agriculture sector absorbed the 80% of households' heads residing in the northern region, 60% in the centre and 41% in the south, evidencing a great spatial variability of the labour markets. The more we move towards the coastal regions the less important agriculture is for the local economy. Greater Accra region is a worthwhile example, showing the lowest share of households employed in this sector. Looking at the dynamics, although there are remarkable differences across the regions, we show a general declining pattern for the agriculture sector in all the areas studied, including the ones that rely more on agriculture. Conversely, the manufacturing sector (mainly constituted by electronics, automotive and light manufacturing, food processing, aluminium smelting and cement) is much more concentrated in the south. Looking at the map, the capital city's region shows the highest share of households (around 15%) employed in the sector, driving the difference between the centre and southern macro regions. We have to bear in mind that Greater Accra and the whole south benefited more by the SAP with respect to the northern and central regions, even though in the long run its effect fades out. In fact, by looking at the coastal area regions, the employment rate of household heads in the manufacturing sector is slightly shrinking (-2%), reducing its absorption of household heads from 15% to 12%. In the south the development process seems to run faster than in the north which is experiencing the industrial phase with a decade of delay (+3% of household heads employed). The same conclusions can be drawn for services, which is the second major segment contributing to the country's gross domestic product. Services include wholesale and retail trade, transport storage and communication, community, social and personal services. Figure 6 depicts disaggregated statistics across regions and over time for the services sector's sub-groups. If we look at the 2005/06 values, we see that in the northern area household heads employed in services are around 6%, 12% in the centre and 17% in the south. We do not find sharp improvements in any of the sectors between the first and the last round, meaning that at the time of the first wave the contribution of each services' segment on the overall regional economy was already stabilized. However, there are small movements that are important to consider to give insights to each region's structural transformation shape. The most interesting patterns are registered within the full sample, whilst for the sub-sample of agricultural households the share of household heads employed in each services' sub-sector does not fluctuate over time. The wholesale, retail and trade sector is the only sector among services representing a larger share of workers. It shows an upward trend in all the three macro-regions, with a major incidence in the coastal one (+3.7% between the first and the last wave). This is the result of the running globalization process that is pushing to invest in services to manage the growth of tourism and a bulky demand of food and manufacturing imports. Demand for labourers in the sector of "Transport, storage and communications" is slightly increasing over time, even though this segment is the one among services that contributes less to the labour supply. In northern areas transport is almost absent, whilst it is particularly relevant in the Greater Accra region. This sector is likely to further grow further from 2005 onwards with the beginning of the digital era. Finally, the share of household heads working for "Community, social and personal services" has almost the same breadth of trade services but has a decreasing trend over time in all the three macro-regions. Once again, the capital region represents the hub also for this sector.

Given the distribution of labour reported above, as well as the nature and characteristics of the households located in the northern area, we expect that the highest share of income in the rural savannah would be dominated by agricultural output sales. Our findings confirm this expectation, but it is intriguing to note that income from self-employment related activities capture an important share of the overall income distribution within the households (see Table 4 in the Appendix). In the agricultural households' sub-sample, income from crops represents the major source of revenue for all households across all macro-regions, while income from self-employment is ranked right after. Self-employment is becoming increasingly important in the northern region (+2%) and this share seems to contribute to the gradual replacement of income from livestock sales (-10%). The analysis of the three surveys reveals a similar pattern for the full sample. In Figure 7 we report maps with pie charts quantifying the share of each source of income over the total per year. The relative importance of each sector varies across regions, confirming the importance of self-employment and non-agricultural wages in the southern macro-region (Central region, Greater Accra, Eastern region among all). Income of households living in the Greater Accra region comes mainly from non- agricultural wages and self-employment forms of labour. This greater concentration of non- agricultural jobs is larger where there has been an increase of services sectors. On the other side, the contraction of income from livestock sales is also confirmed at a more disaggregated level, while it is interesting to note that in regions such as Volta and Western region, there is an improvement in the profitability of crop sales. Agricultural markets are thus changing over time and differently across regions as a result of the slow process of structural transformation gradually occurring in the agricultural sector; this is characterized by a growing importance of agribusiness, with high-value agricultural products and cash crops[10] grown as a form of business. The evolution of cash crop cultures overtime is conspicuous, in particular between the second and third round of the survey (see Figure 8). In the northern macro-region, both food and cash crop values of production are increasing. Moving towards the central part of the country, Northern Region and Brong-Ahafo did not show any significant change in their production systems, which remain balanced between cash and food crops production. Although the cash crops expansion of the early 2000s occurred almost everywhere, there are important spatial differences to be noted in terms of value of production, particularly in the central and southern regions. The Ashanti region, which today is one of the largest world's cocoa suppliers, registers a great expansion in the cash crop value of production, in particular between the second and third wave. This is the most prominent case of specialization we find across the regions. A plausible explanation could be that this variation in the value of production is the consequence of an improvement in both human capital and in a change in the technological means of production, which are the expression of an increased productivity. It is not surprising that northern regions, which are the less educated ones, are lagging behind the rest of the country where a transition from an equilibrium of "subsistence" and "business" agriculture to a "business-based" one is in place

In Table 4 we report figures for the expenditure on agricultural inputs and their intensity of use. We disentangle the intensity of use from macro-regions to a regional scale and we plot in Figure 9 the regional averages of the most relevant figures. In the northern regions this shift towards a modern, and more commercial agriculture, is hindered by the chronic constraints affecting their livelihoods such as the absence of adequate infrastructures, the insufficient access to technology, agricultural inputs, and other facilities. The bar charts regarding the intensity of input use reported in Figure 9 clearly reflect this issue. However, if we look at the trend, there is a slow but increasing variation in all the regions for both pesticides and inorganic fertilizers. Inorganic fertilizers expenditure rose consistently between the second and third wave in almost all the regions apart from Volta, while northern macro- regions are still behind in terms of intensity of use of pesticides, seeds and hired labour.

It must be noted that since the figures reported above do not track the same people over time, it is hard to know whether and how this process of structural transformation can be strongly/weakly associated with households' demographic characteristics, residential choices, access to land, infrastructure and facilities or spatial transformation. In order to provide direct insights into the determinants of such a change, we move to a slightly more complex analysis by taking advantage of the pseudo-panel framework.

4. Empirical methodology

In this section we discuss the econometric models estimated and some econometric issues encountered in analysing patterns and determinants of structural transformation. According to the existing literature three different categories of indicators are usually employed to measure structural transformation. The first one is the change in production structure and it is generally defined by the share of income coming from each activity.

[10] Cocoa, among others.

The second one is a measure of productivity of labour, typically GDP per worker or GDP per hour (Herrendorf, 2013), while the last one is the employment share, which in literature is calculated using either the number of workers or the hours worked by sector (Duarte and Restuccia, 2010). Each dimension explores different aspects of structural transformation; we concentrate on the last one to investigate the determinants of change in time spent working in agriculture, services, industry and manufacturing sectors through time. In theory, when structural transformation occurs, people devote less time working in low productivity sectors (generally agriculture in poor countries), and increase time spent moving towards high productivity ones. Of particular interest here is the potential effect of some key correlates such as demographic shifts, land use, agricultural and non-agricultural wealth, technology adoption and mechanization, access to infrastructure and facilities, credit and migration.

In order to evaluate how structural transformation and agriculture transition may be affected by households' socio-economic characteristics, the best source would be a long-running panel dataset that allows tracking the same households over time. However, in both developed and developing countries, long-running panel datasets are rare, whereas cross sectional household surveys are often conducted on a regular basis, Ghana being no exception. Although such surveys do not allow following individuals over time, to overcome the unavailability of panel data, groups of people may be tracked from one wave to another on the basis of their common observable time-invariant characteristics, like for example date of birth, geographic location, poverty status, quality and size of operated land.

Consequent empirical economic analyses make use of cohort clusters rather than observations at the individual or household level. "Pseudo-panels" based on age cohort have been widely used in the literature, in particular after the seminal work of Deaton (1985), who suggested that cohorts constructed from repeated cross section data can be used to estimate a fixed effects model (e.g., Deaton and Paxson, 1994; Banks, Blundell and Brugiavini, 2001). The idea behind these synthetic panels is that on average the behavior of a group of households is well approximated by the behavior of other households belonging to the same cohort at another point in time. Technically, this approach is formally similar to instrumental variables technique, where the group indicators are used as instruments (Verbeek, 2008).

4.1 Model setup

Let's define i households, and s sectors, representing the four main segments of the Ghanaian economy (i.e. agriculture, services, industry, manufacturing). We define the share of worked hours $Sh_{is,t}$ for household i in sector s at time t as equal to $Sh_{is,t} = \frac{HW_{is,t}}{THW_{i,t}}$, with $HW_{is,t}$ and $THW_{i,t}$ being respectively the number of hours worked per week in sector s and the total number of hours worked in all sectors at time t by household i[11]. We assume that the share of hours worked in each sector can be expressed as a function of a set of controls:

$$Sh^*_{is,t} = f(D_{it}, L_{it}, W_{it}, I_{it}, F_{it}, G_{it}) \quad (1)$$

where $D_{is,t}$, are the demographic characteristics which include the household composition in terms of size and female members (by age), the dependency ratio and the average years of education of adults in working age; $L_{cs,t}$ and $W_{cs,t}$ represent farm-related variables (i.e. size of land (ha) operated, inequality in land distribution and annual expenditure in agricultural labour force) and wealth-related variables (i.e. total Tropical Livestock Units, dwelling ownership and poverty status), respectively. $I_{is,t}$ and $F_{is,t}$ are the access to infrastructure/facilities' variables (i.e. participation in Agricultural Cooperatives, access to electricity, distances from health facility, nearest road and banks[12]). Finally, $G_{is,t}$ is a vector of geographic variables (i.e. belonging to different agro-ecological zones and rural/urban).

We start by examining the linear functional relationship resulting from (1), which is represented as follows:

[11] Information on labour time allocation is reported within the questionnaire for primary, secondary and – eventually - tertiary activities at the individual level. The time span considered is represented by the hours spent working in the last seven days. Data on hours worked were purged from outliers to make sure they would not exceed the cap of 40 weekly hours (per worker) across activities. Values exceeding the maximum were then replaced by a proportional amount of hours in a way that their sum across occupations was equal to 40..

[12] All variables apart from electricity are computed at community level.

$$Sh_{it} = \delta_{it} + \beta_0 + D'_{it}\beta_1 + L'_{it}\beta_2 + W'_{it}\beta_3 + I'_{it}\beta_4 + F'_{it}\beta_5 + G'_{it}\beta_6 + \eta_t + u_{it}, \tag{2}$$

where i indexes households $(i = 1, \ldots, N)$ and t indexes the time span $(t = 1, \ldots, T)$. Then δ_{it} captures the households' unmeasurable and unobserved skills and abilities, η_t the time trend and finally u_{it} the disturbance. Even though this model assumes that the error term u_{it} is not correlated with the predictors and δ_{it}, it must be recognized that δ_{it} might be correlated with any of the demographic controls D'_{it}. Similarly to Ackah and Aryeetey (2012) a pooled analysis of the data based on an equation like Eqn. (2) generates a number of issues regarding individual heterogeneity, "in part because such analysis cannot control for unobservables, and in part because it assumes that repeated observations on each household are independent" (Ackah and Aryeetey, 2012, p. 85).

4.2 Construction of the Pseudo-Panel

Following Deaton (1985) we solve this issue constructing a pseudo-panel by the use of a set of C cohorts $(c = 1, \ldots, C)$, that by definition represent groups of households that share a vector of common characteristics that are constant over time. These are constructed according to a joint set of multiple characteristics, namely the (i) household head's age category, (ii) the head's sex and (ii) his/her residing region for a total of 114 groups followed over time[13]. By tracking the cohorts, we are able to average Eqn. (2) over the cohort members to obtain a new equation (3) expressed in terms of cohort means, that represent the observation units in the new pseudo-panel framework. This procedure, which allows the clearing out of the heterogeneity across households yields the following structural form

$$\overline{Sh}_{cs,t} = \overline{\mathbf{X}'_{ct}}\beta + \overline{\delta_{ct}} + \overline{u_{ct}} + \eta_t, \quad c = 1, \ldots, C; t = 1, \ldots, T \tag{3}$$

In Eqn. (3), $\overline{Sh}_{cs,t}$ and $\overline{\mathbf{X}'_{ct}}$ represent respectively the average values of the share of hours worked in each sector and the vector including all the explanatory variables for all observed households at time t in cohort c. $\overline{\delta_{ct}}$ is defined as the average of the fixed effects for all the households belonging to cohort c in year t, and can be treated as the unobserved cohort fixed effect if the sample size in each cohort is sufficiently large (Warunsiri and McNown, 2010). All error components in (2) that are correlated with the control variables have been purged from the error term, in this way the estimation of equation (3) with cohort fixed effects yields unbiased and consistent results. However, since the number of observations per cell varies substantially, the error term $\overline{u_{ct}}$ is heteroskedastic, leading to biased standard errors. We follow Dargay (2007) and Warunsiri and McNown (2010) and correct this heteroskedasticity using Weighted Least Squares (WLS) estimation by weighting each cohort with the square root of the number of observations contained in each cell.

However, while from one side WLS estimator helps in addressing the heteroskedasticity issue, on the other it may produce inflated R^2. This issue is quite common in the literature, in fact, as reported by Willet and Singer, the goodness-of-fit obtained under WLS regression "is frequently much larger than the value obtained under the corresponding OLS fit. […] This increment reflects, in part, the success of the weighting in solving the problem of heteroscedasticity" (Willet and Singer, 1998, p. 237).

To check for possible biases in the measurement of the coefficients arising from the adoption of the WLS estimator, we supplement the estimates from the WLS with results obtained from the Fixed Effects specification[14].

5. Results and discussion

Before discussing the econometric results, we looked at the mean values of the hours worked in each sector per year and by the seven age-cohort groups. Summaries are reported in table 5 and Figure 10. Overall, comparing the allocation of time in each sector, we see that the average amount of time devoted to agriculture decreases over time (~-6%), with services (~+3%), industry (~+1%) and manufacturing

[13] See Annex A for details about cohorts' construction

[14] A number of supplementary robustness checks will be included at a later stage. These will include (i) results from samples disaggregated by demographic characteristics like gender, rural/urban residence or agricultural households/non-agricultural households; (ii) control of the measurement error problem by improving the size of cells from 6-years age bands to 10-years generation bands.

(~+2%) that conversely experience an upward trend. A more detailed picture is provided in Figure 10 where we plot the share of time disentangling the sample by ages' cohorts. Looking at the differential across years for each age cohort we note that the largest variation of time allocation occurs in particular among cohorts with younger head of households, namely the 15-21 and 22-28 age cohorts. In relation to the first case, the large decrease in time allocated to agricultural jobs (~-14%) is compensated by an improvement in the time devoted to both industry (~+10%) and services (~+5%). Looking at the other cohort, we register a similar pattern; this time all sectors contribute to compensate the shrinkage in time allocation to agriculture: time spent in industry increases by ~+2%, in manufacturing by ~+5% and in services by ~+4%. Smaller movements are registered for the other cohorts.

5.1 WLS estimates

From now on we will discuss the econometric results, focusing on the estimates for equation (3). The estimates from the regressions with FE and WLS are reported in Table 6 and Table 7 in odd and even columns. Both tables present the share of hours worked per week in all the sectors aforementioned. In Table 6, columns (i) and (ii) show the results for hours worked in agriculture, whilst columns (iii) and (iv) concern the services sector. Results for industry (columns (i) and (ii)) and manufacturing (columns (iii) and (iv)) are reported in Table 7. All regressions are conducted on households' demographic, wealth, productivity and facilities' characteristics. Cohorts fixed effects (not shown) are included in order to expunge the dependence between the regressors and the error term evidenced in equation (3). Results are consistent across the two specifications for most of the variables. In order to provide a complete picture of the results we will comment on the two tables jointly. We start by looking at the effect of households' gender composition on the hours worked in each sector. Household composition in terms of share of females in different ages does not really affect the time allocation across occupations. Looking at Table 6 and Table 7 we only find consistent results for time spent in industry, which decreases consistently for young females (15-19) with respect to males. Even though only significant in the FE specification, we find that households with a large share of females aged 20-34 experience a decrease in the share of hours devoted to agriculture. Time spent working in agriculture also decreases as the dependency ratio (or consumer-producer ratio) increases. It is interesting to see that the higher the consumer-producer ratio the greater the work effort (time) allocated to services. Households with a higher than average education for people in working age tend to leave agriculture and enter into services. The average number of years of education significantly and negatively influence the number of hours worked per week in agriculture, and significantly and positively affect the time spent on services. Turning to the vector $L_{cs,t}$, farm related variables are not significant (when correcting for heteroskedasticity) apart from the variable on annual expenditure on agricultural labour, which results in a negative response for services. Operated land has a positive but non-statistically significant coefficient for agriculture, however, both the t-statistics at the border (-1.49) and the significance in the FE specification can provide weak evidence that the higher the land, the more the time spent in agricultural jobs might be economically viable. Interesting, but sometimes counterintuitive results arise when moving to wealth-related variables. For instance, the number of total tropical livestock units is negatively related with time spent in agriculture, and positively related with time spent in services sectors. A counterintuitive result arises when controlling for the percentage of households owning a dwelling, which results in a positive correlation with the time spent in agriculture. When looking for the poverty status, we find negative and statistically significant coefficients for time spent in agriculture and positive and statistically significant coefficients for that which relates to manufacturing. On average, richer households reduce the time spent working in agriculture and increase the time devoted to manufacturing. Regarding infrastructural attributes, of note is the overall effect of the electricity ownership, which we employ as a proxy to control for access to infrastructures: the coefficients for time spent in agriculture have the expected sign (negative), even though weakly significant, while we register an increase in time spent in services and industry sectors. Among the other variables included within the vector of access to infrastructure, only the distance from the nearest motorable road appears to be significant. This variable, which is often used in empirical research as a proxy for household market access is significant for agriculture, whilst in relation to services we can draw some conclusions based only for the FE specification. A longer distance from motorable roads may present a problem for farmers to reach urbanized centres to sell the agricultural products; this may form an incentive to reduce the time spent in agriculture in favour of other sectors. We use the distance to the nearest bank as a proxy for the distance to the nearest city, assuming that banks are located mainly in urbanized centres. Distance to the nearest bank is positively and significantly related to hours spent in agriculture, suggesting that the farther away the town, the more hours people will work in agricultural jobs, since they would face problems moving back and forth from the town easily. This result confirms the finding of Magai et al (2015). However, distance from the nearest bank can also be interpreted as an indicator of financial inclusion, in particular as a measure of access to credit and use of bank services. When access to financial services is not hampered by constraints such as the distance to financial institutions, the time spent for agricultural activities increases. The amount of credit borrowed by households, which is further introduced, confirms the signs of the distance to banks, although not significant. As shown until now, the reasons why people move in/out from agriculture and the other sectors are several and complex. The variability in the households' occupational portfolio, and thus in the sectoral composition of GDP, are often related to spatial changes. Thus, it is crucial to also control for the relevance of migration and how it acts in Ghanaian context. We use in-migration as a proxy for spatial transformation, defining it as the percentage of households within the cohort moving to the village in the previous five years. The resulting coefficient is negatively related to time spent working in agriculture, and positively related to time spent working in manufacturing. The striking finding is that on average in Ghana, people deciding to move away from the original position look to jobs in fields different than agriculture.

6. Final remarks

In Sub-Saharan Africa, the structural transformation process has not been as growth-enhancing as in Asia, but it is characterized by a vivid expansion of the low productive sectors, in particular services. In order to trace an exhaustive picture of the evolution of economy, society and productivity in Ghana we first provide a descriptive analysis of the factors involved in agricultural and economic transition, both at national and regional scale, and afterwards we try to assess which are the determinants influencing workers' time allocation in each sector.

Our findings show that in Ghana structural transformation is occurring slowly, not in every region, and not at the same speed. Overall, the different magnitude of changes is not enough to rapidly transform local economies in the same way. A remarkable dualism emerges between south and north, but more specifically between the coastal area and the rest of the country. This is particularly evident when looking at the reallocation of labour across sectors, at the agricultural production and technology adoption. Northern areas still rely a great deal on low productive agriculture and the economy's transition to high-productive agriculture or other sectors appears to be slow at the moment. The agricultural sector's draining is not compensated by a quick reallocation of labour to services or industry. On the other hand, in southern regions while agricultural employment did decrease, the labour that was released was absorbed mostly by low-productivity sectors, with a presumable low impact on economy wide-productivity. This might be due to the weak and inadequate transformation of the agricultural sector itself, which did not experience an increase in the agricultural productivity that could lead in turn to the development of other spin off industries.

Plausible explanations for that are related to factors such as the level of education, adoption of technologies and as reported in the literature, also by migration flows. In order to investigate the incidence of such correlates on time allocation, we have proposed a pseudo-panel estimation technique based on cohorts clustered at age, sex and region of residence of the household head's level. Controlling for a large set of variables that affect time spent in each sector, our models deal particularly well with agriculture and services related time shares.

One of the most striking findings regards the education of individuals, which is one of the main determinants of households' occupational choices across sectors. Results are robust in particular regarding agriculture and services. Mobility of labour is likely to occur in particular for households with higher educated individuals, who reduce time spent working in agriculture and increase time devoted to services related jobs. Moreover, we show that addressing structural constraints remains crucial for agriculture capacity to generate employment opportunities. Poor connectivity, which accounts for the lack of Green Revolution, leads to limited competition, market fragmentation and undermines households' possibility to shift their production systems towards more sustainable ones. Infrastructure constraints should be lifted in order to promote, first of all, development of agricultural sector, since isolation of Ghanaian households from main infrastructures contributes to trap them in agricultural jobs. Structural transformation in Ghana is associated also with North-South migration and as in most developing countries with a rural-urban mobility (Osei and Jedwab, 2013): this is reflected in an exit from agriculture and in a growth in time spent into manufacturing sector.

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APPENDIX 1

Table 1. Descriptive statistics – Full Sample

	GLSS3 1991-92	GLSS4 1998-99	GLSS5 2005-06
Households living in rural area	65.40	60.33	51.79
Farmer households	65.13	63.34	56.58
Demographics			
Household size	4.48	4.31	4.01
# children in hh	2.08	1.35	1.61
# adults in hh	2.36	2.04	2.43
Dependency ratio	0.47	0.39	0.40
# sons in hh	1.20	0.75	0.99
# daughters in hh	1.06	0.74	0.90
Average yrs of education in hh	2.65	4.00	5.34
Highest yrs of education in hh	4.70	6.19	8.25
Education of female relative all hh members	35.02	27.80	37.43
Head characteristics			
Female headed hh	32.17	31.93	29.72
Head of hh age	44.29	44.94	44.96
Head of hh single	31.24	46.24	45.36
Female head of hh widow	7.37	8.77	8.65
Head of hh yrs of education	3.40	5.11	6.59
N	4520	5998	8688
Participation in labour activities			
# adult hh members employed	1.65	1.29	1.70
# adult hh members unemployed	0.06	0.06	0.06
# adult hh members inactive	0.42	0.47	0.54
Employed adult members of on all adult hh members	72.52	68.61	74.64
Unemployed adult members of on all adult hh members	2.01	2.60	1.73
Inactive adult members of on all adult hh members	13.00	16.66	14.96
Weekly hours worked	36.85	34.52	39.99
Hourly wage - 2005 GH¢	0.15	1.85	0.60
Head employed in agriculture	55.90	49.52	48.98
Head employed in manufacturing	7.98	9.50	9.64
Head employed in wholesale and retail trade	11.85	14.00	13.81
Head employed in transport, storage and communication	3.34	3.88	4.22
Head employed in community, social and personal services	13.16	12.47	11.53
# adults employed in agriculture	1.56	0.81	1.10
# adults employed in manufacturing	0.16	0.17	0.21
# adults employed in wholesale and retail trade	0.30	0.29	0.29
# adults employed in transport, storage and communication	0.04	0.04	0.05
# adult hh members employed in community, social and services	0.17	0.17	0.17
N	4347	5327	7722
Total # people employed in agriculture	9,938,713	10,600,000	13,000,000
Total # people employed in industry	2,511,103	3,323,276	4,786,961
Total # people employed in services	5,833,305	7,131,740	8,933,604
Consumption, annual per adult equivalent spending, 2005 GH¢			
Food expenditure	198.96	359.21	334.92
Non-food expenditure	153.52	259.06	286.12
Expenditure on housing	11.51	16.62	23.19
N	4523	5998	8688

Income

	GLSS3 1991-92	GLSS4 1998-99	GLSS5 2005-06
Gross total household income - 2005 GH¢	765.33	1164.62	1960.05
On-farm crop production - 2005 GH¢	98.73	170.87	390.51
On-farm production of livestock - 2005 GH¢	20.71	52.52	32.41
Wage Employment - Agriculture & Fishing - 2005 GH¢	15.50	11.74	22.07
Wage Employment - Nonfarm Activities - 2005 GH¢	140.64	175.99	287.79
Non-agr business - 2005 GH¢	456.73	702.71	1167.32
Transfers and other sources - 2005 GH¢	33.03	50.79	59.95
On-farm crop production	30.73	32.91	31.87
On-farm production of livestock	5.36	5.71	1.96
Wage Employment - Agriculture & Fishing	2.19	1.53	1.90
Wage Employment - Non-farm Activities	15.53	14.26	17.51
Non-agr business	34.66	30.30	32.14
Transfers and other sources	10.24	12.72	11.45
N	4523	5998	8688
Durables			
Value of durables - 2005 GH¢	643.72	2210.21	1225.30
HH owning refrigerator	9.69	18.81	22.76
HH owning fan	16.81	26.73	31.51
HH owning stove	16.11	14.49	18.94
HH owning furniture	69.54	71.99	57.83
HH owning house	32.25	33.63	33.58
HH owning bike	18.17	21.72	24.21
HH owning car	2.21	2.98	3.31
N	109	1303	1629
value of agricultural assets - 2005 GH¢	332.7	154.1	138.2
N	3848	5261	8638
Access to credit			
Credit beneficiary households	20.01	35.11	28.05
N	4523	5998	8688
Formal loan source	10.72	12.44	23.19
Informal loan source	91.16	84.30	73.27
Informal loan source - Relative and Friends	73.15	57.55	53.74
Outstanding loan amount - 2005 GH¢	79.61	104.97	181.74
Loan purpose - Agriculture activity	17.24	11.36	16.43
Loan purpose - Business	21.33	26.16	27.47
Loan purpose - Housing	3.31	4.81	5.34
N	905	2063	2337
Total households	3,320,000	4,245,694	5,538,133
# farmers	2,958	3,695	4,755
Total farmers	2,171,172	2,561,278	2,883,937

Note: Figures for loan sources and loan purposes are calculated on the subsample of credit beneficiary households, respectively for 910, 1968, 2281 observations (GLSS3, GLSS4, GLSS5). Durable goods are computed

Table 2. Descriptive statistics -Agricultural Households

	GLSS3 1991-92	GLSS4 1998-99	GLSS5 2005-06
Households living in rural area	84.31	83.44	83.13
Demographics			
Household size	4.90	4.78	4.68
# children in hh	2.35	1.43	2.04
# adult in hh	2.52	2.07	2.71
Dependency ratio	0.50	0.39	0.46
# sons in hh	1.36	0.80	1.26
# daughters in hh	1.16	0.75	1.09
Average yrs of education in hh	2.23	3.13	3.85
Highest yrs of education in hh	4.39	5.26	7.03
Education of female relative all hh members	31.12	22.18	33.39
Head characteristics			
Female headed hh	25.56	26.66	23.19
Head of hh age	45.36	46.29	47.11
Head of hh single	26.62	41.31	35.96
Female head of hh widow	6.39	8.67	7.88
Head of hh yrs of education	2.89	4.11	4.98
N	2958	3695	4755
Participation in labour activities			
# adult hh members employed	1.82	1.36	1.91
# adult hh members unemployed	0.03	0.03	0.03
# adult hh members inactive	0.34	0.41	0.50
Employed adult members on all adult hh members	74.52	70.44	74.68
Unemployed adult members on all adult hh members	0.84	1.07	0.97
Inactive adult members on all adult hh members	10.33	14.91	13.37
Weekly hours worked	33.04	33.34	34.14
Hourly wage - 2005 GH¢	0.12	0.64	0.52
Head employed in agriculture	78.14	73.87	77.54
Head employed in manufacturing	3.80	5.34	4.73
Head employed in wholesale and retail trade	5.05	6.28	4.56
Head employed in transport, storage and communication	1.15	1.22	1.46
Head employed in community, social and personal services	7.69	8.27	4.65
# adults employed in agriculture	2.23	1.22	1.78
# adults employed in manufacturing	0.10	0.12	0.16
# adults employed in wholesale and retail trade	0.19	0.17	0.16
# adults employed in transport, storage and communication	0.02	0.01	0.02
# adults employed in community, social and personal services	0.10	0.11	0.08
N	2951	3391	4468
Consumption, annual per adult equivalent spending, 2005 GH¢			
Food expenditure	148.79	278.88	222.14
Non-food expenditure	112.01	197.32	168.99
Housing expenditure	6.26	11.32	9.97
N	2958	3695	4755
Income			
Gross total household income - 2005 GH¢	629.51	911.83	1735.56
On-farm crop production - 2005 GH¢	149.46	253.94	671.76
On-farm production of livestock - 2005 GH¢	30.80	69.76	33.13
Wage Employment - Agriculture & Fishing - 2005 GH¢	13.58	11.02	23.81

	GLSS3 1991-92	GLSS4 1998-99	GLSS5 2005-06
Wage Employment - Nonfarm Activities - 2005 GH¢	75.78	75.96	112.74
Non-agr business - 2005 GH¢	338.10	466.83	855.46
Transfers and other sources - 2005 GH¢	21.80	34.32	38.65
On-farm crop production	46.42	52.28	57.78
On-farm production of livestock	7.89	7.38	2.13
Wage Employment - Agriculture & Fishing	1.87	1.43	2.03
Wage Employment - Non-farm Activities	8.63	6.97	6.12
Non-agr business	27.75	22.90	25.24
Transfers and other sources	7.43	9.04	6.70
N	2958	3695	4755
Farm activity			
Operated land - hectares	2.26	2.47	3.28
Owned land - hectares	3.12	3.77	3.86
HH owning land with deed	5.92	11.05	16.58
Tropical Livestock Unit - cattle	3.1	3.3	3.7
Tropical Livestock Unit - total	0.9	1.4	1.1
Tropical Livestock Unit per hectare	0.8	1.0	0.7
Cash crop production - 2005 GH¢	91.79	92.02	334.09
Food crop production - 2005 GH¢	133.20	110.36	336.14
Cash crop production as a share of total value of production	48.39	41.63	55.36
Food crop production as a share of total value of production	3.19	3.93	5.15
Share of crop production sold	48.4	41.9	55.4
N	2958	3695	4755
Agricultural inputs			
Inorganic fertilizer expenditure - 2005 GH¢	2.26	2.68	11.34
Pesticides expenditure - 2005 GH¢	2.03	3.38	8.20
Seeds and seedlings expenditure - 2005 GH¢	1.60	2.68	2.64
Fertilizer, pesticides and seeds expenditure - 2005 GH¢	6.05	10.03	25.55
Inorganic fertilizer expenditure - 2005 GH¢ per hectare	14.81	16.83	23.91
Pesticides expenditure - 2005 GH¢ per hectare	62.71	70.37	55.99
Seeds and seedlings expenditure - 2005 GH¢ per hectare	1.68	3.01	5.26
Fertilizer, pesticides and seeds expenditure - 2005 GH¢ per hectare	1.20	2.15	5.31
HH hiring labourers for crop production	1.53	3.12	2.25
Hired labour expenditure - 2005 GH¢	4.73	8.97	14.19
Hired labour expenditure - 2005 GH¢ per hectare	16.61	16.46	17.36
N	2958	3695	4755
Agricultural assets			
Value of agricultural assets - 2005 GH¢	335.69	146.70	148.75
N	108	1194	1362
HH owning tractor	0.30	NA[a]	0.32
HH owning plough	0.37	0.13	1.06
HH owning cart	0.24	0.40	0.95
HH owning sprayer	2.16	3.38	6.39
N	2958	3695	4755
Durables			
Value of durables - 2005 GH¢	625.06	2122.26	1195.40
HH owning refrigerator	2.81	7.05	9.02
HH owning fan	5.54	11.79	14.13
HH owning stove	9.03	7.29	7.79
HH owning furniture	62.12	64.92	50.77
HH owning house	41.77	44.16	46.99
HH owning bike	24.40	29.76	34.77

	GLSS3 1991-92	GLSS4 1998-99	GLSS5 2005-06
HH owning car	1.08	1.21	1.57
N	2958	3695	4755
Access to credit			
Credit beneficiary households	29.41	35.34	31.57
N	2958	3695	4755
Formal loan source	10.23	11.49	21.54
Informal loan source	91.38	83.62	74.54
Informal loan source - Relative and Friends	73.68	57.01	54.34
Outstanding loan amount - 2005 GH¢	75.30	80.94	144.62
Loan purpose - Agriculture activity	17.59	17.70	24.58
Loan purpose - Business	20.92	20.18	21.57
Loan purpose - Housing	3.22	4.59	5.27
N	870	1321	1425
Total farmers	2,171,249	2,561,339	2,883,958

[a] Data on number of tractors is not available for GLSS4

Table 3. Descriptive statistics – Full Sample and Agricultural Households, by Macro regions

	Full Sample									Agricultural Households								
	91/92 North	98/99 North	05/06 North	91/92 Center	98/99 Center	05/06 Center	91/92 South	98/99 South	05/06 South	91/92 North	98/99 North	05/06 North	91/92 Center	98/99 Center	05/06 Center	91/92 South	98/99 South	05/06 South
Households Demographic Characteristics																		
Farmers	88.7	88.3	78.6	72.8	66.5	57.5	46.1	39.7	33.9	100	100	100	100	100	100	100	100	100
RURURB==Rural	81.3	81	81.3	72.2	68.9	60.2	49.1	48	42.2	86.2	85	89	84	80.8	79.2	83.6	88.3	86.5
Household size	5.78	5.27	5.62	4.46	4.26	3.87	4.00	3.98	3.56	5.97	5.43	6	4.77	4.67	4.38	4.4	4.46	4.17
Dependency ratio (hh members aged <15 & >64/hh size)	0.49	0.18	0.45	0.49	0.42	0.42	0.45	0.42	0.36	0.5	0.18	0.46	0.5	0.44	0.46	0.49	0.48	0.46
avg years of education in hh	0.85	2.48	2.02	2.85	4.2	5.42	3.09	4.35	6.53	0.66	2.06	1.39	2.67	3.66	4.57	2.45	2.85	4.52
highest years of education in hh	2.36	2.57	4.71	5.05	6.77	8.43	5.14	6.88	9.39	2.15	2.11	3.93	4.99	6.39	7.93	4.77	5.51	7.87
education of female members relative to education of all hh members	14.9	3.42	23.7	37.6	32.6	40.4	39.3	31.2	39	14	1.44	21	36.1	28.8	37.9	33	25.7	35.2
female headed hh	9.26	14.3	13.4	34.3	36.8	33.3	38.1	32.3	31.4	6.9	11.6	8.01	29.3	30.9	27.3	31.5	30.6	28.6
Age - Head	45.8	45.3	46.1	44.9	45	45.2	42.8	44.8	44.2	45.7	45.7	46.2	45.6	46.5	47.6	44.5	46.3	46.9
single head of hh	18.1	19.5	18.9	33.8	53.2	48.7	32.9	47.4	51.4	14.7	16	13.5	29.5	49.2	41.2	29.3	46.1	45.1
female head of hh widow	5.49	7.1	7.63	7.98	8.51	9.48	7.25	9.85	7.95	4.25	6.43	5.34	6.95	7.93	8.57	6.8	12.5	8.58
avg years of education head of hh	1	2.55	2.21	3.62	5.43	6.79	4.03	5.74	8.04	0.85	2.1	1.48	3.42	4.89	5.94	3.25	4.14	6.02
Observations	637	740	1882	2255	3060	3936	1628	2198	2746	565	665	1530	1641	2168	2242	750	862	894
Participation in labour activities																		
hh share of employed adult members on all adult hh members	69.9	76.3	76.3	72	66.6	74.5	74.3	68.5	74.2	70.6	75.5	77.8	73.8	68.1	73.6	79	71.7	74.6
hh share of unemployed adult members on all adult hh members	1.15	1.23	1.04	2.04	2.21	1.47	2.33	3.67	2.36	0.98	0.83	1.01	1.04	0.85	0.94	0.31	1.77	0.99
hh share of inactive adult members on all adult hh members	15.7	13.2	14.5	12.3	17.2	13.7	12.9	17.2	17	15.6	14.2	13	10.1	15.9	13	6.93	13.2	14.4
(mean) hours/week	40.4	35.5	36.8	35.1	34.8	37.5	37.9	33.8	44.7	39.5	34.8	35.5	31.6	33.4	33.3	31.3	32	34.9
(mean) wage/hrly	0.06	0.83	0.47	0.15	1.53	0.53	0.19	2.69	0.73	0.06	0.73	0.42	0.12	0.69	0.49	0.17	0.44	0.65
HH head employed in Agriculture	80.3	70.9	69.6	59.7	51.5	53.2	40.6	38.6	34.9	88	77.8	79.9	75.6	70.1	76.5	76.2	79.2	77.9
HH head employed in Manufacturing	1.9	4.34	4.24	6.58	8.81	9.6	12.5	12.5	11.9	0.88	3.97	2.19	4.46	6.08	5.96	4.55	4.75	4.16
HH head employed in Wholesale and Retail Trade	5.21	9.63	6.65	12.2	13.9	13	14.1	15.9	17.7	2.65	5.68	3.33	5.92	7.11	4.86	4.95	4.89	4.94
HH head employed in Transport	1.42	1.11	1.09	2.94	3.04	3.62	4.68	6.12	6.3	0.71	0.52	0.15	1.28	1.73	1.41	1.2	0.62	2.66
HH head employed in Community	6.32	10.5	6.53	11.9	11.9	10.3	17.7	14.1	15.3	4.42	8.7	3.65	8	9.03	5.26	9.49	6.18	4.15
Observations	633	628	1651	2174	2725	3675	1540	1974	2396	565	565	1373	1638	1996	2215	748	830	880

	Full Sample									Agricultural Households								
	91/92 North	98/99 North	05/06 North	91/92 Center	98/99 Center	05/06 Center	91/92 South	98/99 South	05/06 South	91/92 North	98/99 North	05/06 North	91/92 Center	98/99 Center	05/06 Center	91/92 South	98/99 South	05/06 South
Access to Credit																		
Dummy for credit beneficiary households	16.9	14.6	24.6	23.9	36.1	30.9	15.8	42.3	25.7	18.9	13.7	25.3	31.7	36.1	33.3	32.4	53.7	33.4
Observations	638	740	1904	2255	3060	4003	1630	2198	2780	566	665	1551	1641	2168	2289	751	862	915
Formal Loan source	7.41	17.8	19.5	12.2	13.3	25.2	8.91	10.6	21.3	7.48	13.4	15.9	11.5	11.6	22.6	8.64	10.9	23.1
Informal Loan source	93.5	76.1	78.1	89.6	80.4	71.3	93.4	90.2	74.5	93.5	79.3	82	90.2	79.2	73.7	93	91.8	71.4
Loan source - Relatives and friends	86.1	58.1	65.2	70.5	49.8	51	73.3	67	53.8	86	64	69.5	71	49.3	52.2	74.1	67.7	48.7
Credit amount	32.2	45.7	84.7	88.8	102	180	80.2	117	220	32.3	41.3	78.7	83.2	84.6	157	77.4	84.5	163
Loan purpose - Agriculture	26.9	19.3	27	18.4	12.1	17.9	10.9	9.38	10.1	26.2	23.2	29.8	18.7	17.3	25.8	11.5	17	18.4
Loan purpose - Business	16.7	28.9	21.6	20	23.3	25.8	26	29.2	32.4	16.8	28.4	17.4	19.6	18.4	20.9	25.5	21	26
Loan purpose - Housing	1.85	4.58	5.26	3.53	4.69	5.14	3.49	4.99	5.69	1.87	3.13	5.69	3.27	4.94	4.95	3.7	4.37	5.7
Observations	108	112	413	539	1081	1220	258	870	704	107	96	337	520	786	769	243	439	319
Income																		
Gross total household income	488	707	2190	747	1060	1774	899	1506	2114	463	671	2116	674	906	1564	658	1150	1772
Gross Annual Crop Income- Own Cons Imputed	185	272	903	97.4	154	310	66.7	153	295	206	305	912	132	224	495	144	279	845
Gross income own-farm production of livestock	48.7	42.4	25.5	20.6	32.1	30.9	9.96	85.9	37.2	54.1	47	27.5	27.6	37.5	39.1	20.3	168	25.1
Wage Employment- Agriculture & Fishing	5.4	4.07	8.66	14.5	10.5	22.1	20.9	16.8	27.3	3.99	3.05	8.16	14.4	10.5	22.9	19	19.7	39.9
Wage Employment- Nonfarm Activities	54.9	67.2	119	120	147	208	203	263	459	41.2	44.1	64.9	86.1	88.8	126	79.4	75	127
Gross income from non-agr business	188	305	1119	462	657	1142	555	935	1219	153	256	1089	387	502	833	371	580	694
Transfers and other sources of income	5.76	16.6	15.9	33.5	59.2	60.7	43	53.1	76.3	5.46	15.7	13.8	26.1	44	47.6	24.8	28.6	41.4
Share of income from crops	53	61.4	59.7	31.8	32.9	32.3	20.5	21	20.4	59.3	68.7	70.3	43	48.2	53.2	44.2	46.9	56.6
Share of income from livestock	12.1	9.49	2.62	5.66	5.54	2.25	2.29	4.37	1.33	13.3	9.97	2.59	7.5	6.73	2.33	4.62	6.49	1.26
Share of income ag wage	0.99	0.59	0.58	1.97	1.25	2.11	2.96	2.31	2.15	0.64	0.35	0.51	1.91	1.31	2.05	2.72	2.73	3.36
Share of income from non-ag wage	7.75	6.54	6.17	13.2	12.9	13.8	21.8	19.4	26.9	4.97	4.41	2.59	9.41	8.1	6.98	9.71	6.62	7.39
Share of income from selfemp	23.4	14.9	25.2	34.4	30.4	33.9	39.5	36.7	32.6	19.9	12.1	21.8	29.2	24.4	26.8	30.6	29.5	24.9
Share of transfers and other sources of income	2.41	6.18	4.73	11.9	15.1	12.5	11	12.1	12.7	1.86	4.5	2.18	9.05	11.3	8.65	8.09	7.82	6.5
Observations	638	740	1904	2255	3060	4003	1630	2198	2780	566	665	1551	1641	2168	2289	751	862	915
Durables																		
total value of durables - imputed	348	666	656	725	2116	1163	636	2957	1532	307	668	600	737	2270	1209	600	3076	1704

HH owns a refrigerator	0.6	2.78	5.05	8.07	17.5	20.6	15.1	27.1	32.6	0.45	1.58	2.28	4	9.07	11.1	1.84	7.06	10.5
HH owns a fan	2.82	5.82	11.9	13.5	23.7	27.9	26.3	39.4	44.1	0.68	2.69	6.25	7.01	14.5	16.1	5.67	13.4	16.9
HH owns a stove	9.66	6.23	4.91	13.9	12.1	16.2	21.5	21.1	28.1	8.16	5.48	3.39	9.22	8.32	8.65	9.2	6.43	9.87
HH owns a furniture	31.6	45.5	31.8	70.7	73.9	58.9	81.2	79.8	66.8	28.6	42.3	30	66	69.4	54.3	76.5	74.5	61.7
HH owns a house	39	46.6	51.1	34.2	32.3	31.9	27.2	30.3	28.9	39.5	49.1	55.8	40.5	39.9	41.6	46.2	50	50.9
HH owns a bike	67.6	72.8	73.2	14.5	16.2	20.7	5.79	9.15	9.49	71	76.7	79.8	17.3	19.7	25.2	8.13	11.9	15.3
HH owns a car	1.41	0	1.12	1.91	2.44	2.52	2.89	4.93	5.23	1.13	0	0.71	1.22	1.94	1.81	0.77	0.55	1.82
Observations	497	617	1900	1934	2672	3983	1417	1972	2755	441	548	1551	1399	1905	2289	652	759	915
total value of agricultural assets - imputed	479	135	287	126	181	182	718	284	128	479	109	316	128	169	131	718	102	84.1
Observations	42	103	404	54	800	814	13	400	411	42	97	368	53	762	666	13	335	328

Table 4. Descriptive statistics (land, inputs, livestock, agricultural assets), by Macro-regions

	Agricultural Households								
	91/92	98/99	05/06	91/92	98/99	05/06	91/92	98/99	05/06
Land	North	North	North	Center	Center	Center	South	South	South
Operated land - hectares	2.63	2.28	4.86	2.03	2.26	2.47	2.46	3.12	3.63
Owned land - hectares	2.73	2.47	4.99	2.78	3.94	3.12	4.28	4.02	3.97
(mean) land own_t??	0	0.41	3.55	6.89	10.3	15.9	8.26	22.7	29.9
Cash crop production - 2005 GH¢	47	59.6	177	98.9	68.7	226	110	178	715
Food crop production - 2005 GH¢	152	175	734	162	109	268	56.1	52.8	128
Share of crop production sold	19.8	24.6	39.2	56.1	40.7	57.5	53.1	59.9	65.3
Production value of cash crops relative to food crops ratio	0.57	0.51	0.7	2.34	3.07	4.46	6.9	8.98	10.2
Observations	566	665	1551	1641	2168	2289	751	862	915
Agricultural Input									
Annual agricultural crop costs and expenses.	29.9	42.4	70	36.6	58.1	77.3	37.1	44.9	82.9
Inorganic fertilizer expenditure - 2005 GH¢	5.21	5.19	14.2	1.98	2.47	9.12	0.66	0.84	13.7
Pesticides expenditure - 2005 GH¢	0.21	0.74	1.43	2.26	3.13	9.52	2.9	6.46	11.4
Seeds and seedlings expenditure - 2005 GH¢	3.26	1.69	2.15	1.03	3.47	2.97	1.61	1.73	2.38
Fertilizer, pesticides and seeds expenditure - 2005 GH¢	8.78	12.2	21.8	5.56	9.57	23.6	5.04	9.09	33.3
Hired labour expenditure - 2005 GH¢	7.36	9.79	19	16.7	19.6	26.4	16.4	16.7	22.8
HH hiring labourers for crop production	32.7	57.4	41.7	71.5	75.1	60.4	66.2	71.3	59.2
Inorganic fertilizer expenditure - 2005 GH¢ per ha	2.43	3.74	5.74	1.8	3.73	5.45	0.83	0.59	4.41
Pesticides expenditure - 2005 GH¢ per ha	0.14	0.26	0.55	1.51	2.71	7.86	1.32	2.55	4.01
Seeds and seedlings expenditure - 2005 GH¢ per ha	1.96	1.26	1.2	1.26	4.6	2.7	1.8	1.29	2.22
Fertilizer, pesticides and seeds exp. - 2005 GH¢ per ha	4.8	6.78	9.18	4.98	11.7	16.8	4.13	4.42	13
Hired labour expenditure - 2005 GH¢ per hectare	4.28	7.62	8.08	22.2	22.6	22.7	13.7	10.1	13.9
Observations	566	665	1551	1641	2168	2289	751	862	915
Livestock									
Tropical Livestock Units: cattle	0.98	1.41	1	0.11	0.15	0.17	0.04	0.01	0.02
Tropical Livestock Units: total	2.02	2.76	1.99	0.59	0.78	0.74	0.48	1.02	0.49
Livestock TLU/ha	0.88	1.42	0.78	0.84	1.04	0.72	0.37	0.53	0.35
Observations	496	516	1357	1035	1115	1277	435	448	410
Agricultural Assets									
HH owns tractor(s)	0.71	0	1.03	0.18	0.04	0.17	0.27	0	0
HH owns plough(s)	1.41	0.3	4.69	0.12	0.1	0.05	0.13	0.06	0
HH owns cart(s)	0.53	1.65	4.21	0.24	0.08	0.05	0	0	0
HH owns sprayer(s)	0.18	0.29	1.11	3.11	3.56	8.03	1.6	5.81	7.53
Observations	566	665	1551	1641	2168	2289	751	862	915
Total value of agricultural assets	479	109	316	128	169	131	718	102	84.1
Observations	42	97	368	53	762	666	13	335	328

Table 5. Share (%) Hours/week working in agriculture, services, industry, manufacturing

	GLSS3	GLSS4	GLSS5
	1991-92	**1998-99**	**2005-06**
Agriculture	61.54	54.45	55.2
Services	27.02	31.04	29.93
Industry	1.63	2.12	2.94
Manufacturing	9.7	12.35	11.64
Observations	4,278	5,593	8,098

Table 6. Determinants of share of hours worked in agriculture and services. Fixed Effects and Weighted Least Squares models.

	FE Agriculture (i)		WLS Agriculture (ii)		FE Services (iii)		WLS Services (iv)	
	b	t	b	t	b	t	b	t
Demographic								
% (#/hhsize) of females 15-19	-0.321	[-0.01]	-2.715	[-0.14]	-14.927	[-0.61]	-9.492	[-0.49]
% (#/hhsize) of females 20-34	-16.739*	[-1.97]	-11.564	[-1.49]	2.690	[0.21]	2.680	[0.33]
% (#/hhsize) of females 35-59	-4.553	[-0.55]	-0.977	[-0.16]	5.945	[0.68]	0.861	[0.14]
Household Size (AE)	-0.055	[-0.06]	-0.323	[-0.44]	-0.869	[-0.94]	-0.031	[-0.04]
Dependency ratio (hh members aged <15 & >64/hh members aged 15-64)	-5.982**	[-2.04]	-3.393*	[-1.91]	5.281**	[2.18]	3.269*	[1.71]
Avg years of education (adults 15-60)	-3.230***	[-3.06]	-3.134***	[-4.64]	3.534***	[3.53]	3.249***	[4.41]
Land and Lab. Exp.								
Size of land operated (ha)	0.189**	[2.59]	0.168	[1.49]	-0.053	[-0.85]	-0.014	[-0.12]
Inequality in land distribution within each EA (Gini coefficient)	-2.824	[-0.24]	4.146	[0.54]	14.069	[0.76]	-5.284	[-0.63]
Annual expenditure on hired labour (cedis/ha)	0.050**	[2.01]	0.036	[1.25]	-0.114***	[-3.22]	-0.099***	[-2.97]
Wealth								
Tropical Livestock Units: total	-3.479***	[-2.97]	-2.417***	[-3.40]	2.196	[1.62]	1.750**	[2.13]
Owns a house	11.382**	[2.07]	9.343**	[2.02]	-1.059	[-0.21]	-6.394	[-1.32]
Poverty Status	-8.273*	[-1.88]	-6.731***	[-2.80]	-0.031	[-0.01]	1.822	[0.72]
Access to infrastructure								
Farmers participate in Agr Coop	7.099	[1.57]	3.586	[0.92]	-6.045	[-1.14]	-5.299	[-1.23]
Household has Electricity	-1.983	[-0.22]	-10.507*	[-1.66]	11.383	[0.97]	17.491**	[2.57]
KM from nearest road	-1.407**	[-2.53]	-1.086**	[-2.10]	1.058*	[1.87]	0.703	[1.26]
Facilities								
Permanent market within the community	-6.220	[-1.01]	-4.719	[-1.17]	12.378**	[2.33]	7.716*	[1.82]
KM from rural community to health facility	-0.006	[-0.08]	-0.026	[-0.66]	0.020	[0.28]	0.015	[0.35]
KM from rural community to nearest bank	0.189**	[2.54]	0.104**	[2.43]	-0.238***	[-2.95]	-0.159***	[-3.39]
Credit								
Credit amount (cedis)	0.005	[0.69]	0.008	[1.32]	-0.005	[-0.73]	-0.008	[-1.20]
Migration (HH moved to village in prev. 5y)	-17.387*	[-1.82]	-14.503**	[-2.19]	-6.230	[-0.50]	3.066	[0.44]
Geo								
RURURB==Rural	23.165**	[2.33]	23.05***	[3.88]	-19.269*	[-1.89]	-14.595**	[-2.37]
Agroecological zone 1	1.170	[0.40]	0.116	[0.05]	-2.074	[-0.66]	-2.171	[-0.85]
Agroecological zone 2	2.284	[0.84]	-0.403	[-0.21]	-0.520	[-0.19]	0.160	[0.07]
year==1998/99	3.080	[1.43]	4.307**	[2.34]	-5.009*	[-1.87]	-5.313***	[-2.70]
year==2005/06	10.59***	[3.90]	10.14***	[4.33]	-10.15***	[-2.95]	-9.800***	[-3.99]
Constant	65.57***	[5.91]	48.00***	[4.61]	25.687**	[2.33]	46.75***	[3.69]
Observations	342		342		342		342	
r2	0.419		0.993		0.364		0.986	
F	12.391		205.137		3.714		106.987	

Note: (i) Heteroskedastic-consistent standard errors are estimated in WLS; robust standard errors clustered at cohort level are estimated for FE models;
(ii) t-statistics in brackets;
(iii) Significance levels: *p<0.1, **p<0.05, ***p<0.001.

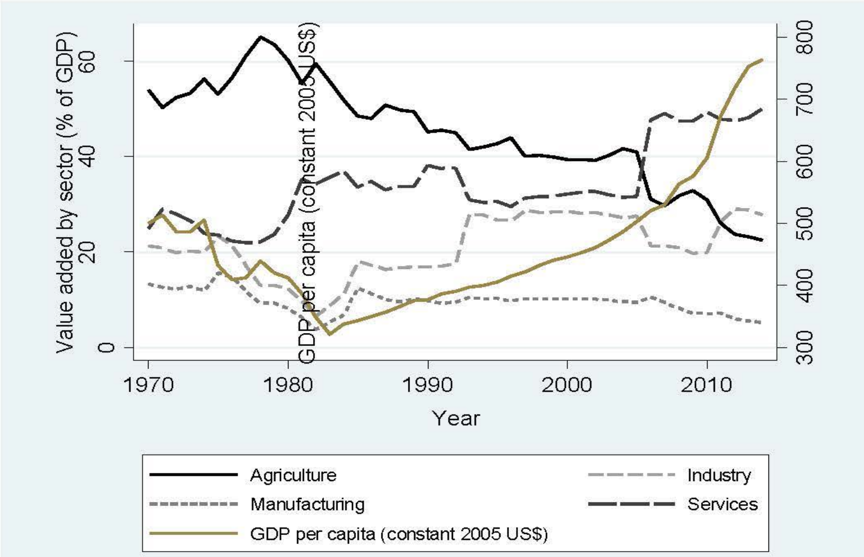
Table 7. Determinants of share of hours worked in industry and manufacturing estimates. Fixed Effects and Weighted Least Squares models.

	FE Industry (v)		WLS Industry (vi)		FE Manufacturing (vii)		WLS Manufacturing (viii)	
	b	t	b	t	b	t	b	t
Demographic								
% (#/hhsize) of females 15-19	-10.78**	[-2.26]	-10.69***	[-3.07]	26.325	[0.95]	16.534	[0.94]
% (#/hhsize) of females 20-34	-2.167	[-1.02]	-2.105	[-1.22]	15.062	[1.22]	9.189	[1.31]
% (#/hhsize) of females 35-59	-0.732	[-0.52]	-0.709	[-0.62]	-1.516	[-0.19]	1.683	[0.31]
Household Size (AE)	0.206	[0.89]	0.211	[1.21]	0.775	[1.00]	0.056	[0.08]
Dependency ratio (hh members aged <15 & >64/hh members aged 15-64)	-0.529	[-0.98]	-0.517	[-1.28]	1.069	[0.35]	1.126	[0.72]
Avg years of education (adults 15-60)	-0.138	[-0.79]	-0.136	[-0.79]	-0.195	[-0.19]	0.065	[0.11]
Land and Lab. Exp.								
Size of land operated (ha)	-0.024	[-0.84]	-0.024	[-0.77]	-0.112	[-1.44]	-0.157	[-1.57]
Inequality in land distribution within each EA (Gini coefficient)	1.229	[0.67]	1.181	[0.63]	-13.006	[-0.81]	3.952	[0.59]
Annual expenditure on hired labour (cedis/ha)	-0.002	[-0.25]	-0.003	[-0.30]	0.067**	[2.22]	0.016	[0.66]
Wealth								
Tropical Livestock Units: total	-0.456*	[-1.70]	-0.466**	[-1.98]	1.755	[1.48]	0.752	[1.23]
Owns a house	-0.512	[-0.68]	-0.521	[-0.56]	-9.826*	[-1.88]	0.556	[0.13]
Poverty Status	0.707*	[1.72]	0.704	[1.31]	7.575	[1.55]	4.728**	[2.19]
Access to infrastructure								
Farmers participate in Agr Coop	0.505	[0.47]	0.495	[0.47]	-1.473	[-0.27]	1.102	[0.32]
Household has Electricity	5.807***	[2.89]	5.847***	[3.98]	-15.147*	[-1.76]	-12.07**	[-2.15]
KM from nearest road	0.014	[0.12]	0.014	[0.10]	0.400	[0.76]	0.541	[1.18]
Facilities								
Permanent market within the community	0.984	[1.51]	0.977	[1.15]	-7.204	[-1.30]	-3.067	[-0.84]
KM from rural community to health facility	0.019	[1.45]	0.019	[1.31]	-0.035	[-0.42]	0.000	[0.01]
KM from rural community to nearest bank	0.000	[0.01]	-0.000	[-0.04]	0.051	[0.56]	0.024	[0.63]
Credit								
Credit amount (cedis)	-0.001	[-0.77]	-0.001	[-0.76]	0.002	[0.19]	0.002	[0.46]
Migration (HH moved to village in prev. 5 yrs)	0.785	[0.59]	0.776	[0.51]	22.237*	[1.80]	10.194*	[1.71]
Geo								
RURURB==Rural	-3.148**	[-2.55]	-3.166**	[-2.59]	-1.057	[-0.16]	-7.333	[-1.36]
Agroecological zone 1	0.457	[0.99]	0.447	[0.66]	0.483	[0.24]	1.258	[0.63]
Agroecological zone 2	0.478	[1.36]	0.463	[0.81]	-2.376	[-1.42]	-0.898	[-0.53]
year==1998/99	-0.821	[-1.64]	-0.805	[-1.57]	2.941	[1.12]	1.490	[0.91]
year==2005/06	-0.709	[-1.11]	-0.710	[-1.27]	0.195	[0.06]	-0.772	[-0.37]
Constant	2.044	[1.33]	1.474	[0.56]	7.303	[0.75]	15.016	[1.41]
Observations	342		342		342		342	
r2	0.277		0.678		0.217		0.895	
F	1.815		3.094		2.351		12.578	

Note: (i) Heteroskedastic-consistent standard errors are estimated in WLS; robust standard errors clustered at cohort level are estimated for FE models;
(ii) t-statistics in brackets;
(iii) Significance levels: *p<0.1, **p<0.05, ***p<0.001.

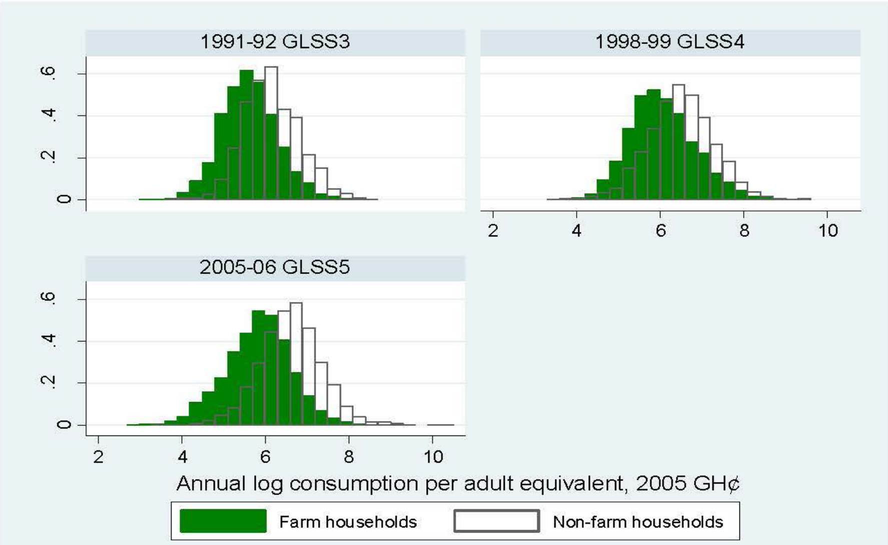
APPENDIX 2 – List of Figures

Figure 1. Value Added by sector (% of GDP), 1965- 2014



Source: The World Bank, World Databank, Development Indicators, 2016.

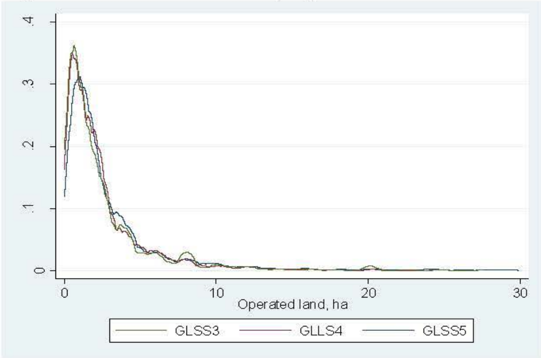
Figure 2. Frequency distribution of consumption for GLSS3, GLSS4, and GLSS5



Source: Authors' computation based on 1991-92, 1998-9, 2005-06 Ghana Living Standards Survey (GLSS).

Note: We perform a t-test for the comparison of means between the agricultural/non-agricultural households for each year ($H_0: \mu_0 = \mu_1$). The two-tailed p-value confirms that in all cases the difference in means is statistically significantly different from 0.

Figure 3. Distribution of operated land sizes: kernel density functions by GLSS waves, ha



Note: Kernel density functions for each wave use the Epanechnikov kernel and optimal bandwidth.

Figure 4. Landholding sizes: pie chart by year

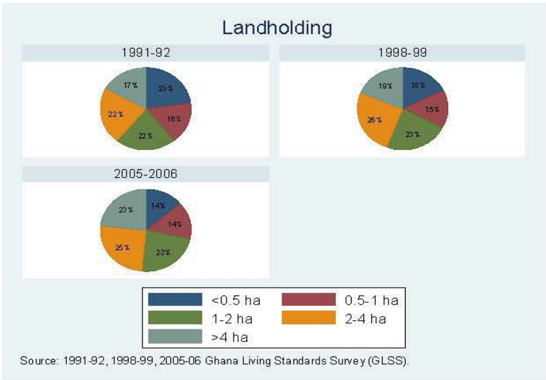


Figure 5. Use of agricultural inputs by land endowment

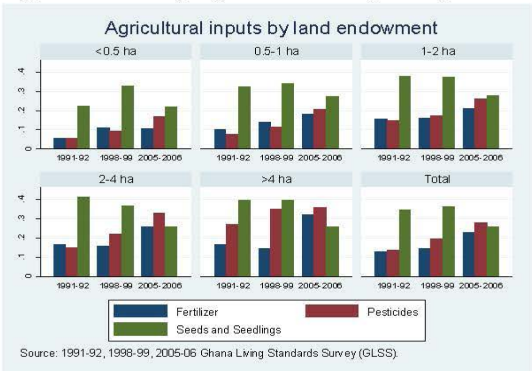


Figure 6. Share of household heads employed in agriculture, manufacturing and services, trend across regions.

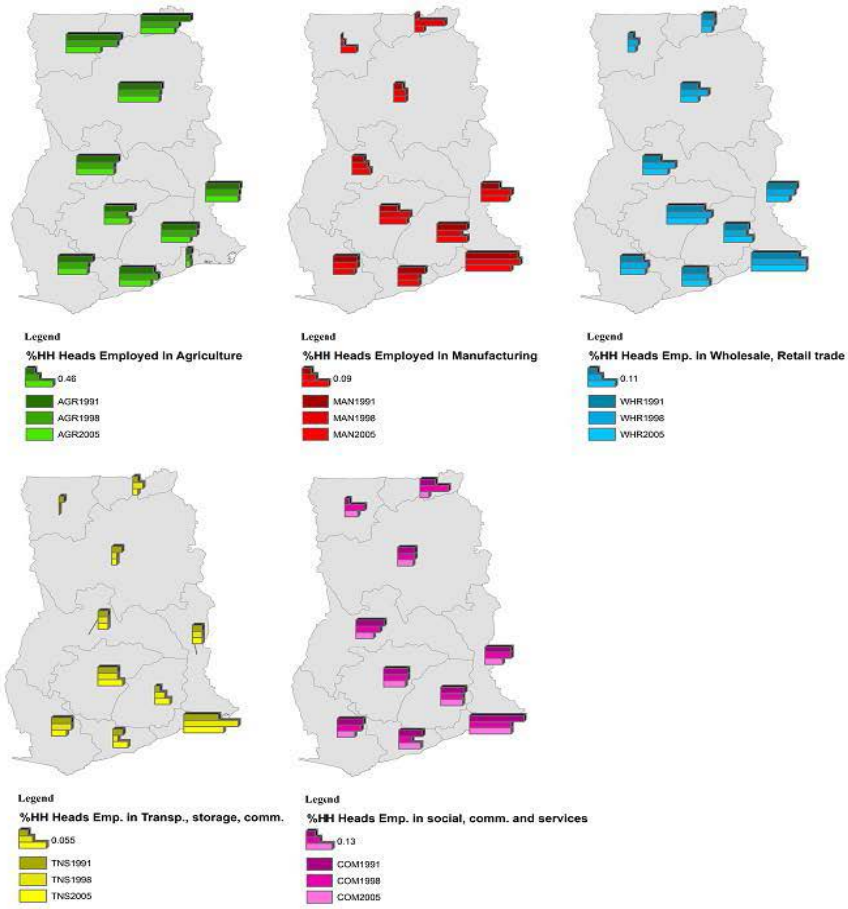


Figure 7. Share of income by sources, across regions in 1991, 1998, 2005.

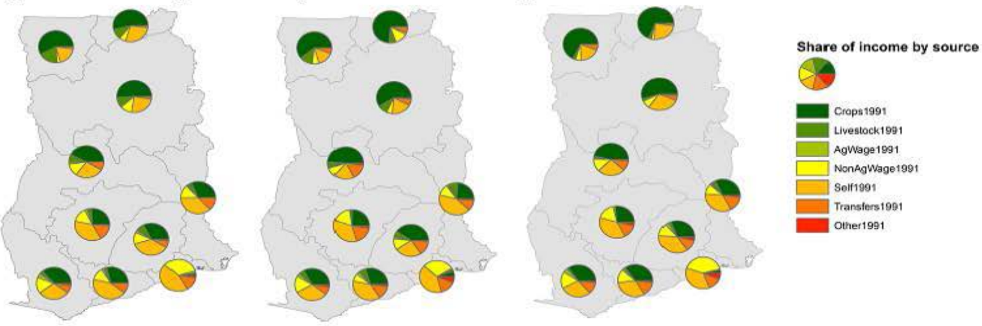


Figure 8. Total value of production of cash crops and food crops, trend across regions

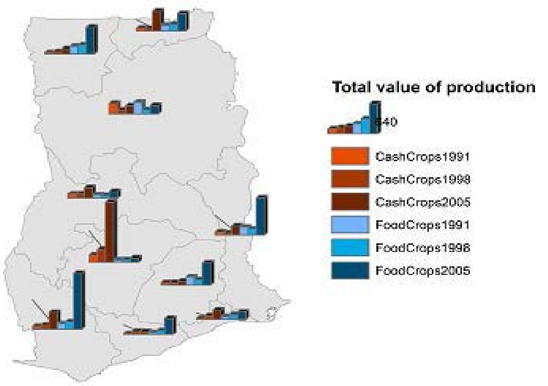


Figure 9. Input expenditure per Ha, trend across regions

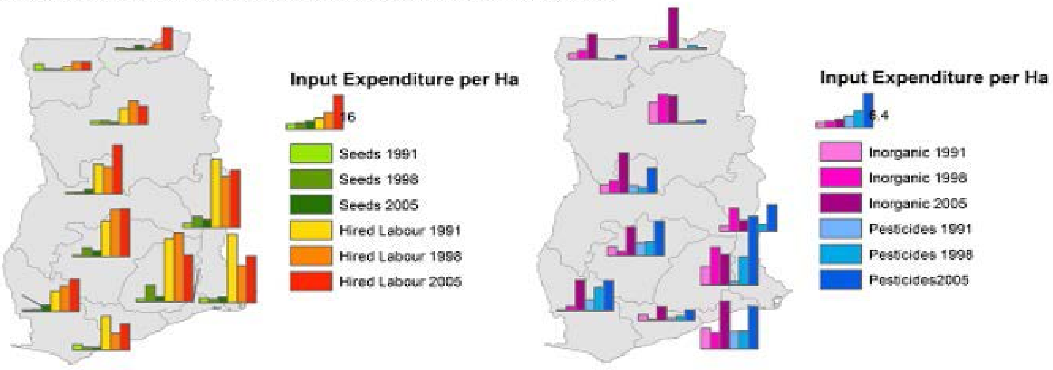
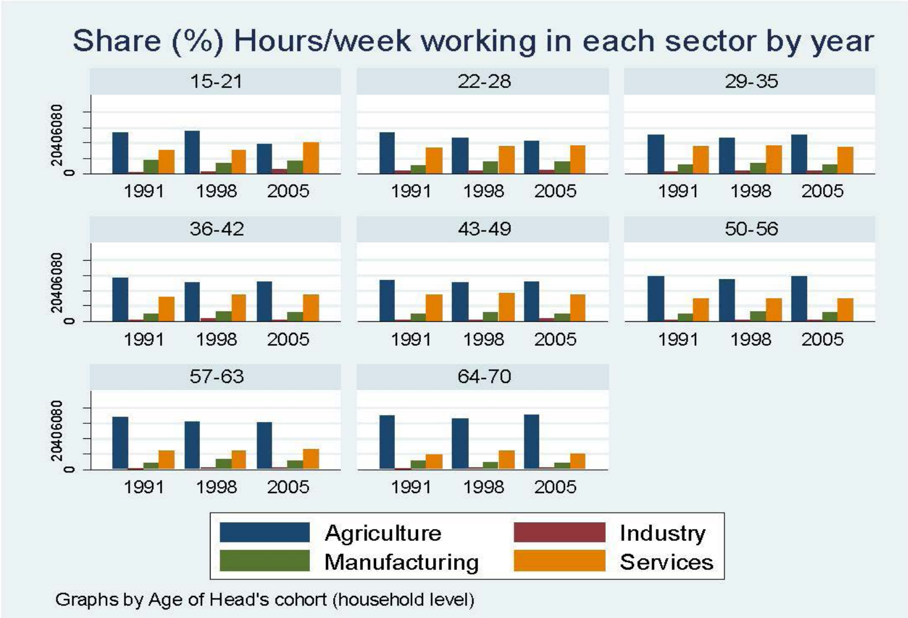


Figure 10. Share of hours/week worked in agriculture, industry and services, by age of head's cohorts, over time.



ANNEX A – Cohorts construction

A.1 Cohorts construction

Cohorts can be defined in terms of single or multiple characteristics. Using a multidimensional grouping system would help increase ing the number of cohort-groups. Hence, we construct our pseudo-panel by grouping households into cohorts according to a joint set of multiple characteristics, namely the household head's age category, his/her sex and residing region.

Since we also want to also analyze the sector of economic activity of the head, we restrict the sample to households with heads aged 15 to 64. More specifically, since the three cross sections fall seven years apart from each other, we reduce the first sample (1991/92) to households whose heads are 15 to 50 years old, the second (1998/99) to households with heads between 22 and 57 y. o. and the third round (2005/06) to household heads with ages ranging between 29 and 64. Similarly to Ackah et al. (2012) we allow households to "age" over time by tracking the same groups across the years.

For each variable included into the analysis, averages within each cohort are treated as individual observations within the pseudo-panel. Following Verbeek and Nijman (1993) we construct the cohorts ensuring that the number of observations per group would be as large as possible to reduce biases in the estimates. On the other hand, since we have only three cross- sections, if the cohorts include a large number of households, the number of cohort-groups generated will be too small, affecting the overall cross-sectional dimension of the panel. We use seven-years bands to define the generational cohorts, which result in eight age classes (15-21, 22-28, 29-35, 36-42, 43-49, 50-56, 57-63 and 64 to 70) generated for each region in each survey year. Our pseudo- panel finally results from the interaction of 7-years generation bands with the ten regions of domicile and a gender variable (male/female) for the household's head, for a total of 114 (out of 160) cohorts tracked over time15[15].

Households whose heads are of these ages and are found in the relevant cross-sections are pooled to form the pseudo cohorts. Even though the households interviewed will change in each round, they will still be fully representative of the cohort designed according to the characteristics of the population.

[15] Most authors include the birth region or more often year of birth intervals (Propper, Rees and Green, 2001), which are both time invariant variables. In a cohorts' framework, each household belongs to the same group for the whole period.

ANNEX B – Unemployment

To check the robustness of our estimates, we also include among the time allocation the time spent not working, accounting for the time declared by people in working age as not working/inactive. We consider as non-working time: (i) when job is not declared and registered time is missing, (ii) the difference between the total amount of workable hours per week – which we set as 40 (8 hours/day per 5 working days) – and the real time worked. Similarly to the procedure applied for $Sh_{is,t}$ variable, we winsorize all values exceeding 40. Differently from $Sh_{is,t}$ the share of hours worked is computed over 40 as follows: $Sh^{40}_{is,t} = \frac{HW_{is,t}}{40}$.

$$Sh^{40}_{unemp,it} = 1 - \sum_{s=1}^{4} \frac{HW_{is,t}}{40}$$

which will be 0 in case of full employment (all individuals within the same household i work 40 hours per week), and 1 in case of full unemployment.

Hereafter we report the descriptive statistics of the share of hours/week worked in the different fields, overall and divided by cohorts. We have to bear in mind that data refers to the last week before the interview. Share of time spent not working is quite high. First of all, this may be due to sensitivity of responses to the agricultural business cycle; in addition the date of the interview reflects possible seasonal movements across months. Secondly, respondents can be reticent or underreport the time spent working. Third, data does not consider time spent in domestic chores, which will presumably capture a great share of time in particular for women.

Table B.1. Share (%) Hours/week working in agriculture, services, industry, manufacturing, not working, by year

	GLSS3 1991-92	GLSS4 1998-99	GLSS5 2005-06
Agriculture	42.44	31.86	30.67
Industry	1.16	1.54	1.46
Manufacturing	6.82	7.91	6.17
Services	18.91	20.36	16.63
Not Working	30.61	38.31	44.86
Observations	4,278	5,593	8,098

Table B.2. **Share (%) Hours/week working in agriculture, services, industry, manufacturing, not working by age cohort and year**

	GLSS3 91-92	GLSS4 98-99	GLSS5 05-06	GLSS3 91-92	GLSS4 98-99	GLSS5 05-06	GLSS3 91-92	GLSS4 98-99	GLSS5 05-06	GLSS3 91-92	GLSS4 98-99	GLSS5 05-06
Age cohort	*15-21*	*15-21*	*15-21*	*22-28*	*22-28*	*22-28*	*29-35*	*29-35*	*29-35*	*36-42*	*36-42*	*36-42*
Agriculture	39.69	37.11	20.08	41.24	33.38	27.77	38.11	33.5	34.14	39.96	32.86	31.55
Industry	0.59	1.64	3.12	2.64	2.7	3.18	2.22	2.56	2.39	1.49	1.81	1.62
Manufacturing	13.05	9.3	8.17	7.99	11.05	9.65	8.49	9.88	7.67	6.92	7.81	7.19
Services	22.4	20	21.1	25.75	26.3	23.8	26.69	26.61	23.54	23.26	22.67	20.57
Not Working	24.26	31.95	47.54	22.15	26.46	35.33	24.27	27.43	31.81	28.36	34.78	38.92
Observations	96	84	156	629	686	1108	851	1036	1476	748	1075	1504

	GLSS3 91-92	GLSS4 98-99	GLSS5 05-06	GLSS3 91-92	GLSS4 98-99	GLSS5 05-06	GLSS3 91-92	GLSS4 98-99	GLSS5 05-06	GLSS3 91-92	GLSS4 98-99	GLSS5 05-06
Age cohort	*43-49*	*43-49*	*43-49*	*50-56*	*50-56*	*50-56*	*57-63*	*57-63*	*57-63*	*64-70*	*64-70*	*64-70*
Agriculture	33.95	28.59	27.79	35.6	31.07	30.9	43.41	33.39	31.72	46.25	36.71	34.29
Industry	1.05	1.18	1.5	1.14	1.21	0.96	0.81	0.84	1	0.47	1.07	0.92
Manufacturing	6.46	6.38	5.67	6.46	6.93	5.8	4.99	7.37	5.7	6.98	4.64	3.61
Services	22.13	20.74	18.41	18.17	16.98	15.63	15.11	12.77	13.69	12.44	12.84	9.63
Not Working	36.41	43.1	46.26	38.46	43.77	46.56	35.67	45.64	47.72	33.87	44.72	51.23
Observations	597	817	1250	613	843	1187	405	541	726	339	511	691

Note: Household level statistics based on household head's age-cohort membership

THEMATIC SET

A4 MEASURING THE SOCIAL DIMENSION OF AGRICULTURE

Session Organizer
B. Davis | FAO | Rome | Italy

ABSTRACT

Within the context of the development of the SDGs and the most recent generation of integrated household surveys, the importance and relevance of the interconnectedness of the social and economic dimensions of agricultural households is gaining prominence. While a recognition of the role in influencing behavior of the inseparability of the agricultural household in the context of market failure is well established in the literature, more generalized collection of the necessary broad types of data is more recent. This session will focus on the measurement and analysis of social topics within the context of agricultural households and the particular environment and constraints in which they live. Papers can focus on such diverse topics as the multi-dimensional nature of resilience, the implications of social protection for agriculture, the role of human capital in agricultural productivity, the role of agriculture in youth un- and under employment, etc. Papers can focus on an application to a specific topic in a given country, or focus on methodological issues.

LIST OF PAPERS

(Mis)Measuring the contribution of livestock to household livelihoods: evidence and lessons from LSMS surveys in Tanzania and Uganda

G. Zane | LSE | London | United Kingdom

L. Nsiima | Ministry of Livestock and Fisheries Development | Dar es Salaam | United Republic of Tanzania

U. Pica-Ciamarra | FAO | Rome | Italy

J. Sserugga | Ministry of Agriculture, Animal Industry and Fisheries | Entebbe | Uganda

DOI: 10.1481/icasVII.2016.a04

How does social protection affect household resilience? Results from the Malawi cash transfer program

S. Handa | UNICEF | Florence | Italy

F. Otchere | UNICEF | Florence | Italy

DOI: 10.1481/icasVII.2016.a04c

A04

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DOI: 10.1481/icasVII.2016.a04

ABSTRACT

Livestock are estimated to contribute to the livelihoods of about 60 percent of rural households in developing countries, including the poor. Measuring the extent of such contribution has been traditionally challenging because of data gaps. This paper presents an attempt to assess the contribution of livestock to household livelihoods, measuring both tradable and non-tradable or marginally tradable outputs. It builds on the National Panel Surveys of Uganda and Tanzania, that presents a comprehensive livestock module, as well as on ad hoc surveys implemented by the Ministries responsible for livestock in both countries to fill some NPS information gaps. Results suggest that non-tradable and marginally traded livestock outputs represent about half of the contribution of livestock to household livelihoods.

Keywords: LSMS, livestock, non-tradable outputs, social capital

PAPER

1. Introduction

Livestock are estimated to contribute to the livelihoods of about 60 percent of rural households in developing countries. Measuring the extent of such contribution has been traditionally challenging because of because of data gaps. In recent yearsa number of African countries have released Living Standards Measurement Studies (LSMS) datasets with a specific focus on agriculture. These datasets provide an unparalleled opportunity to measure with statistical accuracy the contribution of agricultureto household livelihoods,including specifically that of livestock.

This paper relies upon the Tanzania 2012/13 National Panel Survey (TZNPS) and the Uganda 2011/12 National Panel Survey (UNPS) to quantify the contribution of livestock to household livelihoods. The National Panel Surveys of both countries currently represent one of the largest sets of livestock data at household level throughout Africa. They include information on livestock ownership and husbandry and production practices, such as on labour, feed and health inputs, and both tradable and non-tradable or marginally tradable outputs, such as manure and animal power. The NPSs, however, also present some data gaps if the objective is to measure the contribution of livestock to household livelihoods, as they include neither questions on the quantities and unit prices of non-tradable livestock outputs nor questions specifically aimed at measuring social capital. To fill these gaps, the Ministries responsible for livestock in Tanzania and Uganda undertook two ad hoc surveys with local expertson "measuring the non-measured contribution of livestock to household livelihoods. By combining data from the NPSs and the Ministries'surveys, the paper develops and applies a methodology to estimate the full contribution of livestock to household livelihoods. This involves measuring net the income stream from sales of meat, milk, eggs and other livestock products, such as hides and skins; quantifying the value of manure, transport services and draught power rendered by animals; assessing the value of live animals as savings and insurance; and estimating the contribution of live animals to social capital. Results indicate that non-tradable outputs represent about half of the total contribution of livestock to household livelihoods. The remainder of the paper proceeds as follows. Section 2 illustrates the data and reports summary statistics. Section 3 discusses the methodology. Section 4 reports the results. Section 5 draws conclusions.

2. Data and Summary Statistics

2.1 The datasets

This paper uses data on livestock collected by the Tanzania National Bureau of Statistics (NBS) and the Uganda Bureau of Statistics (UBOS) as part of the implementation of the Tanzania and Uganda National Panel Surveys respectively (TZNPSs and UNPSs)[1]. For Tanzania, data are available for the 2008/09, 2010/11 and 2012/13 TZNPS,for Uganda for the 2009/10, 2010/11 and 2011/12 UNPS.

[1] These surveys have been implemented in the context of the Living Standard Measurement Studies – Integrated Surveys on Agriculture (LSMS-ISA) Project of the World Bank.

The 2012/13 TZNPS and the 2011/12 UNPS include an expanded livestock module, with between 80 and 100 questions. The NPS surveys collect information on livestock ownership and herd dynamics due to different reasons (e.g. sales; thefts; gifts; etc.), breeds, differentiated by local/indigenous and improved/exotic; use of inputs, including feed, water, labour, vaccines and drugs; production of livestock products, including not only meat, milk and eggs, but also dung and other services provide by livestock, such as transport; consumption and self-consumption of animal source foods.These surveysrepresent one of the largest sources of household-level livestock data throughout Africa[2]. As a way of comparison, traditional LSMS surveys include between 5 and 20 questions on livestock.

Although the livestock module in the NPSs is particularly comprehensive, it does not collect quantity and price parameters on some important non-marketable or marginally traded livestock outputssuch as dung, draft power and transport. In addition, the surveys do not explicitly target the measurement of social capital,which is often considered as a major value of livestock In order to address these gaps, the Ministry of Agriculture, Livestock and Fisheries in Tanzania and the Ministry of Agriculture, Animal Industry and Fisheries in Uganda implemented two on line surveys with local experts. The two surveys were completed by a total of 145 experts, 61 from Tanzania and 84 from Uganda, and collected

Table 1: Livestock ownership in Tanzania and Uganda

Variables		Mean	Standard deviation	Observations
Livestock owners (% of all households)	Tanzania	0.56	0.50	12,190
	Tanzania Rural	0.70	0.46	7,908
	Uganda	0.57	0.49	8,514
	Uganda Rural	0.66	0.47	6,558
Herd/flock size in TLUs (livestock owners only)	Tanzania	2.39	7.76	5,890
	Uganda	1.65	6.05	5,507
Large ruminants owner (% of livestock owners)	Tanzania	0.32	0.47	5,895
	Uganda	0.44	0.50	5,507
Number of large ruminants (large ruminants owners only)	Tanzania	11.15	21.50	1,844
	Uganda	6.04	17.17	2,554
Small ruminants owner (% of livestock owners)	Tanzania	0.43	0.49	5,891
	Uganda	0.64	0.48	5,507
Number of small ruminants (small ruminants owners only)	Tanzania	9.88	22.32	2,320
	Uganda	3.15	3.14	3,509
Pigs owner (% of livestock owners)	Tanzania	0.11	0.32	5,890
	Uganda	0.23	0.42	5,507
Number of pigs (pigs owners only)	Tanzania	2.49	3.36	593
	Uganda	1.54	1.54	1,287
Poultry owner (% of livestock owners)	Tanzania	0.87	0.34	5,890
	Uganda	0.71	0.45	5,507
Number of poultry (poultry owners only)	Tanzania	13.39	25.22	5,042
	Uganda	7.90	26.69	3,962

Source: own elaboration based on TNPS waves 2008/09, 2010/11 & 2012/13 and UNPS waves 2009/10, 2010/11 & 2011/12

[2] The information collected through these newly added questions has been systematically reviewed and validated by experts from the Ministries responsible for livestock in both countries through a series of workshops within the project "Livestock in Africa: improving data for better policies" joint with the FAO and the countries' statistical institutes.

information on dung production per day by animal species; unit price of dung by animal species; frequency of use of cattle and equines for transporting goods and persons and for draft power; unit cost of animal hiring; on the relative contribution of different representative herds to cash, food, animal power, insurance and savings and social capital.

2.2 Livestock ownership

Table 1 reports summary statistics of livestock ownership in Tanzania and Uganda over the 3 survey rounds. The data indicate that 56%of all Tanzanian households and 57% of all Uganda households own livestock, with these percentages being 70% and 66% in rural areas respectively.In Tanzania, 87% of livestock owners have poultry, 43% have small ruminants and 32% have large ruminants. The ranking is the same in Uganda where 71% of livestock keepers have poultry, 63% have small ruminant and 44% have large ruminants. Pigs are more common in Uganda (23%) than in Tanzania (11%).

The average herd/flock size in the two countries is reported both in terms Tropical Livestock Units (TLUs) and number of animals owned by species One TLU is equivalent to 250 kg of live weight. The conversion factors used for this paper are 0.5 for large ruminants, 0.1 for small ruminants, 0.2 for pigs and 0.01 for poultry. The average herd/flock size in Tanzania is larger than in Uganda: they measure 2.39 and 1.65 TLUs, respectively. Tanzanian livestock owners seems to have more of all types of animals but the largest difference can be found for small ruminants where the average herd size in Tanzania is 9.88 and in Uganda is only 3.15.

2.3 Household income

Table 2 presents details on the different sources of household income, including income from livestock, as calculated using the Rural Income Generating Activities (RIGA) methodology developed by the FAO.Household income derives from 6 main sources including wages, self-employment, crop production, livestock production, transfers, and other sources; it only includes regular income, and excludes investments, windfall gains, and purchase and sale of durable goods (Carletto et al., 2007). The advantage of this methodology is that it is developed specifically for LSMS data, with the purpose to generate figures comparable across countries. In both Tanzania and Uganda, the major source of household income in is crop agriculture, averaging 50% for rural households. Self-employment in non-farm activities comes second in both countries. The contribution of livestock to household income is estimated at8.7% and 8.5% for all Tanzanian and Ugandan households respectively, at 11.2% and 8.3 in rural areas.These estimates provide a lower bound of the overall contribution of livestock to household livelihoods as they not take into account outputs that are non-tradable or marginally tradable and the value of livestock as social capital.

Table 2: Components of household income (%) – RIGA methodology

Income components	Tanzania		Uganda	
	Rural	Total	Rural	Total
Agricultural wages	6.37	5.09	5.96	5.11
Non-agricultural wages	9.25	18.11	9.04	12.17
Crop income	49.94	38.19	50.06	44.23
Livestock income	11.23	8.73	9.34	8.05
Self-employment	14.71	22.30	16.96	19.53
Transfers	8.36	7.46	7.66	9.38
Other sources	0.15	0.12	0.99	1.54
Total Income	100	100	100	100
Observations	7,836	12,003	6,393	8,205

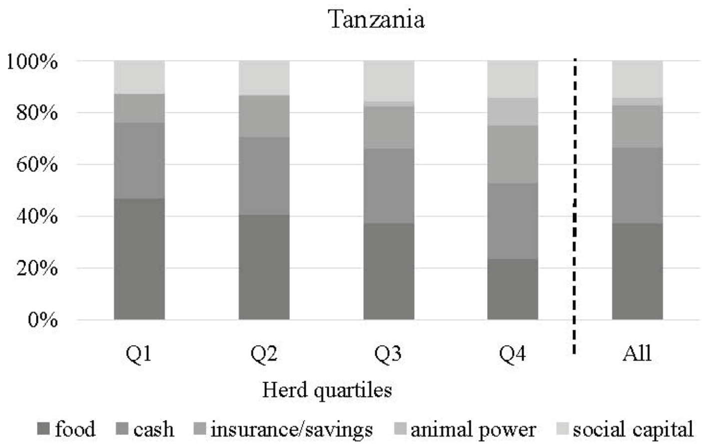
Source: RIGA project WB based TNPS waves 2008/09, 2010/11 & 2012/13 and UNPS waves 2009/10, 2010/11 &2011/12

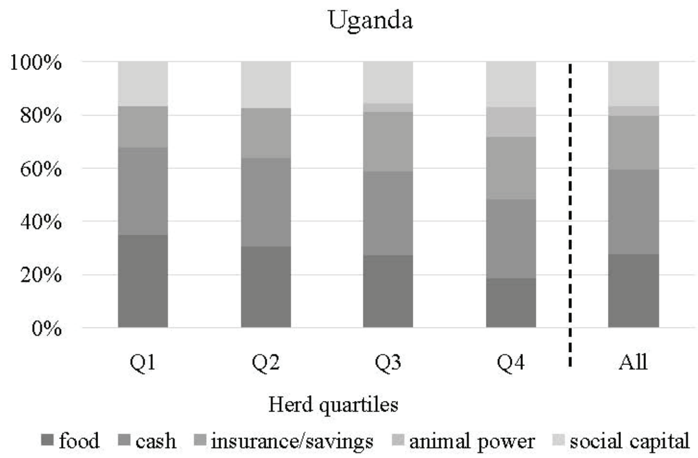
2.4 Tradable and non-tradable livestock outputs

Figure 1 displays the relative contribution of livestock to food, cash, insurance and savings, animal power and social capital. These are presented for herds quartile (Q) of the TLU distribution. In Tanzania the bottom herd quartileis composed by 7 chickens; the second by 1 goat and 13 chickens; the third by 1 cattle, 4 goats, 1 pig and 11 chickens; and the top quartile by 18 cattle, 16 goats, 1 pig and 15 chickens. In Uganda, the bottom herd quartile comprises a flock of 5 chickens; the second herd quartile includes 2 goats and 5 chickens; the third 1 cattle, 3 goats, 1 pig and6 chickens; and the top quantile includes 10 cattle, 7 goats, 1 pig and 12 chickens.

The figure indicates that while tradable livestock outputs, including self-consumption of animal protein and cash from the sale of animal products and live animals represent the main channel through which livestock contribute to household livelihoods, as they make up 67% and 59% of the total value of livestock "outputs" in Tanzania and Uganda respectively. Their relative contribution

Figure 1 - Contribution of livestock to household livelihoods by livelihood dimension





Source: own elaboration based on data collected by the Tanzania and Uganda Ministries responsible for livestock

of tradable outputsto livelihoods decreases with herd / flock size as only households that keep a relatively large herd, comprising at least one cattle in the sample,significantly benefitfrom other livelihood services provided by livestock and most notably insurance, savings and animal power. As the figure presents relative value, note that in all cases households in the upper herd quartiles derive more benefits in absolute terms from both tradable and non-tradable outputs.

3. Measuring tradable and non-tradable livestock outputs

This section presents a methodology to compute the contribution of livestock household livelihoods taking into account non-tradable and marginally tradable livestock outputs.The starting point is livestock income as calculated applying the RIGA methodology, to which we add measures of the benefits obtained from non-tradable outputs: savings andinsurance; and self-consumption of marginally traded outputs, including animal power and dung. In particular, we slightly modified the RIGA methodology to assure comparability of the results between the two countries and computed livestock income as the sum of income from sale of live animals and livestock products and by–products, minus recurrent expenses and purchase of live animals. Equation 1illustrates the calculation.

$$\begin{aligned} \text{Livestock income} = \; & + \text{sale of livestock} \\ & + \text{sale of livestock byproducts (milk, eggs, dung, draught power, etc.)} \\ & + \text{value of self consumption of livestock food products} \\ & - \text{expenses for feed, water and hired labour} \\ & - \text{expenses for veterinary services} \\ & - \text{purchase of livestock} \end{aligned} \quad (1)$$

We consider sale and purchases as income and expenditure rather than investment and disinvestment for the reasons both that purchase and sales of animals is common, particularly pf small ruminants and poultry, and that in many cases animals are not necessarily sold when they are no longer productive. Since the price data are noisy we use the median sale and purchase price for the region of reference to calculate the value of animals sold and purchased. As animal dung is mainly used by the household as manure, we calculate its value by using the data provided in the crop production sections of the survey.In particular, the data provide information on the use of organic fertilizer and the quantity purchased, which allow us to compute the value of self-consumption of organic fertilizer. As for transport, insurance and savings and social capital, we usedthe data collected by the Ministries responsible for livestock described in section 2.1. For each quartile of livestock ownership distribution, we have data on the contribution of livestock to household livelihoods from food, cash, savings/insurance, animal power and social capital. We use this information to impute the value of each of these outputs as a share the household's cash and food livestock income, which we calculate from the NPS data.

4. Results

Table 3 reports the decomposition of livestock income into its components as obtained from the modified RIGA methodology computation illustrated by equation 1. The table relies only on the 2012/2013 Tanzania NPS and the 2011/12 Uganda NPS, which include the expanded module of livestock with detailed information on production and husbandry practices. The relative importance of the different components is similar in the two countries. Households derive most of their livestock income from the self-consumption of animal products, which contribute 48% and 51% of the gross revenue from livestock (60% and 68% of the net livestock income). The sale of live animals come second, representing 42% and 35% of the gross livestock revenue, followed by the sale of meat, milk and eggs which account for 10% and 14%.

Table 3: Livestock contributionto household income (rural livestock keepers only)

Income components	Tanzania		Uganda	
	TZS	% livst income	UGS	% livst income
Sale of livestock	201,740	52.27	87,496	47.07
Sale of livestock by-products	47,250	12.24	27547	15.63
Sale of dung	19	0.01	42	0.02
Sale of animal power	N/A	N/A	6600	3.74
Food self-consumption	229,654	59.50	126,327	67.95
Expenditure (feed, water, labor)	-23,018	-5.96	-18,691	-10.05
Vet services	-14,809	-3.84	-14,827	-7.98
Purchase of livestock	-54,867	-14.22	-38,212	-20.55
Livestock income	385,970	100	176,282	100
Observations	1,780		1,585	

Source: own elaboration based on TNPS 2012/13 and UNPS 2011/12. Livestock by-products include milk, meat and eggs. Sale of animal power includes draught power and hauling services, this information was not collected for Tanzania

Table 4 reports the calculation of the total contribution of livestock to household livelihoodsbut also includes non-tradable or marginally-tradable outputs.The data indicate, first of all, that the contribution of livestock to household livelihoods is highly underestimated if only tradable outputs are measured: the benchmark measure of livestock income (table 3) accounts for less than 43% of the total contribution of livestock to livelihoods in Tanzania and for about 36% for Uganda. In particular, the results show that 45% and 43% of the livestock gross revenuecomes from non-tradables, including use of dung, animal power, insurance and savings and social capital. Dung account for 6% and 10%. The other half comes revenue from the sale of live animals, meat, milk and eggs.

Table 4: Contribution of livestock to household livelihoods (livestock keepers only)

Income components	Tanzania		Uganda	
	TZS	% tot contribution	UGS	% tot contribution
Cash(sales of livestock and by-products)	257,230	28.36	131,304	26.97
Food self-consumption	229,654	25.32	126,327	25.95
Dung self-consumption	59,340	6.54	57,447	11.80
Insurance, social capital, animal power	453,588	50.00	243,525	50.02
Expenditure (feed, water, labor)	-23,018	-2.54	-18,691	-3.84
Vet services	-14,809	-1.63	-14,827	-3.05
Purchase of livestock	-54,867	6.05	-38,212	-7.85
Total contribution	907,138	100	486,873	100
Livestock income (benchmark)	385,970	42.55	176,282	36.21
Observations	1,780		1,585	

Source: own elaboration based on TNPS 2012/13 and UNPS 2011/12

5. Conclusion

This paper presents an attempt to assess the contribution of livestock to household livelihoods, measuring both tradable and non-tradable or marginally tradable outputs. It builds on the National Panel Surveys of Uganda and Tanzania, that presents a comprehensive livestock module, as well as on ad hoc surveys implemented by the Ministries responsible for livestock in both countries to fill some NPS information gaps. The results suggest that non-tradable and marginally traded livestock outputs play an important role for household livelihoods In particular, savings/insurance, social capital and animal power are estimated to account for as much as 50% of the total contribution of livestock to household livelihoods Standard methods to estimate livestock income, therefore, significantly underestimate the contribution of livestock to livelihoods.

While these findings need to be certainly substantiated with additional and more detailed analyses, they suggest that statistics offices should attempt to better measure the non-tradable dimensions on livestock in selected surveys and that policy makers should be caution when designing market-based policies to promote the development of livestock, as the market-related contribution of animals to household livelihoods is limited.

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How does social protection affect household resilience? Results from the Malawi cash transfer program

A04

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ABSTRACT

The concept of resilienceis increasingly gaining traction in the international development literature as a way to profile, rank and predict the response capacity of households to shocks and stressors to livelihoods, particularly those that threaten to food security.The objective is to provide a more rigorous framework and a single reference indicator for the design and implementation of sustainable long-term development initiatives that minimize the need for perennial mobilization for humanitarian and emergency assistance. While there are still debates about the construct and measurement, there is general consensus that a household's resilience encompasses aspects of household income generating capacity and diversification, ownership of agricultural and non-agricultural assets, access to social safety nets and basic services, as well as household stability and adaptive capacity to shocks.

By providing a steady and predictable source of income, particularly one that is unconditional, the SCTP is hypothesized to impact positively on the productive capacity of households and asset ownership without negatively affecting pre-existing social safety nets and access to basic services. The net effect of this should be improved food security and more resilient households able to respond to shocks and stressor with more positive coping strategies that are not detrimental to long term development prospects. This report accordingly examined the impacts of the SCTP on the dimensions of resilience and overall resilience score. We further examine the validity of the resilience index in predicting future food security.We find significant positive impacts of the SCTP on agricultural and non-agricultural asset ownership, crop production, livestock ownership and household debt situation. We find no ‗crowding out' effects of the SCTP on access to private and public social safety nets, and no signs of reduced labour hours although there is some reduction in the hours spent on casual labour. We also find significant positive impacts of about MWK 13,000 on overall per capita consumption as well as a MWK 7900 on per capita food consumption. In addition, we find significant positive effect on household food security, meal frequency, meal quality and dietary diversity. Our estimate of household resilience, using the FAO RIMA II model, also shows significant improvement in the household resilience index for the T households.

Using the information on actual household coping responses to shocks over the last 12 months, we assess the ‗reliability' of the resilience score be examining its predictive power on the coping strategies adopted by households in response to shocks. We find a strong positive association between the resilience index and the share of positive coping responses to shocks. While 37 per cent of households in the lowest quintile of the resilience score are able to adopt positive coping strategies to shocks, the corresponding figure for households in the highest quintile is 71 per cent, with noticeable difference between T and C households. We also examine the predictive power of the resilience score to food security using only the sample of C households in order to exclude the effect of the SCTP. The results of this analysis also show that high resilience score at baseline was reasonably predictive of food security at endline among the C households, indicating a reasonable level of reliability of the resilience score.

While the SCTP had no explicit objective on resilience, the overwhelming evidence of increased resilience and the association thereof with actual positive coping strategies to shocks experienced by the households suggests that households that benefit from unconditional cash transfer programs are able to make the right decisions that contribute to building household resilience in the many dimensions it is construed.

Keywords: Resilience, RIMA II, Cash Transfer, Social Protection, Food Security

PAPER

1. Background

The concept ofResilience is becoming increasingly popular within the international development community as aframework for profiling and ranking households in terms of their response capacity to shocks and stressors to livelihoods, particularly those that threaten food security. The objective is to providea single reference indicator for summarizing multidimensional aspects of household livelihoods in order to better inform development and humanitarian interventions and also summarize program impacts. The term has a long history of use in mental health studies where resilience is defined as "the ability to withstand and rebound from disruptive life challenges" In the development literature, resilience is discussed in relation to threats to livelihoods, often occasioned by shocks that can be natural or man-made, exogenous or endogenous, seasonal or recurrent, short or protracted (D'Errico et al. 2013; FAO II 2014). The definition of resilience in the development literatureis still a matter of some discussiondue to the multidimensional nature of the term, and contemporary definitions differ mainly in terms of scope and emphasis on the types of threats to livelihoods that have to be taken into consideration. The Resilience Alliance defines the resilience as "The capacity of a system to absorb disturbance and reorganise while undergoing change." DFID defines it as "..the ability of countries, communities and households to manage change, by maintaining or transforming living standards in the face of shocks or stresses—such as earthquakes, drought or violent conflict—without compromising their long-term prospects," while the FAO's Resilience Measurement Technical Working Group defines it as "...the capacity that ensures adverse stressors and shocks do not have long-lasting adverse development consequences." (Resilience Alliance, 2002) . Barrett and Constas (2014) define development resilience as "the capacity over time of a person, household or other aggregate unit to avoid poverty in the face of various stressors and in the wake of myriad shocks. If and only if that capacity is and remains high over time, then the unit is resilient" The common thread through these and other definitions is the notion that resiliency reflects an ability to successfully avoid poverty and food insecurity even in the event of negative shocks or stressors to an established pattern of livelihood.The relevance of this concept cannot be overemphasized due to the increasing disruption in food supplies and agricultural productivity caused by climate change, as well as the frequent outbreaks of civil unrest and armed conflict. Conceptually, a more resilient household is one that is better able to anticipate and manage its exposure to negative shocks to livelihood, and when preventive measures fail, be able to withstand with more positive coping strategies. For example, households that make use of irrigation or other soil management techniques in farming are generally better positioned to avert the full effect of droughts, and also more likely to have higher productivity that minimizes the risk of food insecurity. Efforts to measure resilience are still very much debated both theoretically and empirically. However, there seems to be general consensus that a household's resilience encompasses aspects of household income generating capacity and diversification, ownership of agricultural and non-agricultural assets, access to social safety nets and basic services, as well as household stability and adaptive capacity to shocks. By providing a steady and predictable source of income, particularly one that is unconditional, the SCTP is hypothesised to positively impact on household income generation capacity, ownership of assets and household human capital such as health and education. We also hypothesise that the SCTP would not negatively impact on pre-existing access to social safety nets and basic services, or household demographic composition. The net effect of these effects should result in improved food security, lower exposure to the effects of perennial or seasonal shocks, and strengthened households' ability to cope with negative shocks with more positive coping strategies that do not undermine long term development objectives.

This expected outcome is not automatic or guaranteed. The use to which households put the SCTP money determines how much they can improve on their livelihood and ability to manage shocks and stressors to livelihoods. The choice of investments can also be constrained by the household's pre-existing conditions as households with tighter food consumption budget constraints may not be able to make medium to long term productive investments or asset accumulation to improve their resilience. This report examines the impacts of the SCTP on household resilience and provide some validity test of the resilience score by analysing the relationship between the resilience score and the use of positive coping strategies in response to shocks. We also examine the predictive power of the resilience score for use as a ranking tool by examining the relationship between endline food security and baseline resilience for the control households who had no exposure to the SCTP treatment. The next section of provides an overview of the SCTP programme followed by a description of the broader impact evaluation design and the data source for the analysis. Section four provides the broad intent-to-treat (ITT) impact estimates on the various dimensions of resilience. Section five provides a description and estimation of household resilience capacity index using the FAO RIMA II model, and analysis the program impacts and the validity tests described above. Section six provides a summary and conclusion.

2. Overview of the Malawi SCTP Programme

The Malawi Social Cash Transfer Programme (SCTP) is one of the several cash transfer programs currently being implemented by governments and development partners acrossAfrica. Locally known as the Mtukula Pakhomo, the SCTP is an unconditional cash transfer programme targeted to ultra-poor, labour-constrained households. The programme began as a pilot in Mchinji district in 2006 and is run by the Government of Malawi (GoM). Since 2009, the programme has expanded to reach 18 out of 28 districts in Malawi. The programme has experienced impressive growth beginning in 2012, and most notably in the last two years. By December 2015, the SCTP had reached over 163,000 beneficiary households.

The objectives of the SCTP are to reduce poverty and hunger, and to increase school enrolment rates in these ultra-poor households. The first evaluation of the programme, the 2007-2008 impact evaluation of the pilot project in Mchinji, demonstrated that the Malawi SCT Pilot Scheme had a range of positive outcomes including increased food security, ownership of agricultural tools and curative care seeking[1]. Since that time, the programme has witnessed some changes in targeting and operations, and significant expansion. The expectation is that these improvements will lead to even stronger impacts for the larger target population. The SCTP is administered by the Ministry of Gender, Children, Disability and Social Welfare (MoGCDSW) with additional policy oversight provided by the Ministry of Finance, Economic Planning and Development (MoFEPD). UNICEF Malawi provides technical support and guidance. Funding for the programme from 2007-2012 was largely provided by the Global Fund to Fight AIDS, Tuberculosis and Malaria (GF). In 2011, the German Government (through Kreditanstalt für Wiederaufbau, or KfW) and the GoM signed an agreement to provide substantial funding for paying arrears in existing areas. In 2013, Irish Aid signed an agreement to expand into one new district, and in 2014, KfW and the European Union (EU) topped-up donor contributions to enable full coverage in the seven existing districts, as well as scale-up intoeight additional districts. Also in 2014, GoM launched a ǧgovernment-fundedč district (Thyolo) and the World Bank committed to providing resources to expand into two additional districts. The SCTP was launched in these 11 newly funded districts starting in mid-2014 through early 2015,bringing coverage to 18 districts.

Eligibility criteria are based on a household being ultra-poor (unable to meet the most basic urgent needs, including food and essential non-food items such as soap and clothing) and labour-constrained (defined as having no member ďfit to work' or having the ratio of čnot fit to work' to ďfit to work' of more than three). Household members are defined as ǔunfit to work' if they are below 19 or above 64 years of age, or if they are aged 19 to 64 but have a chronic illness or disability, or are otherwise unable to work[2]. Beneficiary selection is done through a community-based approach with oversight provided by the local District Commissioner's (DC's) Office and the District Social Welfare Office (DSWO). Community members are appointed to the Community Social Support Committee (CSSC), and the CSSC is responsible for identifying households that meet these criteria and creating a list. These lists are to include roughly 12 per cent of the households in each Village Cluster (VC), and after further screening, the list is narrowed in order to achieve a target coverage rate of 10 percent. The ultra-poor eligibility condition is implemented through a proxy means test (PMT). The transfer amount varies based on household size and there is a čschooling bonus' determined by the number of children in the household enrolled in primary and secondary school. Transfer amounts were updated just prior to the start of this evaluation in 2012. Due to inflation and decline of the value of the real transfer, transfer amounts were increased again in May 2015. The transfer amounts are shown in Table 2.1.1.

Table 2.1.1 – Structure and Level of Transfers (Current MWK)

	2013 to May 2015	After May 2015
1 Member	1,000	1,700
2 Members	1,500	2,200
3 Members	1,950	2,900
4+ Members	2,400	3,700
Each primary school child[1]	300	500
Each secondary school member[2]	600	1,000

[1]Provided for household residents age 21 or below in primary school. 2 Provided for household residents age 30 or below in secondary.

To put these amounts in perspective, Table 2.1.2 shows the average transfer payment and transfer as share of the household baseline consumption. On average, the total annual transfer amount received by households was MWK25,622 and the average monthly per capita of the transfer was MWK 559. We find that on average, the transfer represented 20 per cent of baseline consumption among all beneficiaries, but was higher at 27 per cent among the poorest 50 per cent of households at baseline.Additional details of the implementation and operational performance can be found in the main impact evaluation report (Handa et al, 2016). In particular, there was high adherence in terms of disbursement with up to 99 per cent of target beneficiaries receiving payments as expected. The quantum of money received was also generally consistent with the schedule in Table 2.1.1 except for lack of adjustment for rolling household size. There was little reference to corruption in terms of program officers demanding payments from recipients, and recipients were generally satisfied with the mode of payment. Although there were some misconceptions about eligibility for receiving the SCTP, perceived conditionalitiesregarding the expenditure of the SCTP money, how long into the future beneficiaries expect to receive the transfer, and delays encountered in going to receive the transfer, there is reason to believe that treatment has been very successful for which reason we would expect to see the theorized impacts.

3. Impact Evaluation Design

This section provides key highlights of the impact evaluation design and the analytical framework. Additional details can be found in main impact evaluation report (Handa et al, 2016).

[1] Miller, C., Tsoka, M., & Reichert, K. (2010). Impacts on children of cash transfers in Malawi. In S. Handa, S.

[2] Social Cash Transfer Inception Report, Ayala Consulting. July 2012.

Table 2.1.2 – Average Transfer Payment and Transfer Share

	Midline				
	Total	Poorest 50 per cent	Small hhld	Large hhld	Female head
Household Size	4.47	5.49	2.68	6.39	4.49
Real hhld total annual transfer (MWK)	22,310	24,300	19,016	25,855	22,486
Real PC total monthly transfer (MWK)	520	413	678	350	521
Real transfer share	0.18	0.25	0.19	0.17	0.19
Proportion of hhlds with transfer share < 20 per cent	0.68	0.45	0.65	0.71	0.67
N	1,649	818	843	806	1,361
	Endline				
Household Size	4.67	5.58	2.75	6.48	4.71
Real hhld total annual transfer (MWK)	25,622	28,180	21,347	29,663	25,697
Real PC total monthly transfer (MWK)	559	467	730	396	551
Real transfer share	0.20	0.27	0.20	0.20	0.20
Proportion of hhlds with transfer share < 20 per cent	0.64	0.39	0.63	0.64	0.61
N	1,157	615	553	604	954

Notes: Transfer values expressed in real August 2013 national prices, MWK. Small households contain four or fewer members. Descriptive statistics are corrected for multi-stage survey design.

3.1 Study Design

The impact evaluation for Malawi's SCTP uses a mixed method, longitudinal, experimental study design, combining quantitative surveys, qualitative interviews and group discussions, and simulation models to demonstrate wider community economic impacts[3]. The study districts, Salima and Mangochi, were selected for the study in order to integrate with GoM's SCTP expansion plans. The MoGCDSW had plans to conduct retargeting in existing programme areas, and to expand the SCTP to cover 18 districts, starting in 2012. The districts scheduled for scale-up in early 2013 were Salima and Mangochi, so the MoGCDSW took this opportunity to integrate an impact evaluation into the planned expansion activities. Subsequently, the research team worked with MoGCDSW, Ayala Consulting and development partners to randomly select two study Traditional Authorities (TAs) in each district (Maganga and Ndindi TAs in Salima, and Jalasi and M'bwana Nyambi TAs in Mangochi). The quantitative survey design consists of a cluster-randomized longitudinal study with baseline surveys (household, community and business) which began in July 2013 and two follow-up surveys (household and community) – the midline survey was conducted starting in November 2014 and the endline survey was conducted starting in October 2015. The qualitative survey is an embedded longitudinal study of 16 treatment households, which includes three main components: in-depth interviews (IDIs) with the caregiver and a young person (aged 13-19 at baseline) from each household at baseline and follow-up; key informant interviews (KIIs) with community members at follow-up; and focus group discussions (FGDs) in each study TA at baseline and follow-up. Insights from these qualitative interviews and discussions with community members provide complementary data to that obtained through the surveys and will allow us to examine certain topics in more depth, in particular, the role and evolution of social networks and the mechanisms and dynamics that shape outcomes related to the cash transfer programme.

Baseline data collection was conducted to allow the study team to accurately describe characteristics of beneficiary households before receiving any cash transfers. Midline and endline data has been compared to data collected at baseline using a difference-in-differences (DD) estimation approach to assess the full impacts of the SCTP. Data collected on the control group allows the researchers to

[3] The FAO, with direct funding from the Department for International Development-United Kingdom (DFID-UK), built a simulation model to predict the potential of the SCTP to generate local economy-wide effects. Those results are reported separately in: Thome, K., Taylor, J.E., Tsoka, M., Mvula, P., Davis, B. and Handa, S., Local Economy-wide Impact Evaluation (LEWIE) of Malawi's Social Cash Transfer (SCT) Programme, PtoP project report, FAO - March 2015.

identify which impacts over time are directly attributable to the cash transfer, controlling for outside influences. This is done by taking the overall changes experienced by beneficiaries and subtracting the changes also experienced by control households. The difference in these two are attributed to the programme and considered programme impacts.

3.2 Sampling and Data Collection

The sample for the quantitative longitudinal impact evaluation includes 3,531 SCTP-eligible households and 821 non-eligibles located in 29 VCs across the four TAs in the two districts at baseline. There are 14 VCs (1,678 households) in the treatment (T) group and 15 VCs (1,853 households) in the control (C) – or delayed-entry— group. Data on the non-eligible households were collected to enable FAO to build the local economy simulation model.6The study design uses both random selection (for the selection of study areas at the TA and VC level) and random assignment (to determine T and C VCs), the most rigorous approach available according to evaluation literature[4]. This randomization was done in cooperation with GoM, and was a transparent process open to the public, and the assignment to T-C status was public and attended by local community leaders. The baseline data was used to check for balance between T and C households in order to ǎassess' the performance of the randomization and the results showed that T and C households were balanced on more than 100 relevant variables that were examined. After treatment and control VCs were assigned, the qualitative sample of 16 households was selected from treatment VCs for IDIs of the caregiver and a young person. We used a stratified sampling approach to facilitate comparison across sex and orphan status, resulting in a sample that was half male and half orphaned. Geographically, our sample covers two districts, Salima and Mangochi, and four TAs (Salima – Maganga and Ndindi TAs; Mangochi – Jalasi and M'bwana Nyambi TAs). Four households were selected from each TA. We determined the sample size based on our previous experience, guidelines for longitudinal qualitative research, and feasibility. A prerequisite for selection of a household was that the household had to have at least one youth aged 13-19 years of age (at the time of baseline) who had completed the Young Person's Module in the quantitative survey. This allows for a richer analysis of the youth IDIs, as the qualitative interview could be linked to information on behaviour and attitudes of this same youth from the quantitative survey. These households were then sorted based on gender and age of caregiver and young person, and other characteristics of the young person. Sixteen households were selected on the basis of having a balance of characteristics among the youth respondents, including female/ male, orphan/ non-orphan, had sex/ never had sex and currently enrolled in school/ not currently enrolled in school. Alternate households with similar characteristics were selected to match each of the 16 selected, in case participants refused the IDI or were unavailable.

Focus group discussions (FGDs) at midline were held with two separate groups (beneficiaries and non-beneficiaries) in each of the four TAs, for a total of 10 FGDs[5]. The groups were divided into programme beneficiaries and community members not receiving the transfer in order to allow participants to speak freely, without stigma or judgement from the other group. FGD participants were community members aged 18 and above who have detailed knowledge of the community and were invited by the local village heads. The number of FGDs was determined by the fact that we wanted to cover each TA to account for general geographical and cultural differences that could affect the impacts, perceptions, and operations of the SCTP. The specific locations within the TAs were driven by the fact that, for logistical purposes, the FGDs were conducted during the same time period as the IDIs; therefore, FGDs were held in the same VCs where the IDIs were given.

The survey instruments used consists of six major components:

1. Household Survey administered to the main respondent for the household;

2. Young Person's Module for up to three youth ages 15-22 in the household (age at endline);

3. Anthropometric Measures for children ages 6 months to 71 months in the study households;

4. Community Survey given to a group of knowledgeable community members to gather information on community norms, resources, pricing and access to services;

5. IDIs for caregiver and one youth from 16 treatment households;

6. KIIs and FGDs with knowledgeable community members to discuss impacts, perceptions, and operations of the SCTP. Beneficiary and non-beneficiary FGDs were held separately.

Survey instruments were reviewed for ethical considerations and approved by the UNC Internal Review Board (IRB) and Malawi's National Commission for Science and Technology (NCST), National Committee for Research in Social Sciences and Humanities (UNC IRB Study No.14-1933; Malawi NCST Study No. RTT/2/20). Instruments are available online at: https://transfer.cpc.unc.edu/?page_id=196

[4] Shadish WR, Cook TD, Campbell DT. Experimental and Quasi-Experimental Designs for Generalized Causal Inference. Boston: Houghton-Mifflin. 2002.

[5] An additional set of FGDs was conducted in Mangochi since time permitted the team to do so.

3.3 Attrition

Attrition occurs when households from the baseline sample are missing in the follow-up surveys. There are different reasons for households not responding in subsequent survey waves. Migration, death, separation, or the dissolution of households can cause attrition and make it difficult to locate a household in the second or third wave of data collection. Attrition can cause problems for an evaluation because it not only decreases the sample size (leading to less precise estimates of programme impact), but it could also introduce bias into the analytic sample. If attrition is selective, it could lead to incorrect programme impact estimates, or it could change the characteristics of the sample and therefore, it could affect the representativeness of the impact results. There are two types of attrition: differential and overall. Differential attrition occurs when the treatment and control samples differ in the types of households or individuals who leave the sample. Differential attrition can create biased samples by reducing or eliminating the balance between the T and C groups achieved at baseline. Since we will conduct the analysis using the households present in all three waves of the survey, it is also important to examine for overall attrition, which is the total share of observations missing at the follow-up surveys from the original baseline sample. Overall attrition can change the characteristics of the remaining sample of analysis and render it non-representative of the population from which it was obtained. Overall attrition can affect the ability of the study's findings to be generalized to the population of interest. Ideally, both types of attrition should be null or small. We investigated attrition at endline for the quantitative sample by testing for similarities at baseline between (1) treatment and control groups for all households included in the panel of households, that is, for the households interviewed at baseline and in both follow-up surveys (differential attrition) and, (2) all households in the panel and the households who were missing in either the midline or the endline survey (overall attrition). Fortunately, we do not find evidence of differential attrition, meaning that we preserve the balance between the T and C groups found in the baseline survey. Summary attrition tables are given in Appendix A. However, there is evidence of overall attrition in the sample which we correct for by using modelled inverse probability weights. The attrition rates and effective sample sizes are shown in Table 3.3.1.

Table 3.3.1 – Household "In the Panel" and Attrition Rates by T - C Status and District

		In Panel Rate (Per cent)	Attrition Rate (Per cent)	N
Total sample		93.5	6.5	3,531
Treatment group		94.0	6.0	1,678
Control group		93.2	6.8	1,853
District	Status			
Salima	Treatment	95.1	4.9	800
Salima	Control	93.4	6.6	975
Mangochi	Treatment	92.9	7.1	878
Mangochi	Control	92.8	7.2	878

For the qualitative sample, the caregiver and one youth, aged 13-19 from 16 households were interviewed at baseline, for a total of 32 participants. At midline, three female youth had left their homes for marriage, and one went to live with relatives. One male youth left home to attend secondary school in another district. While these five youth were no longer in the SCTP households at follow-up, the research team was able to trace all of them for the follow-up interviews. One caregiver, a grandmother, had passed away shortly before midline interviews and the youth had gone to live at his aunt's house. Both the youth and the aunt were interviewed at midline. Therefore, at midline, 32 interviews were conducted, and 31 of those were with the same baseline participants, the only exception being the deceased participant. Our team had similar success with retention at endline; while six youth (three boys, three girls) were no longer living at the households where they were initially recruited, the interviewers were able to track and interview all of them. Of note, among the six who had left their households, all three females had married while all three males had left to study (two in secondary, one in madrasa). Three females who had married had returned home by endline and were interviewed in their original households. Overall, 32 interviews were conducted at endline with the same 32 respondents from midline.

4. Program Impact on Resilience Domains

This section presents the program impacts on the various domains of resilience. The domains include economic activities, asset ownership, access to credits and transfers, access to social safety nets, labour use, shocks and coping, consumption and food security. Impacts are estimated using DD regression and are reported as average treatment effects.

4.1 Impact on Economic Activities

One of the objectives of the SCTP is to reduce poverty and hunger among beneficiaries. Since household poverty and hunger are invariably the result of household production being in deficit of household demand, we recognize that increasing household production is the more sustainable way to reduce poverty and hunger in the long term. The SCTP cash is hypothesized to act as a catalyst for behavioural responses and necessary investments in household economic activities that will result in increased production. Our analysis shows an impact of 62kg in overall crop harvest, driven mainly by an impact of 60kg on the five main staple crops (maize, groundnut, rice, pigeon pea and pumpkin). There is also an impact of MWK 12,000 on the total value of crop harvest. On livestock production, the proportion of T householdsinvolved in livestock production at baseline more than doubled at endline (from 29 per cent to 59 per cent) and the impact on raising livestock was 22 pp. Livestock owned, measured in terms of the standard tropical livestock unit (TLU) equivalents also more than doubledamong T households from baseline to endline, and the impact on this indicator was about 5 pp. We also found significant positive impacts on livestock consumption, and expenditure on livestock purchases over the past 12 months. We generally do not find any impacts on the operation of non-farm household enterprises (NFE) or on enterprise profitability. Overall, we find an impact of 0.24 units in the number of economic activities that households are engaged in, an indicator of income source diversification and strengthening (Table 4.1.1).

Table 4.1.1 – Summary Impacts on Economic Activities

Dependent Variable	Endline Impact (1)	Midline Impact (2)	Impact Diff (EL-ML) (3)=(1)-(2)	Baseline Treated Mean (4)	Endline Treated Mean (5)
Crop production household	0.016	-0.012	0.029**	0.929	0.968
	(1.11)	(-0.86)	(2.41)		
Total crop harvest (kg)	62.418***	12.825	49.593***	175.116	272.444
	(5.07)	(0.85)	(3.18)		
Total crop harvest (kg) - Staples	60.342***	9.614	50.728***	168.444	260.526
	(4.73)	(0.71)	(3.23)		
Total value of crop harvest (MWK)	12,175.419***	389.573	11,785.845***	29,280.146	48,110.731
	(3.80)	(0.12)	(3.86)		
Raised or owned livestock	0.220***	0.135***	0.084***	0.288	0.593
	(5.15)	(2.78)	(3.24)		
TLU owned presently	0.051***	0.034**	0.017	0.039	0.102
	(3.73)	(2.47)	(1.67)		
Household has non-farm enterprise	0.010	-0.046	0.056*	0.238	0.240
	(0.28)	(-1.36)	(1.78)		
Number of economic activities	0.246***	0.079	0.167***	1.455	1.800
	(3.98)	(1.45)	(3.53)		
N	9,902	9,902		1,576	1,575

Notes: Estimations use difference-in-differences modelling among panel households. Binary outcomes are estimated using LPM. All estimations control for baseline head of household's characteristics (age in years, sex, indicator of any schooling, indicator of literacy, marital status), household demographic composition and size, indicators for new household members and household member outmigration, and a vector of contemporaneous cluster level prices. Robust t–statistics were obtained clustering at the different levels of the sampling design and are shown in parenthesis. * 10% significance ** 5% significance; *** 1% significance

The main impact evaluation report (Handa et. al, 2016) has extensive coverage on various aspects of these household economic activities including impacts inputs into crop production (fertilizer use, farm size, etc), crop sales, livestock consumption and sales, and the specific livestock types (goat/sheep, chicken, duck/geese). We also present some of the heterogeneous treatment effects on these indicators. In particular, we find similar effects, often with larger coefficient sizes, for the baseline bottom 50 per cent of households. Annex B of this report provides some of the activity specific and heterogeneous impact tables.

4.2 Impacts on Asset Ownership

We investigate the impacts of the SCTP on ownership and investments in agricultural and non-agricultural assets. At baseline, about 93 of households owned or cultivated land, and the inability to own basic farming tools often led to borrowing or renting of assets, taking away from already scarce household resources and reducing productivity. Ownership of basic durable goods is indicative of improved quality of life and also serves as a store of ‘wealth’ thatcan be sold or pawned to deal with 9 emergencies arising out of shocks or stressors to livelihood. Tables 4.2.1 and 4.2.2 provide a summary of the impacts on ownership of assets. Table 4.2.2 is based on cross-sectional differences for midline and endline since the information on asset ownership was not collected at baseline. In either case, we find significant positive impacts on a household ‘wealth’ index based on the first principal component for the ownership of the agricultural or non-agricultural assets. We also find significant impacts on asset purchases in the last twelve months as well as the monetary value of purchases. Details on the specific assets purchased and of the heterogeneous impacts are provided in main evaluation report by Handa et al, 2016.

Table 4.2.1 – Impacts on Ownership and Purchases of Agricultural Assets

Dependent Variable	Endline Impact (1)	Midline Impact (2)	Impact Diff (EL-ML) (3)=(1)-(2)	Baseline Treated Mean (4)	Endline Treated Mean (5)	Endline Control Mean (6)
Own any asset	0.065***	0.014	0.051***	0.882	0.962	0.886
	(3.21)	(0.60)	(2.79)			
Number of asset types	0.249**	0.080	0.169*	1.615	1.922	1.491
	(2.41)	(0.68)	(1.70)			
Asset ownership index	0.302**	0.121	0.181	-0.133	0.269	-0.228
	(2.68)	(0.91)	(1.64)			
Any Asset Purchase in last 12m	0.072**	0.089***	-0.018	0.081	0.184	0.096
	(2.76)	(3.40)	(0.72)			
Total expenditure on purchases (MWK)	174.323*	152.698**	21.625	210.918	394.152	173.112
	(2.02)	(2.11)	(0.36)			
N	9,901	9,901		1,576	1,574	1,726

Notes: Estimations use difference-in-differences modelling among panel households. Binary outcomes are estimated using LPM. See Table 4.1.1 for additional explanatory notes on model specification, including a list of control variables utilized. * 10% significance ** 5% significance; *** 1% significance

Table 4.2.2 – Impacts on Ownership and Purchases of Durable Goods

Dependent Variable	Endline Impact (1)	Midline Impact (2)	Midline Treatment Mean (3)	Midline Control Mean (4)	Endline Treated Mean (5)	Endline Control Mean (6)
Owns any durable good	0.141***	0.085***	0.582	0.497	0.880	0.733
	(7.50)	(3.74)				
Number of durable goods owned	0.619***	0.124*	1.061	0.924	2.553	1.835
	(5.21)	(1.87)				
Durable good ownership index	0.326***	0.093	-0.049	-0.152	0.319	-0.103
	(3.47)	(1.20)				
Any expenditure on goods in last 12 months	0.068***	0.029***	0.061	0.029	0.234	0.148
	(3.07)	(4.55)				
Expenditure on durable goods in last 12 months (MWK)	228.344**	287.615***	473.672	150.329	782.372	459.948
	(2.17)	(3.01)				
N	3,300	3,299	1,574	1,725	1,574	1,726

Notes: Coefficients representcross-sectional differences between panel T and C households at Midline and at Endline. Binary outcomes are estimated using LPM. See Table 13.1.1 for additional explanatory notes on model specification, including a list of control variables utilized. * 10% significance ** 5% significance; *** 1% significance.

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4.3 Impacts on Access to Credit and Transfers

Access to credit and other transfers is another important dimension to household livelihood. Credits and transfers could be relied upon to smoothen consumption and other expenditure in times deficit. This could be during the lean agricultural season or illness of household members. Credits and transfers could also be necessary for occasional large expenses such as payment of school fees at the start of the school year, or investment in equipment for a non-farm business.Borrowing and purchases on credit could prove regressive especially if they come with high-interest payments and are used directly for consumption. By providing unconditional regular cash to the households, the SCTP is expected to ease the demand for credits, especially for consumption. At the same time, it is possible that being enrolled in the SCTP could extricate beneficiaries from networks of friends and relatives who would otherwise provide credit or other types of support. Additionally, beneficiaries may often be obligated by social norms to share their money with other friends and relatives through increased out-transfers. The net effect of all these dynamics can have profound effects on how the SCTP improves the livelihood of beneficiaries.

The survey instrument therefore elicited information on various aspects of credit and transfer activities and behaviour in all three waves. Questions were asked about outstanding debts that originated more than 12 months prior to each survey round, as well as loans and credit purchases in the 12 month period preceding each data collection. Our analysis shows a five pp impact reduction in the proportion of households with a debt on a loan that originated more than 12 months prior to the survey. We also find a nine pp impact reduction in purchases on credit and a further seven pp impact reduction on the proportion of credit purchases that have been fully repaid. We find no impacts on the taking a loan in the last 12 months or fully repaying the loan taken (Table 4.3.1). Putting it all together, a household was in debt if it had outstanding balances from more than 12 months ago, or had not fully repaid any loan or credit purchases (including any accruing interest) taken in the past 12 months. Overall, we find a 10 pp impact reduction on theproportion of households in debt, and a comparative decrease ofMWK 916 in the total debt in T households.

Table 4.3.1 – Impacts on Loans and Credits

Dependent Variable	Endline Impact (1)	Midline Impact (2)	Impact Diff (EL-ML) (3)=(1)-(2)	Baseline Treated Mean (4)	Endline Treated Mean (5)	Endline Control Mean (6)
Still owes on loan from 12+ months	-0.052**	-0.016	-0.036**	0.066	0.087	0.146
	(-2.69)	(-0.80)	(2.24)			
Took a loan in last 12m	-0.012	-0.035	0.023	0.243	0.217	0.230
	(-0.34)	(-1.22)	(0.76)			
Loan fully paid	0.024	0.032	-0.008	0.821	0.860	0.817
	(0.83)	(1.44)	(0.36)			
Purchased on credit in last 12m	-0.087**	-0.069**	-0.017	0.295	0.196	0.243
	(-2.34)	(-2.52)	(0.54)			
Credit on purchases fully paid	0.072***	0.049**	0.023	0.847	0.908	0.846
	(2.88)	(2.52)	(1.03)			
Currently Owes	-0.096**	-0.074**	-0.023	0.306	0.244	0.341
	(-2.66)	(-2.59)	(0.74)			
Total current debt (MWK)	-915.935***	-430.842**	-485.093**	935.322	1,155.823	2,000.854
	(-3.22)	(-2.43)	(2.18)			
N	9,902	9,902		1,576	1,575	1,726

Notes: Estimations use difference-in-differences modelling among panel households. Binary outcomes are estimated using LPM. See Table 4.1.1 for additional explanatory notes on model specification, including a list of control variables utilized. * 10% significance ** 5% significance; *** 1% significance.

Further to the positive outlook on household debts, we investigate if this is caused by differential credit constraints. The results in Table 4.3.1 could be observed if T households were more likely to be refused loans or credits when in fact they needed it and actually applied for it. Additionally, if T households did not seek a loan or seek to purchase on credit because they were sure they would be refused, then we could still get the results in Table 4.3.1. There would be some concern if either of these reasons contributes significantly to the results in Table 4.3.1. There were question in the survey instrument to interrogate all these mechanisms, and our estimations show that T households were significantly less likely to have been refused a loan they applied for, or denied to buy on credit. We also find null effects on the baseline situation regarding access to sources of credit purchase and loans. Ouroverall indicator on credits is household credit constraint. A household is considered credit constrained if the household:

a. has a loan debt, but actually wanted more loan than it received at the same interest rate; or

b. would ask for a loan or purchase on credit if they were sure they could get it; or

c. has been refused a loan or denied a purchase on credit when they actually asked.

This does not control for whether they actually needed a loan or credit, but rather whether they had any barriers in case they needed it. We find no significant impact on this overall indicator (Table 4.3.2). In reconciling this with the result in Table 4.3.1, we can be quite sure that the positive outlook on credit among T households is not likely a result of differential credit constraints, but more likely a result of lack of need for credit. We also recognize that a credit is not necessarily a bad thing, especially if it can be put to productive use to generate multiplying effects. We accordingly examine impacts on the purpose for obtaining a loan or credit and find an eight pp impact decline in the share of household using credit for consumption. The impacts on use of credit or loan for health, education and productive investments are all null (Table 4.3.3).

Table 4.3.2 – Impacts on Credit Constraints

Dependent Variable	Endline Impact (1)	Midline Impact (2)	Impact Diff (EL-ML) (3)=(1)-(2)	Baseline Treated Mean (4)	Endline Treated Mean (5)	Endline Control Mean (6)
Applied for loan but refused	-0.016**	-0.011	-0.006	0.045	0.016	0.027
	(-2.17)	(-1.00)	(0.48)			
Asked to buy on credit but refused	-0.045**	-0.018	-0.027	0.095	0.038	0.076
	(-2.19)	(-0.71)	(1.53)			
Wanted larger loan at same interest rate	-0.012	-0.022	0.010	0.125	0.097	0.088
	(-0.45)	(-0.85)	(0.36)			
Sure to get a loan if applied	-0.051	-0.030	-0.021	0.190	0.119	0.127
	(-1.27)	(-1.01)	(0.63)			
Would apply for loan if sure can get	-0.060	-0.014	-0.046*	0.148	0.091	0.140
	(-1.49)	(-0.46)	(1.76)			
Sure can buy on credit if asked	-0.007	0.035	-0.042	0.167	0.171	0.175
	(-0.20)	(0.91)	(0.74)			
Would ask to purchase on credit if sure can get	0.012	0.009	0.003	0.105	0.085	0.067
	(0.40)	(0.35)	(0.10)			
Loan/Credit Purchase constrained	0.027	0.012	0.015	0.869	0.895	0.886
	(0.96)	(0.50)	(0.50)			
N	9,902	9,902		1,576	1,575	1,726

Notes: Estimations use difference-in-differences modelling among panel households. Binary outcomes are estimated using LPM. See Table 4.1.1 for additional explanatory notes on model specification, including a list of control variables utilized. * 10% significance ** 5% significance; *** 1% significance.

On transfers in and out of the household, we examine transfers of cash, food or labour. We find no impacts on any in- or out transfers, both at the intensive and extensive margins (Table 4.3.4). We also investigate the question of whether households could get any such support when they actually needed it, and also found no impacts (Table 4.3.5).It can thus be argued that the SCTP does not induce a č crowding outčof pre-existing sources of in-transfers or excess demand for out-transfers.

4.4 Impacts on Access to Social Safety Nets

Apart from individuals, the GoM and other non-governmental organizations also provide various social safety nets (SSN) to which poor households have access. It is also desirable that the SCTP will not have any čcrowding-outčeffect on the access to these social safety nets. To derive the most benefit from the SCTP, it is essential that the cash transfers act as a complement to these networks and social safety nets, not as a substitute. Table 4.4.1 shows the impacts of the SCTP on access to social safety nets. Overall, we do not find any impacts on benefiting from at least one SSN or on the number of SSNs households benefit from. We also do not find an impact on the value of the SSN benefits received, nor on benefits from the voucher for fertilizer program (FISP) – aflagship government program to boost

Table 4.3.3 – Impacts on Credit Use

Dependent Variable	Endline Impact (1)	Midline Impact (2)	Impact Diff (EL-ML) (3)=(1)-(2)	Baseline Treated Mean (4)	Endline Treated Mean (5)	Endline Control Mean (6)
Some loan used for prod. invest	0.003	-0.003	0.006	0.036	0.034	0.027
	(0.33)	(-0.49)	(0.75)			
Some loan used for consumption	-0.009	-0.022	0.013	0.164	0.165	0.175
	(-0.30)	(-1.08)	(0.46)			
Some loan used for education	-0.008	-0.001	-0.007	0.009	0.022	0.026
	(-0.88)	(-0.12)	(0.96)			
Some loan used for health	-0.014	-0.006	-0.008	0.043	0.055	0.061
	(-0.84)	(-0.39)	(0.67)			
Some credit used for prod. invest	0.004	0.004	0.001	0.006	0.006	0.003
	(1.07)	(0.81)	(0.18)			
Some credit used for consumption	-0.081**	-0.077***	-0.004	0.267	0.177	0.225
	(-2.27)	(-2.84)	(0.13)			
Some credit used for education	-0.002	0.000	-0.003	0.001	0.002	0.004
	(-0.84)	(0.07)	(0.80)			
Some credit used for health	-0.009	-0.000	-0.009	0.016	0.010	0.012
	(-1.23)	(-0.06)	(1.36)			
N	9,902	9,902		1,576	1,575	1,726

Notes: Estimations use difference-in-differences modelling among panel households. Binary outcomes are estimated using LPM. See Table 4.1.1 for additional explanatory notes on model specification, including a list of control variables utilized. * 10% significance ** 5% significance; *** 1% significance.

Table 4.3.4 – Impacts on Credit Use

Dependent Variable	Endline Impact (1)	Midline Impact (2)	Impact Diff (EL-ML) (3)=(1)-(2)	Baseline Treated Mean (4)	Endline Treated Mean (5)	Endline Control Mean (6)
Any in-transfer of cash, food or labour	0.081	0.002	0.078	0.759	0.747	0.700
	(1.16)	(0.03)	(1.17)			
Any out-transfer of cash, food or labour	0.036	-0.003	0.038	0.049	0.109	0.065
	(1.44)	(-0.10)	(1.52)			
Total value of cash, food of labour in-transfer (MWK)	917.306	1,074.855	-157.550	8,223.733	9,448.599	9,162.363
	(0.55)	(0.69)	(0.11)			
Total value of cash, food of labour out-transfer (MWK)	564.025	-126.827	690.851**	836.981	1,326.460	919.906
	(1.41)	(-0.36)	(2.12)			
Net transfer of cash, food or labour (MWK)	353.281	1,201.682	-848.401	7,386.752	8,122.139	8,242.456
	(0.24)	(0.84)	(0.64)			
N	9,899	9,899		1,576	1,575	1,726

Notes: Estimations use difference-in-differences modelling among panel households. Binary outcomes are estimated using LPM. See Table 4.1.1 for additional explanatory notes on model specification, including a list of control variables utilized. * 10% significance ** 5% significance; *** 1% significance

agricultural productivity through fertilizer use.

We analyse the impacts on specific SSNs and find generally null impacts except on the proportion of households that benefit from the other free food program, which has seen a negative 14 pp impact. However, we do not find an impact on the value of free food received which is quite surprising given the

Table 4.3.5 – Perceived Availability of Support

Dependent Variable	Endline Impact (1)	Midline Impact (2)	Impact Diff (EL-ML) (3)=(1)-(2)	Baseline Treated Mean (4)	Endline Treated Mean (5)	Endline Control Mean (6)
Household sure can get Cash Transfer in case of need	0.078	0.058	0.020	0.459	0.532	0.492
	(1.03)	(0.70)	(0.33)			
Household sure can get Food/Other Consumables in case of need	0.057	-0.005	0.062	0.746	0.677	0.670
	(0.76)	(-0.07)	(0.86)			
Household sure can get Labour or Time in case of need	0.005	-0.037	0.042	0.428	0.405	0.393
	(0.07)	(-0.62)	(0.86)			
Household sure can get Agric Implements/Inputs in case of need	0.025	-0.019	0.043	0.318	0.230	0.224
	(0.35)	(-0.34)	(0.77)			
N	9,898	9,898		1,576	1,575	1,726

Notes: Estimations use difference-in-differences modelling among panel households. Binary outcomes are estimated using LPM. See Table 4.1.1 for additional explanatory notes on model specification, including a list of control variables utilized. * 10% significance ** 5% significance; *** 1% significance

Table 4.4.1 – Impacts on Social Safety Nets

Dependent Variable	Endline Impact (1)	Midline Impact (2)	Impact Diff (EL-ML) (3)=(1)-(2)	Baseline Treated Mean (4)	Endline Treated Mean (5)	Endline Control Mean (6)
Any SSN benefit	-0.038	-0.043	0.005	0.693	0.616	0.589
	(-0.74)	(-0.80)	(0.11)			
No. of SSN benefits	-0.300	-0.215	-0.085	1.120	0.777	0.845
	(-1.53)	(-1.31)	(0.70)			
Value of SSN benefits (MWK)	-187.629	-281.150	93.521	9,008.590	9,074.040	8,303.158
	(-0.12)	(-0.21)	(0.10)			
Voucher for fertilizer (FISP)	0.022	-0.007	0.029	0.532	0.507	0.439
	(0.42)	(-0.13)	(0.83)			
Value of Voucher for fertilizer	665.030	298.784	366.246	6,343.765	6,955.533	5,853.329
	(0.83)	(0.36)	(0.45)			
N	9,901	9,901		1,576	1,575	1,726

Notes: Estimations use difference-in-differences modelling among panel households. Binary outcomes are estimated using LPM. See Table 4.1.1 for additional explanatory notes on model specification, including a list of control variables utilized. * 10% significance ** 5% significance; *** 1% significance

huge impact on the extensive margin (Table 4.4.2).

4.5 Impacts on Labour Use

The extent to which a household has available labour is likely to play a mediating role on how the SCTP impacts household economic activities and productivity. If labour is available and under-utilized due to liquidity or knowledge constraints, an increase in work participation would be expected for less labour-constrained households. This would increase household productivity and create a multiplying effect beyond the size of the SCTP amount. Conversely, households with tighter labour constraints may be less responsive in their work participation if members are not fit to work, and the SCTP cash would go directly into consumption. The more desirable outcome is that households are able to re-allocate labour from less productive activities to more productive ones, and to be able to move away from hazardous labour, particularly for children. Appropriatemodules in the surveys allow for analysis of these effects.

Table 4.4.2 – Impacts on Specific Social Safety Nets

Dependent Variable	Endline Impact (1)	Midline Impact (2)	Impact Diff (EL-ML) (3)=(1)-(2)	Baseline Treated Mean (4)	Endline Treated Mean (5)	Endline Control Mean (6)
Free maize	-0.110	-0.080	-0.029	0.162	0.020	0.074
	(-1.26)	(-1.15)	(0.71)			
Quantity of Free Maize (kg)	-13.978	-12.386	-1.592	20.674	0.702	5.323
	(-1.02)	(-0.97)	(0.25)			
Other free food	-0.143**	-0.074	-0.069*	0.154	0.054	0.118
	(-2.09)	(-1.14)	(1.99)			
Value of Other free food	-306.485	-41.966	-264.519	988.138	203.563	434.956
	(-0.34)	(-0.05)	(1.19)			
Food/Cash for work	0.008	-0.013	0.021	0.065	0.009	0.019
	(0.46)	(-0.87)	(1.33)			
Value of Food/Cash for work	3.884	-144.391**	148.275	289.692	49.417	83.475
	(0.05)	(-2.10)	(1.64)			
School Feeding	-0.068	-0.043	-0.025	0.161	0.133	0.140
	(-1.24)	(-1.24)	(0.45)			
Value of School Feeding	-569.197	-438.594	-130.603	989.345	1,022.74 0	1,216.213
	(-1.04)	(-1.35)	(0.23)			
Community Based Childcare	0.005	0.006	-0.002	0.026	0.021	0.014
	(0.31)	(0.29)	(0.12)			
Value of Community Based Childcare	6.629	-48.403	55.032	128.140	112.316	57.279
	(0.09)	(-0.58)	(0.91)			
N	9,901	9,901		1,576	1,575	1,726

Notes: : Estimations use difference-in-differences modelling among panel households. Binary outcomes are estimated using LPM. See Table 4.1.1 for additional explanatory notes on model specification, including a list of control variables utilized. * 10% significance ** 5% significance; *** 1% significance

We first analyze the household labour constraint situation at baseline. A household is defined as severely labour constrained if it has no member fit to work (FTW). A person is considered fit to work if person is aged between 19 and 64 years, and has no chronic illness or disability, or is otherwise unable to work. If a household has at least one member FTW and the ratio of not fit to work (NFTW) members to FTW member is greater than or equal to 3, then the household is considered moderately labour constrained. A household is labour unconstrained only if the ratio of NFTW to FTW members is less three. The labour constraint classification is purely a function of the household's own demography, and it is important to add that this classification does not take into consideration the ability of the household to engage hired labour or rely on exchange labour. Additionally, there are less labour intensive income generating activities which household members with chronic conditions or disability, or who are older than 64 years of age could engage in. Accordingly, analysis of actual labor supply extends beyond labour supplied by those who are FTW. Table 4.5.1 shows the distribution of households and household members living in each of these household types at baseline. About 29 per cent of households were moderately labour constrained, but these accounted for 39 per cent of individuals. Severely labour constrained households made up 54 per cent of household count and contained 42 per cent of individuals. Overall, there is balance between treatment and control, and this is discussed in greater detail in the main report. Figure 4.5.1 shows the proportion of the sample FTW by age. As expected, the share of FTW decreases with age, and the distribution is essentially identical for T and C.

Next, we examine the impact of the SCTP on household labour constraint. There are a number of pathways through which the SCTP could influence how household labour constrain status would evolve. If SCTP households are able to ǎttract' new household members FTW, then this would improve the labour constrain status of the household. For example if a 65 year old single member is now able to attract a caregiver to live with because of the improved financial situation, then the labour constrain status changes immediately from severely constrained to unconstrained. Similarly SCTP households may be more able to avert the departure of household members when they are faced with a shock. The result of such effect on household welfare is ambiguous since there could be both negative and positive effects and the outcome depends on which of the effects dominates.

Table 4.5.1 – Baseline Labour Constraint Status at Household and Individual Levels

	Household			Individuals		
Status	C	T	Total	C	T	Total
Unconstrained	18.29	16.15	17.28	19.93	17.83	18.94
Moderately Constrained	29.52	28.49	29.03	39.34	39.00	39.18
Severely Constrained	52.19	55.36	53.70	40.74	43.17	41.88
Total	100.00	100.00	100.00	100.00	100.00	100.00

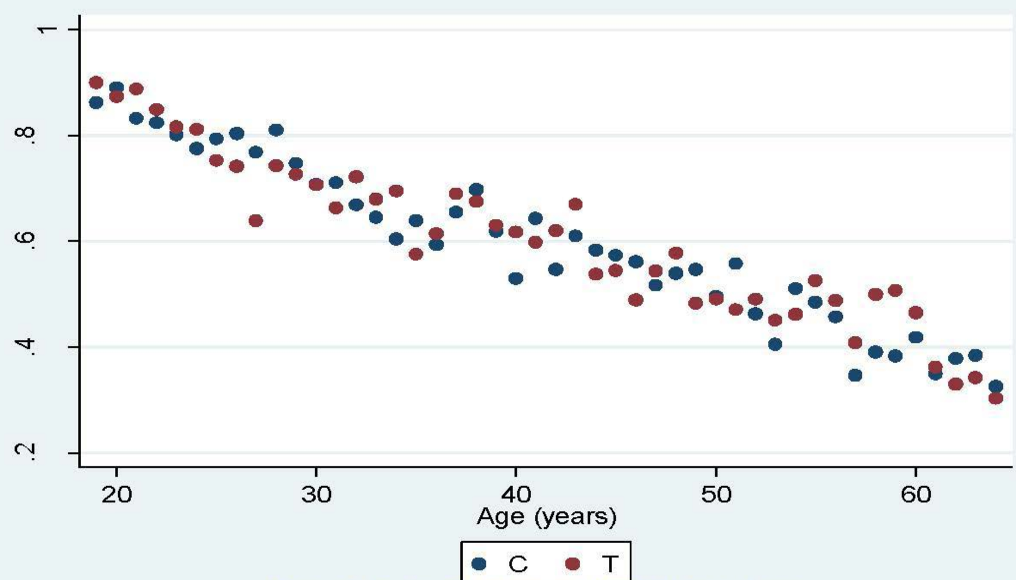


Fig. 4.5.1: Share of FTW by Age

Analysis shows that there were no impacts on the number of household members FTW, number of males FTW, share of households severely labour constrained and share of households labour constrained (moderately or severely). Impacts on the number of female members FTW and share of households moderately labour constrained were only marginally significant at the 10 per cent level (Table 4.5.2). Thus, it can be argued that changing labour constraint is not a plausible mechanism through which the SCTP could impact other outcomes.

Table 4.5.2 – Impacts on Labour Supply

Dependent Variable	Endline Impact (1)	Midline Impact (2)	Impact Diff (EL-ML) (3)=(1)-(2)	Baseline Treated Mean (4)	Endline Treated Mean (5)	Endline Control Mean (6)
Total Members FTW	0.043	0.018	0.025	0.621	0.735	0.750
	(0.97)	(0.42)	(0.70)			
Males FTW	-0.020	-0.038*	0.019	0.235	0.296	0.299
	(-0.73)	(-1.83)	(1.11)			
Females FTW	0.062*	0.056*	0.006	0.385	0.439	0.451
	(2.02)	(1.88)	(0.24)			
Severely Labour Constrained	-0.035	-0.037	0.002	0.564	0.503	0.483
	(-1.27)	(-1.34)	(0.11)			
Moderately Labour Constrained	0.038*	0.012	0.026*	0.279	0.304	0.305
	(2.02)	(0.60)	(1.83)			
Labour Constrained	0.003	-0.025	0.028	0.843	0.806	0.788
	(0.16)	(-1.26)	(1.50)			
N	9,906	9,906		1,576	1,576	1,726

Notes: Estimations use difference-in-differences modelling among panel households. Binary outcomes are estimated using LPM. See Table 4.1.1 for additional explanatory notes on model specification, including a list of control variables utilized. * 10% significance ** 5% significance; *** 1% significance

We further examine the impacts on labour use for household chores and economic activities at the household level. Chores include time spent collecting water, time spent collecting firewood and time spent taking care of children, cooking or cleaning. We find no impacts on time spent on all household chores, own farm activities, fishing and then livestock activities. However, the number of hours in the last seven days spent on casual part time work reduces from 11 to 6 hours among T households with a significant impact of a four hour reduction. We also find a significant impact of three months decrease on the amount of time spent doing casual labour for others (ganyu work) in the last 12 months.We also find an impact of more than one hour increase in the amount of time spent on work outside of the household (excluding ganyu). Finding no impacts on the time spent on livestock production activities is quite surprising in view of the huge impacts on livestock production at both the extensive and intensive margins. This could be an indication of increasing returns to scale, particularly for households which raised livestock at baseline, or through the use of hired labour. To further explore the dynamics of labour use, we examine labour use for each of the main activities to try and see if there are any shifts that still keep the overall time use unchanged despite the significant increases in crop production. We also examine the possible role for the use of hired labour in this dynamic. Table 4.5.4 shows the impacts on household and hired labour use for the various farm activities: land preparation and planting, farm management (weeding, fertilizing, etc) and harvest. Here we find no impacts on household re-allocation of labour among the activities, but we find significant impacts on the use of hired labour at both the intensive and extensive margins. There is a three pp impact increase in the proportion of households using hired labour. We also find that hired labour is mostly utilized for land preparation and planting.

Table 4.5.3 – Impacts on Labour Use by Activity

Dependent Variable	Endline Impact (1)	Midline Impact (2)	Impact Diff (EL-ML) (3)=(1)-(2)	Baseline Treated Mean (4)	Endline Treated Mean (5)	Endline Control Mean (6)
All Chores (Hours Yesterday)	0.146	0.045	0.101	8.178	8.448	8.280
	(0.20)	(0.07)	(0.19)			
Own Farm Activities (Days in Past Season)	6.795	-0.560	7.355	87.342	100.023	91.613
	(0.84)	(-0.06)	(0.96)			
Fishing (Days in Last 7 Days)	-0.079	-0.098	0.019	0.033	0.032	0.161
	(-1.10)	(-1.15)	(0.30)			
Non-Farm Enterprise (Hours in Last 7 Days)	0.406	-0.735	1.140**	3.365	1.726	1.256
	(0.35)	(-0.78)	(2.50)			
Livestock Activities (Hours in Last 7 Days)	0.349	0.057	0.292	0.783	1.388	0.718
	(1.10)	(0.19)	(0.81)			
Casual, Part time activities (Hours in Last 7 Days)	-3.994***	-3.500**	-0.494	10.716	5.778	9.948
	(-3.51)	(-2.16)	(0.35)			
Ganyu Work (Months in last 12 Months)	-3.307**	-2.921**	-0.386	7.376	6.268	9.107
	(-2.75)	(-2.59)	(0.34)			
Work Outside Household excluding Ganyu (Hours in Last 7 Days)	1.003**	0.570	0.433	0.747	0.695	1.062
	(2.07)	(1.28)	(1.07)			
N	9,906	9,906		1,576	1,576	1,726

Notes: Estimations use difference-in-differences modelling among panel households. Binary outcomes are estimated using LPM. See Table 4.1.1 for additional explanatory notes on model specification, including a list of control variables utilized. * 10% significance ** 5% significance; *** 1% significance

This is reasonable in view of the fact that land preparation and planting is mostly time bound and requires a lot of upfront input to set the stage for the rest of the season.

Finally, we examine labour allocation across the various activities by broad age-sex groups, namely males FTW, Females FTW, All Men (aged 18-64 years), Elderly (men and women aged 64 years or older) and children (males or females aged 6-17 years). Overall, the pattern of labour allocation is very similar

Table 4.5.4 – Impacts on Household and Hired Farm Labour

Dependent Variable	Endline Impact (1)	Midline Impact (2)	Impact Diff (EL-ML) (3)=(1)-(2)	Baseline Treated Mean (4)	Endline Treated Mean (5)	Endline Control Mean (6)
HH Lab. for Land Preparation and Planting (Days in Past Season)	0.863	0.797	0.066	46.990	53.300	51.303
	(0.21)	(0.16)	(0.02)			
HH Lab. for Field Management (Days in Past Season)	5.018	-0.849	5.868	33.044	37.982	33.059
	(1.22)	(-0.17)	(1.47)			
HH Lab for Harvesting (Days in Past Season)	0.914	-0.508	1.422	7.308	8.741	7.251
	(1.17)	(-0.54)	(1.41)			
Any Hired Farm Labour	0.030**	0.011	0.019	0.044	0.074	0.033
	(2.08)	(1.13)	(1.56)			
Hired Farm Labour (Days in Past Season	0.475*	0.123	0.352	0.800	1.030	0.497
	(1.94)	(0.36)	(1.09)			
Hired Lab for Land Preparation and Planting (Days in Past Season)	0.266**	0.127	0.139	0.349	0.476	0.236
	(2.23)	(0.92)	(0.96)			
Hired Lab for Field Management (Days in Past Season)	0.162	-0.005	0.167	0.305	0.474	0.227
	(1.18)	(-0.03)	(1.11)			
Hired Lab for Harvesting (Days in Past Season)	0.047	-0.000	0.047	0.145	0.081	0.034
	(0.55)	(-0.00)	(0.59)			
N	9,901	9,901		1,576	1,574	1,726

Notes: Estimations use difference-in-differences modelling among panel households. Binary outcomes are estimated using LPM. See Table 4.1.1 for additional explanatory notes on model specification, including a list of control variables utilized. * 10% significance ** 5% significance; *** 1% significance

to the pattern in Table 4.5.3. There are no impacts on labour allocation for all household chores, farm activities, fishing and NFE activities. There is an impact on labour allocation to livestock activities by FTW males, but this is significant only at the 10 per cent level. We also do not find impacts on female withdrawal from casual part time activities, or intensification in work outside the household (excluding ganyu). There is a significant negative impact (positive outcome) in children participation in ganyu work.

Table 4.5.5 – Endline Impacts on Intra-Household Labour Allocation

Dependent Variable	Members FTW	Males FTW	Females FTW	All Mem. 18-64	Elderly (64+)	Children (6-17)
All Chores (Hours Yesterday)	0.280	0.140	0.075	0.054	0.178	-0.016
	(1.10)	(0.68)	(0.20)	(0.20)	(0.96)	(-0.08)
Own Farm Activities (Days in Past Season)	3.857	1.630	4.555	2.779	3.568	1.348
	(1.02)	(0.46)	(1.05)	(0.81)	(1.29)	(1.10)
Fishing (Days in Last 7 Days)	-0.053	-0.111	-0.002	-0.014	-0.015	-0.016
	(-1.00)	(-0.84)	(-0.12)	(-0.47)	(-1.06)	(-1.21)
Non-Farm Enterprise (Hours in Last 7 Days)	0.138	-0.054	0.236	0.206	-0.281	0.126
	(0.21)	(-0.08)	(0.29)	(0.40)	(-0.75)	(0.67)
Livestock Activities (Hours in Last 7 Days)	0.231	0.242*	0.245	0.194	-0.062	0.085
	(1.44)	(1.91)	(1.04)	(1.53)	(-0.32)	(1.11)
Casual, Part time activities (Hours in Last 7 Days)	-1.872**	-2.762**	-1.206	-1.665**	-0.373	-0.610***
	(-2.37)	(-2.06)	(-1.54)	(-2.27)	(-0.82)	(-2.86)
Ganyu Work (Months in last 12 Months)	-1.309**	-1.313*	-1.324*	-1.266**	-0.501	-1.096
	(-2.09)	(-1.89)	(-1.94)	(-2.25)	(-0.88)	(-1.67)
Work Outside Household excluding Ganyu (Hours in Last 7 Days)	0.817**	1.771*	0.300	0.530*	0.471*	0.080
	(2.09)	(1.74)	(0.99)	(2.00)	(1.78)	(1.01)
N	7,055	2,683	4,372	12,042	6,182	21,618

Notes: Estimations use difference-in-differences modelling among panel households. Binary outcomes are estimated using LPM. See Table 4.1.1 for additional explanatory notes on model specification, including a list of control variables utilized. * 10% significance ** 5% significance; *** 1% significance

4.6 Impacts on Shocks and Coping

Perhaps more directly related to the issue of resilience is the actual experience of shocks and how the households cope when they experience such shocks. Respondents were asked whether they were negatively affected by a series of shocks and their response to try and maintain their standard of livelihood. These shocks are categorized as covariate shocks (which typically affect the entire community – such as droughts, floods/landslides) and idiosyncraticshocks, which are more household specific (such as death of the main income earner in the household, sickness, theft of money, etc.). Coping to these shocks could usually include a mix of strategies some of which are negative (reducing consumption or sending children out to work), positive (relying on own savings/SCTP payment, receiving unconditional help from social networks), or ambiguous depending on the extent of the response (e.g. labour intensification could be positive or negative depending on the initial level and thresholds). In Table 4.6.1, we summarize the impacts of the SCTP on the experience of the aggregate shocks and the use of positive and negative coping strategies. We find no impacts of the SCTP on the experience of any negative shock, and on either covariate or idiosyncratic shocks. This is largely expected since the SCTP cannot per se avert the occurrence of many of the shocks listed. However, consistent with expectation, we find a significant 26 pp impact on the share of positive coping strategies and a significant negative impact of 23 pp on the share of negative coping strategies adopted. These two categories are not necessarily substitutes since households typically employ a mix of strategies. At the endline, we also enquired about whether households had experienced any positive shocks such as an inheritance, better

Table 4.6.1 – Impacts on Shocks and Coping

Dependent Variable	Endline Impact (1)	Midline Impact (2)	Impact Diff (EL-ML) (3)=(1)-(2)	Baseline Treated Mean (4)	Endline Treated Mean (5)	Endline Control Mean (6)
Any Negative Shock	-0.045	0.016	-0.061	0.953	0.858	0.916
	(-1.41)	(0.39)	(1.19)			
No. of Shocks	-0.053	0.079	-0.132	2.516	2.248	2.363
	(-0.29)	(0.40)	(0.57)			
Any Covariate Shock	-0.061	0.016	-0.078	0.923	0.828	0.894
	(-1.32)	(0.27)	(1.28)			
Number of covariate shocks	-0.029	0.045	-0.074	2.118	1.783	1.803
	(-0.18)	(0.22)	(0.37)			
Any Idiosyncractic Shock	0.002	0.023	-0.022	0.266	0.138	0.166
	(0.04)	(0.61)	(0.77)			
Number of idiosyncratic shocks	-0.011	0.019	-0.030	0.309	0.156	0.200
	(-0.20)	(0.40)	(0.88)			
Share of Positive Coping Strategies	0.259***	0.152**	0.106	0.421	0.695	0.404
	(3.74)	(2.09)	(1.14)			
Share of Negative Coping Strategies	-0.232***	-0.063	-0.169**	0.245	0.290	0.493
	(-4.02)	(-1.01)	(2.36)			
N	8,722	8,722		1,508	1,383	1,594

Notes: Estimations use difference-in-differences modelling among panel households. Binary outcomes are estimated using LPM. See Table 4.1.1 for additional explanatory notes on model specification, including a list of control variables utilized. * 10% significance ** 5% significance; *** 1% significance

Table 4.6.2 – Impacts on Specific Shocks

Dependent Variable	Endline Impact (1)	Midline Impact (2)	Impact Diff (EL-ML) (3)=(1)-(2)	Baseline Treated Mean (4)	Endline Treated Mean (5)	Endline Control Mean (6)
Drought/irregular rains	-0.077	-0.013	-0.064	0.603	0.596	0.629
	(-1.04)	(-0.14)	(0.93)			
Unusually high level of crop/livestock pest/disease	0.023	0.016	0.006	0.098	0.073	0.076
	(0.59)	(0.37)	(0.17)			
Unusually high prices of food	0.044	0.029	0.014	0.839	0.693	0.666
	(0.91)	(0.44)	(0.19)			
Serious illness or accident to household member(s)	-0.005	0.007	-0.011	0.177	0.085	0.095
	(-0.15)	(0.22)	(0.56)			
Death of household income earner(s)	-0.011	-0.005	-0.006	0.039	0.026	0.039
	(-0.95)	(-0.55)	(0.72)			
N	9,902	9,902		1,576	1,575	1,726

Notes: Estimations use difference-in-differences modelling among panel households. Binary outcomes are estimated using LPM. See Table 4.1.1 for additional explanatory notes on model specification, including a list of control variables utilized. * 10% significance ** 5% significance; *** 1% significance pay/job or death of a chronically ill household member (on whom the household had to make a lot of expenses). We find no cross-sectional difference in the experience of positive shocks between T and C households as well.

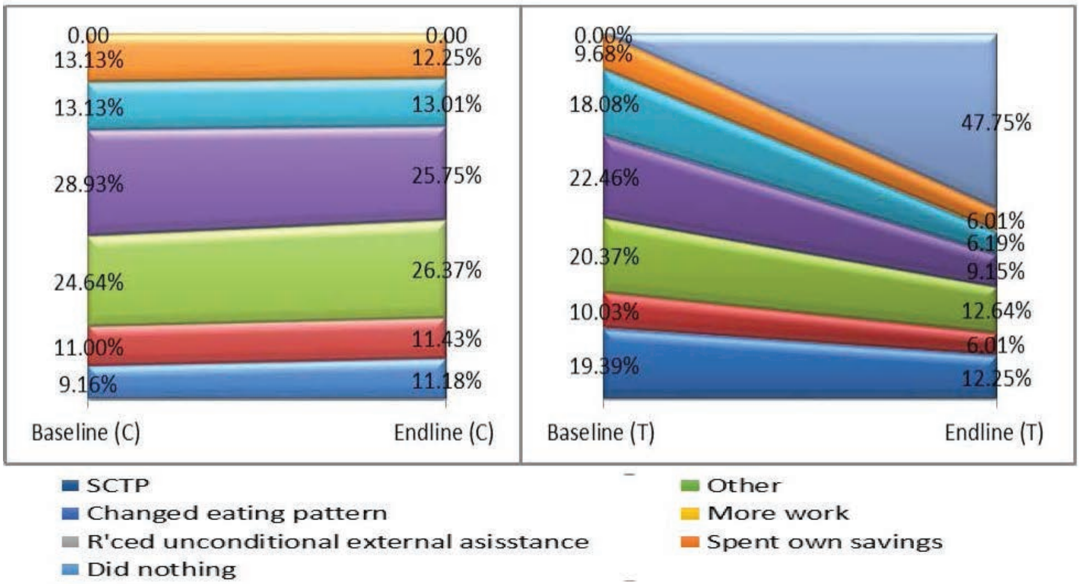
Table 4.6.2 gives the impacts on the specific shocks. We find no impacts on the proportion of households that experienced any of the specific shocks in the 12 month period preceding the surveys. Perhaps the one shock the SCTP could have affected is the death of a household income earner through improved health seeking behaviour, but the incidence of this is quite low and also likely to suffer from ceiling effects. The impacts on the specific coping strategies are given in Table 4.6.3. We find a significant

Table 4.6.3 – Impacts on Coping Strategies

Dependent Variable	Endline Impact (1)	Midline Impact (2)	Impact Diff (EL-ML) (3)=(1)-(2)	Baseline Treated Mean (4)	Endline Treated Mean (5)	Endline Control Mean (6)
Did nothing	-0.131	-0.022	-0.109	0.217	0.222	0.352
	(-1.37)	(-0.24)	(1.35)			
Own savings	-0.082	-0.085	0.003	0.191	0.080	0.175
	(-1.49)	(-1.37)	(0.05)			
R'ced external assistance	-0.221***	-0.077	-0.144**	0.499	0.198	0.354
	(-4.35)	(-1.07)	(2.48)			
More work	-0.245***	-0.196***	-0.049	0.457	0.134	0.366
	(-3.54)	(-3.50)	(0.83)			
Borrowed	-0.045**	-0.009	-0.036**	0.027	0.032	0.066
	(-2.60)	(-1.02)	(2.12)			
Household members moved out	-0.007	-0.005	-0.002	0.006	0.006	0.014
	(-1.38)	(-0.76)	(0.27)			
Changed eating pattern	-0.197***	-0.054	-0.142***	0.222	0.109	0.297
	(-3.21)	(-1.24)	(3.13)			
N	8,720	8,720		1,508	1,383	1,594

Notes: Estimations use difference-in-differences modelling among panel households. Binary outcomes are estimated using LPM. See Table 4.1.1 for additional explanatory notes on model specification, including a list of control variables utilized. * 10% significance ** 5% significance; *** 1% significance

Figure 4.6.1 - Strategies for coping with negative shocks(aggregate shares)



negative impact of 20 pp on the proportion of households that had to cope by changing eating pattern (relying on less preferred food options, reducing food proportions or number of meals per day). We also find a five pp impact reduction on the use of borrowing as a coping strategy to shocks. The mix of coping strategies, including the role of SCTP is depicted in Fig. 4.6.1.

4.7 Impacts on Consumption and Food Security

The overarching objective of the SCTP is to mitigate the effects of poverty by ensuring food security and maintaining consumption. Adequate consumption and food security are not only essential for survival, but are also instrumental for wellbeing and particularly important for child growth and development. We estimate the impacts on consumption using total annual per capital consumption at the household level. Table 4.7.1 shows the impacts on household consumption expenditures. There is a MWK 10380 impact on overall per capita consumption and a MWK 7920 impact on food expenditures. Computations use the national poverty and ultra-poverty lines provided by the National Statistics Office (NSO). Details of the poverty lines and inflation factors to account for the timing of the surveys are found in the main impact evaluation report (Handa et al, 2016).

A breakdown of food consumption by the major food groups reveals a decrease in the share of expenditure on cereals and an increase in the share of the expenditure on meats and beverages. This shift may be an indication of a shift in preference, but also reflects a quality-for-quantity substitution that augurs well for household nutritional balance. A simple measure of dietary diversity – a count of the number of the broad categories a household meal typically comes from – shows significant increase

Table 4.7.1 – Impacts on Household Consumption Expenditures

Dependent Variable	Endline Impact (1)	Midline Impact (2)	Impact Diff (EL-ML) (3)=(1)-(2)	Baseline Treated Mean (4)	Endline Treated Mean (5)	Endline Control Mean (6)
Per capita expenditure	10,380.358***	4,627.682	5,752.676**	45,845.828	54,025.969	41,306.919
	(4.29)	(1.55)	(2.40)			
Food expenditures	7,920.807***	2,121.136	5,799.671***	34,804.042	40,577.144	30,586.176
	(4.20)	(0.93)	(3.01)			
	(1.75)	(1.42)	(0.56)			
Clothing expenditures	692.732***	730.565***	-37.833	376.021	1,081.369	277.493
	(7.29)	(5.87)	(0.37)			
Housing expenditures	-241.855	-283.815	41.961	5,251.642	5,467.615	5,473.656
	(-0.52)	(-1.17)	(0.10)			
Furnishings	568.801***	653.925***	-85.124	1,244.229	1,655.791	1,002.999
	(4.55)	(6.02)	(0.59)			
Health expenditures	-5.642	443.215	-448.857	1,490.464	1,773.787	1,755.153
	(-0.02)	(1.43)	(1.51)			
Communication expenditures	-0.396	-6.598	6.202	49.906	84.628	82.998
	(-0.01)	(-0.26)	(0.18)			
Recreation expenditures	-0.931	-3.502	2.571	4.475	3.930	2.103
	(-0.32)	(-1.03)	(0.77)			
Education expenditures	202.381***	198.167***	4.214	330.936	503.493	328.249
	(3.19)	(3.55)	(0.07)			
Misc Goods & Services expenditures	428.084***	280.834***	147.250*	707.277	1,147.720	680.000
	(4.28)	(3.78)	(1.72)			
N	9,775	9,775		1,559	1,530	1,707

Notes: Estimations use difference-in-differences modelling among panel households. Binary outcomes are estimated using LPM. See Table 4.1.1 for additional explanatory notes on model specification, including a list of control variables utilized. * 10% significance ** 5% significance; *** 1% significance

in dietary diversity (Table 4.7.2). We also find a significant positive impact on the food consumption score (FCS) – a composite score based on dietary diversity and the relative nutritional importance of different food groups. Finally, there is also a significant positive impact on the Simpson's Index of Dietary diversity – an index that takes into account not only the count of the food groups, but also the expenditure shares allocated to each group. The computations of the FCS and the Simpson's diversity index follows WFP and FAO methodology[6].

[6] See for example: Elliot Vhurumku: Food Security Indicators - Integrating Nutrition and Food Security Program-

Table 4.7.2 – Impacts on Dietary Diversity, FCS and Simpson's Index

Dependent Variable	Endline Impact (1)	Midline Impact (2)	Impact Diff (EL-ML) (3)=(1)-(2)	Baseline Treated Mean (4)	Endline Treated Mean (5)	Endline Control Mean (6)
Dietary Diversity	1.205***	0.378	0.827***	5.820	6.912	5.620
	(4.11)	(1.42)	(2.98)			
Food Consumption Score	2.298***	0.679	1.619***	8.260	10.369	7.975
	(4.49)	(1.45)	(3.58)			
Simpson's Diversity Index	0.066***	0.022	0.045**	0.594	0.661	0.580
	(3.48)	(1.01)	(2.41)			
N	9,906	9,906		1,576	1,576	1,726

Notes: Estimations use difference-in-differences modelling among panel households. Binary outcomes are estimated using LPM. See Table 4.1.1 for additional explanatory notes on model specification, including a list of control variables utilized. * 10% significance ** 5% significance; *** 1% significance

Table 4.7.3 – Food Security – Enough Food and Meals per Day

Dependent Variable	Endline Impact (1)	Midline Impact (2)	Impact Diff (EL-ML) (3)=(1)-(2)	Baseline Treated Mean (4)	Endline Treated Mean (5)	Endline Control Mean (6)
Worried about having enough food for past 7 days	-0.204*** (-3.20)	-0.113** (-2.39)	-0.091** (2.10)	0.839	0.698	0.899
Number of meals eaten per day	0.294*** (5.92)	0.184*** (4.18)	0.110** (2.32)	1.906	2.227	1.954
Eats more than 1 meal per day	0.136*** (4.20)	0.077*** (3.09)	0.059** (2.42)	0.794	0.936	0.816
N	9,769	9,769		1,559	1,528	1,704

Notes: Estimations use difference-in-differences modelling among panel households. Binary outcomes are estimated using LPM. See Table 4.1.1 for additional explanatory notes on model specification, including a list of control variables utilized. * 10% significance ** 5% significance; *** 1% significance

On food security, we were interested to know whether households were about having enough food, number of meals eaten per day, and whether household eat more than one meal per day. We find an impact of 20 pp reduction in the share of households worried about having enough to eat in the past 7 days, and a 14 pp impact on the share of households eating more than 1 meal per day (Table 4.7.3).

5. Household Resilience Capacity and Structure

This section of the report focuses on the estimation of household resilience capacity index and analysis of its structure and validity. The method for estimating the resilience index follows the FAO RIMA II model[7]. It must be stated that while the SCTP evaluation survey instruments were not explicitly designed with the RIMA II model in mind,we have enough variables that match all the RIMA II indicators and constructs quite closely. In addition, having actual data on shocks and coping strategies allows for some validity test which may be elusive for most studies. The panel data also allows for both contemporaneous and lagged analysis of the predictive power of the resilience capacity index for food security and responses to shocks.

5.1 The FAO RIMA II model, indicators and the SCTP instrument

The RIMA II model assumes resilience as a latent construct with multiple predictors and multiple outcomes. The predictors are grouped into four main categories called pillars. The pillars are namely access to basic services (ABS), ownership of assets (AST), social safety nets (SSN) and household

ming for Emergency response workshop, 25 to 17 February 2014.

[7] Resilience Index Measurement and Analysis – II. Food and Agricultural Organization of the United Nations. Rome 2016.

adaptive capacity (AC).Each pillar is a latent variable of itself determined by a number of household level indicators. The household is considered the unit of analysis because it is the unit of decision making for household production and consumption. The outcomes are per capita food consumption and the Simpson's Dietary Diversity Index. For the pillar of ABS, we do not have any direct measures to construct in index. However, since we are mostly concerned about resilience profiles for T and C households, it is reasonable to assume that, by design, C and T households are equally clustered in terms of this covariate dimension of resilience. For the other pillars, Table 5.1.1 shows the typical indicators that FAO considers for each pillar and the corresponding indicators that we have available from the SCTP instrument.

The outcome variables of per capita food expenditure and the Simpson's index are identical, so are the AST indicators of asset ownership (agricultural and non-agricultural) and livestock. For SSN, we have total in-kind transfers, credit constraint and perceived available support in times of need. Credit constraint and perceived available support captures a potential for support when shocks set in, and these are more relevant for measuring resilience. We recognize a potential downside to using the variable of in-kind assistance as a measure of resilience. Households that are better off by themselves may have little in-kind assistance, especially in ǒnormal' times, and so the indicator of whether support can be activated when needed is likely a more appropriate ex-ante measure. On AC, we have an indicator on number of income sources and the ratio of FTW to NFTW. Ideally, we would prefer to have the total income from each of these domains as a more direct measure of capacity and importance to household livelihood. We also have a binary variable of whether the household is crop production only household, or it does crop production with other income generating activities. Each measured variable is constructed to be positive that such more is better, and for binary variables, the better outcome is coded as 1.

Table 5.1.1 – RIMA Domain Indicators by FAO and SCTP Equivalents

Domain	FAO suggested indicators	SCTP Equivalents/Proxies
Outcome Indicators	Average per person daily income, Average per person daily expenditure, Food consumption score/other nutrition proxy, dietary diversity and food frequency score, dietary energy consumption	V1. Per capita food expenditure V2. Simpson's Diversity Index
AST	Agric assets, Non-Agric Assets, TLU, Land owned	V3. 'Wealth' index of agric assets, durable goods, housing& household characteristics V4. Per capita TLU owned V5. Per capita Total Land Cultivated
SSN	Amount of cash and in-kind assistance, Social Networks, Frequency of assistance, Formal/Informal Transfers	V6. Log of total in-kind transfers V7. Log of value of free maize V8. Credit Constraint, V9. Perceived available support in times of need
AC	Diversity of income sources, Educational level (household average), Employment ratio, Available coping strategies	V10. Number of income sources V11. Ratio of FTW to NFTW, V12. Not Crop production only household

5.2 Model Estimation and Summary Results

Empirically, the Resilience Capacity Index (RCI) is estimated using the Multiple Indicator and Multiple Outcome model (MIMIC) in a structural equation framework. The RIMA model is estimated using structural equation model based on the conceptual path diagram in Fig. 5.2.1. Each pillar is separately estimated using factor analysis of the variables that make up the dimension.The predicted value of each of the components is standardized to range from 0-100 and in-turn used to construct the RCI in the MIMIC model. In the MIMIC estimation, several approaches are used to estimate the weights as check for robustness and also try to eliminate any bias on the weights due to the treatment. Weights are generated using only the C households at baseline and endline, or only baseline data for T and C, or baseline for T and C and endline for C, and using all the data. The results are robust under all specifications and so we proceed with the model that uses all the data since this is recommended. Tables 5.2.1a, 5.2.1b and 5.2.1c give a summary of the MIMIC estimation. Table 5.2.1a gives the standardized coefficients of the pillars, the Z values and the significance. We find that each of the pillars is significant in the model at the one per cent level of significance. Table 5.2.1b gives the standardized coefficients to the reflective indicators. The coefficient of per capita consumption is standardized to one to make the coefficient of the Simpson's index interpretable. We find that a 1 unit increase in the RCI results in a 0.13 increase in the standard deviation of the Simpson's index.

The summary model fit statistics indicate that the chi-square value is significant at the 1 per cent level. The root mean square estimate of approximation is 0.0947 and the p-value indicates that there is greater than the

Table 5.2.1a: Model Output on Formative Indicators (Pillars)

Covariate	Coefficient	Z	P >|z|
Assets, AST	0.1111	28.2887	0.0000
Social Safety Nets, SSN	0.0028	8.9865	0.0000
Adaptive Capacity, AC	0.0019	5.6091	0.0000

Table 5.2.1b: Model Output on Reflective Indicators (Food Security)

Covariate	Coefficient	Z	P >|z|
Log PC Food	1.0000		
Simpsons Food Diversity Index	0.1308	17.1302	0.0000

Table 5.2.1c: Summary Model Fit Statistics

N	Chi-Square (p-val)	RMSEA (p RMSEA<0.05)	CFI	TLI	CD
6,595	120.3428 (0.0000)	0.0947 (0.0000)	0.9301	0.7554	0.3607

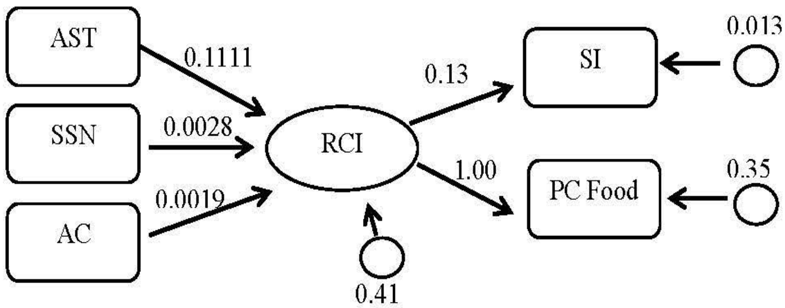


Fig. 5.2.1: Schematic representation of RIMA II MIMIC model and results.

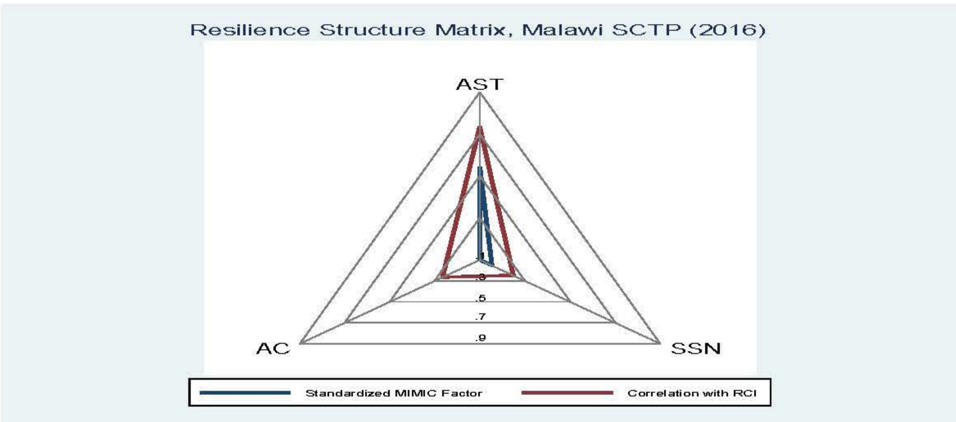


Fig. 5.2.2: Resilience structure matrix and correlation with RCI for Resilience Pillars

Table 5.2.2: Distribution of RCI by Treatment Status and Wave

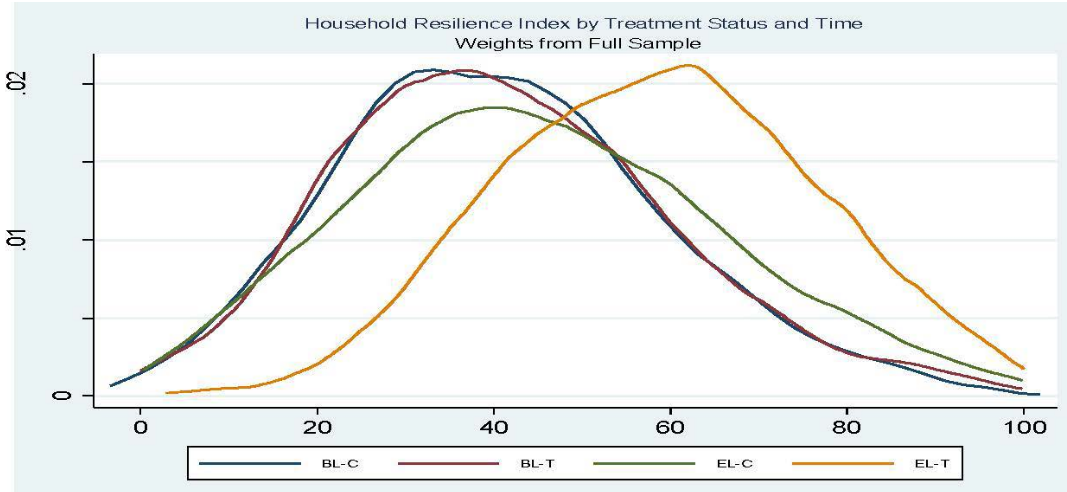
	Baseline			Endline		
Resilience Quintiles	C	T	Total	C	T	Total
Lowest	21.96	24.12	22.99	27.86	12.92	20.73
Second	22.40	18.93	20.75	19.15	15.40	17.36
Middle	18.83	19.22	19.02	17.88	19.73	18.76
Fourth	17.70	18.69	18.17	17.30	22.79	19.91
Highest	19.10	19.04	19.08	17.82	29.15	23.22
Total	100.00	100.00	100.00	100.00	100.00	100.00

Table 5.2.3: Impacts on Resilience Capacity Index (Overall and Heterogeneous)

Dependent Variable	Endline Impact (1)	Baseline Treatment Mean (2)	Baseline Control Mean (3)	Endline Treated Mean (4)	Endline Control Mean (5)
Full Sample	12.432***	42.144	41.493	58.457	45.076
	(7.67)				
N	6,472	1,556	1,686	1,532	1,698
Baseline poorest 50%	14.516***	28.249	28.114	54.380	38.462
	(9.87)				
N	3,283	780	853	785	865
Baseline Small Households	11.797***	48.970	48.854	62.482	49.456
	(6.28)				
N	3,188	782	826	753	827
Baseline Labour Constrained Households	13.144***	41.806	40.952	58.189	44.073
	(7.88)				
N	5,236	1,302	1,369	1,231	1,334

Notes: Estimations use difference-in-differences modelling among panel households. Binary outcomes are estimated using LPM. See Table 4.1.1 for additional explanatory notes on model specification, including a list of control variables utilized. * 10% significance ** 5% significance; *** 1% significance.

Figure 5.3 – RCI by treatment status and time



recommended threshold of 0.05. However, there is no universal agreement on these quality fit threshold. The CFI and the TLI are both appreciable high to indicate a good fit. Fig. 5.2.1 shows the diagrammatic representation of the model results. Fig. 5.2.2. gives a radar plot of the resilience structure matrix and correlation of pillars with RCI.

Table 5.2.2 gives a summary of the RCI scores for T and C groups at baseline and at endline, and this is depicted with the kernel density in Fig. 5.2.3. We find a clear increase in the distribution of the resilience scores for the T group at endline compared to the near identical resilience distribution of C and T at baseline. Table 5.2.3 gives the impact estimation results on resilience for the overall sample, baseline bottom 50 per cent of households, baseline small households, and baseline labour constrained households. We find that the impacts are significant for all groups.

5.3 Resilience Capacity and Coping with Shocks

To examine the predictive power of the resilience index, we further analyse the actual coping responses to shocks against the resilience index. The coping mechanism to shock was not an input to the determination of the resilience index and we would expect that more resilient households would tend to cope with positive responses as compared to less resilient households. Table 5.2.4 shows the distribution of the resilience and the share of positive coping responses to shocks at baseline and endline. The results show a high degree of agreement between the resilience scores and the share of positive responses to shocks that are adopted by households. At baseline, we find that the share of households adopting positive responses to shocks increases from 26 per cent for those in the lowest resiliency quintile to 59 percent for those in the highest resiliency quintile. This distribution is pretty much the same for C and T households. At endline, we find that the distribution of the share of households with positive coping responses to shocks stays essentially the same for C households as it was at baseline, but the share of households with positive coping responses to shocks is much higher

Table 5.2.4 – Share of Positive Coping Responses to Shocks by Resiliency Quintiles

	Baseline			Endline		
Resilience Quintiles	C	T	Total	C	T	Total
Lowest	0.23	0.29	0.26	0.25	0.63	0.37
Second	0.31	0.34	0.33	0.34	0.67	0.47
Middle	0.42	0.42	0.42	0.40	0.69	0.54
Fourth	0.49	0.47	0.48	0.51	0.76	0.64
Highest	0.59	0.59	0.59	0.62	0.77	0.71
Total	0.39	0.41	0.40	0.40	0.72	0.55

Figure 5.4 – Lowess graph of positive coping and RCI

at all quintiles for the T group, increasing from 63 per cent for those in the lowest quintile to 77 per cent for those in the highest quintile. A lowess graph of the RCI and share of positive coping strategies to shocks is further depicted in Fig. 5.4 and clearly shows the concomitant agreement between the RCI and positive coping with shocks.

Table 5.2.5 – Baseline resilience and endline food security among C households

Baseline RCI quintiles among C households	Endline Food Security Indicators			
	Mean PC Food (MWK)	No food worry	Simpson's Index	Food Consumption Score
Lowest	19790.400	0.053	0.526	6.281
Second	25427.950	0.057	0.582	7.934
Middle	34004.360	0.071	0.595	8.873
Fourth	39047.250	0.140	0.620	9.342
Highest	54268.380	0.205	0.668	9.703

5.4 Baseline Resilience and Endline Food Security among C Households

Another examination of the validity of the RCI is its predictive power of food security, regardless of the treatment. This is done by examining the effect of baseline resilience and endline food security among C households. As shown in Table 5.2.5, we find that endline food security generally increases with increasing baseline RCI. This also shows that the RCI has reasonable validity for use in predicting future food security and as ranking tool for targeting of interventions.

6. Summary and Conclusions

This paper has examined the impacts of Malawi's SCTP program on the concept of resilience. We find that the SCTP has positively impacted household production, asset ownership, income diversification and strengthening as hypothesized. The SCTP has not led to a reduction in labour supply by beneficiary households has is often a concern for unconditional cash transfers. We also find that the SCTP has not produced any "crowding-out' effect on pre-existing social safety nets, both public and private. There is increased per capita food consumption, dietary diversity and food security. Using the FAO RIMA II model, we estimate the impact of these dynamics of household resilience and find that although the SCTP was not explicitly designed with increasing resilience in mind, nonetheless, the SCTP has positively impacted resilience. Thus, there is reason to believe that cash transfer, even one that is unconditional, can produce positive impacts on household resilience.

We examine the validity of the resilience index by analysing its correlation with positive coping to shocks and find that increasing resilience is associated with positive coping to shocks. Additionally, by analysing only the C sample, we find that baseline resilience is predictive of endline food consumption and food security. This implies that the RCI can be used as a profiling and ranking tool for interventions.

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Annex A: Attrition Analysis Tables

A.1 Selective Attrition

Table A.1.1: Individual-Level Characteristics (Controls versus Treatment for Panel Households)

Variables	Control Mean	Control N1	Treatment Mean	Treatment N2	Mean Diff	Diff SE	p-value
Age (in years)	24.907	8,017	25.813	7,234	0.905	1.015	0.380
Child under-five	0.121	8,017	0.121	7,234	-0.000	0.009	0.980
Child ages 5-17	0.498	8,017	0.484	7,234	-0.014	0.012	0.241
Adult (18-64)	0.249	8,017	0.245	7,234	-0.004	0.014	0.749
Elderly (65 and older)	0.137	8,017	0.156	7,234	0.019	0.018	0.279
Orphan (one or both parents)	0.206	8,017	0.224	7,234	0.018	0.026	0.481
Female	0.571	8,017	0.572	7,234	0.001	0.007	0.913
Chronic illness	0.149	8,017	0.174	7,234	0.024	0.016	0.140
Any disability	0.007	8,017	0.006	7,234	-0.001	0.001	0.307
Currently in school	0.373	8,017	0.356	7,234	-0.017	0.022	0.450

Notes: Weighted results; standard errors obtained considering multi-stage sampling design

Table A.1.2: Main Respondent Characteristics (Control versus Treatment for Panel Households)

Variables	Control Mean	Control N1	Treatment Mean	Treatment N2	Mean Diff	Diff SE	p-value
Female	0.852	1,726	0.831	1,577	-0.021	0.022	0.345
Age (in years)	56.904	1,726	58.908	1,577	2.004	2.198	0.370
Widowed	0.419	1,726	0.440	1,577	0.022	0.036	0.551
Divorced/Separated	0.645	1,726	0.645	1,577	0.000	0.036	0.991
Currently in school	0.007	1,726	0.010	1,577	0.003	0.003	0.255
Ever attended school	0.296	1,726	0.298	1,577	0.001	0.054	0.982
Highest grade completed	3.587	549	3.624	531	0.037	0.269	0.891
Chronic illness	0.408	1,726	0.471	1,577	0.062	0.043	0.157
Any disability	0.011	1,726	0.012	1,577	0.001	0.004	0.826

Notes: Weighted results; standard errors obtained considering multi-stage sampling design

Table A.1.3: Household Demographic Characteristics (Control versus Treatment for Panel Households)

Variables	Control Mean	Control N1	Treatment Mean	Treatment N2	Mean Diff	Diff SE	p-value
Numbers of persons in household	4.579	1,726	4.533	1,577	-0.046	0.224	0.840
No. of children under 5	0.556	1,726	0.549	1,577	-0.007	0.059	0.912
No. of children 5-17	2.281	1,726	2.195	1,577	-0.086	0.132	0.519
Number of adults (18-64)	1.142	1,726	1.111	1,577	-0.031	0.105	0.766
Number of elderly (65+)	0.626	1,726	0.708	1,577	0.082	0.056	0.154
Number of orphans	0.943	1,726	1.017	1,577	0.074	0.126	0.563
Household has a disabled	0.033	1,726	0.027	1,577	-0.005	0.005	0.295
Number of working age (15-64)	1.493	1,726	1.469	1,577	-0.025	0.123	0.843
No. of dependents (<15 or >65)	3.085	1,726	3.064	1,577	-0.021	0.127	0.870
No. currently in school	1.707	1,726	1.614	1,577	-0.093	0.141	0.516
No. of persons per room	2.462	1,719	2.521	1,573	0.059	0.159	0.714

Notes: Weighted results; standard errors obtained considering multi-stage sampling design

Table A.2.1: Individual-Level Characteristics (Attriters versus Panel Households)

Variables	Attriters Mean	N1	Panel Mean	N2	Mean Diff	Diff SE	p-value
Age (in years)	28.280	827	25.352	15,251	-2.927	1.426	0.049
Child under-five	0.138	827	0.121	15,251	-0.017	0.012	0.163
Child ages 5-17	0.442	827	0.491	15,251	0.050	0.020	0.019
Adult (18-64)	0.237	827	0.247	15,251	0.010	0.011	0.361
Elderly (65 and older)	0.193	827	0.146	15,251	-0.047	0.020	0.025
Orphan (one or both parents)	0.201	827	0.215	15,251	0.015	0.026	0.582
Female	0.594	827	0.571	15,251	-0.023	0.016	0.169
Chronic illness	0.203	827	0.161	15,251	-0.041	0.017	0.021
Any disability	0.007	827	0.007	15,251	-0.001	0.003	0.854
Currently in school	0.331	827	0.365	15,251	0.034	0.027	0.230

Notes: Weighted results; standard errors obtained considering multi-stage sampling design

Table A.2.2: Main Respondent Characteristics (Attriters versus Panel Households)

Variables	Attriters Mean	N1	Panel Mean	N2	Mean Diff	Diff SE	p-value
Female	0.750	228	0.841	3,303	0.092	0.028	0.003
Age (in years)	59.918	228	57.894	3,303	-2.024	1.903	0.297
Widowed	0.482	228	0.429	3,303	-0.052	0.036	0.160
Divorced/Separated	0.666	228	0.645	3,303	-0.021	0.038	0.586
Currently in school	0.014	228	0.008	3,303	-0.005	0.006	0.415
Ever attended school	0.273	228	0.297	3,303	0.024	0.039	0.532
Highest grade completed	3.996	72	3.605	1,080	-0.391	0.359	0.286
Chronic illness	0.522	228	0.439	3,303	-0.082	0.028	0.007
Any disability	0.020	228	0.012	3,303	-0.009	0.009	0.334

Notes: Weighted results; standard errors obtained considering multi-stage sampling design

Table A.2.3: Household Demographic Characteristics (Attriters versus Panel Households)

Variables	Attriters Mean	N1	Panel Mean	N2	Mean Diff	Diff SE	p-value
Numbers of persons in household	3.558	228	4.556	3,303	0.998	0.174	0.000
No. of children under 5	0.490	228	0.552	3,303	0.062	0.051	0.236
No. of children 5-17	1.572	228	2.238	3,303	0.667	0.135	0.000
Number of adults (18-64)	0.844	228	1.127	3,303	0.283	0.052	0.000
Number of elderly (65+)	0.687	228	0.667	3,303	-0.020	0.042	0.636
Number of orphans	0.713	228	0.980	3,303	0.266	0.111	0.023
Household has a disabled	0.026	228	0.030	3,303	0.004	0.011	0.684
Number of working age (15-64)	1.046	228	1.481	3,303	0.435	0.069	0.000
No. of dependents (<15 or >65)	2.511	228	3.075	3,303	0.564	0.128	0.000
No. currently in school	1.177	228	1.661	3,303	0.484	0.141	0.002
No. of persons per room	2.223	228	2.491	3,292	0.268	0.149	0.083

Notes: Weighted results; standard errors obtained considering multi-stage sampling design

Annex B: Variable Factor Loadings and Uniqueness

Table B1: AST Variables Factor Loadings and Uniqueness

Variable	Factor1	Factor2	Uniqueness
PC TLU	0.2843	0.1883	0.8837
PC Land Holding (Acres)	0.3040	-0.1821	0.8744
Wealth Index	0.4606	0.0039	0.7878

Table B2: SSN Variables Factor Loadings and Uniqueness

Variable	Factor1	Factor2	Factor3	Uniqueness
Perceived support	0.2565	0.1919	-0.0785	0.8912
Value of social network	0.5410	0.0352	0.0146	0.7059
Log of free maize	0.4245	-0.1956	0.0104	0.7814
Credit constraint	0.0837	0.1767	0.0938	0.9530

Table B3: AC Variables Factor Loadings and Uniqueness

Variable	Factor1	Factor2	Uniqueness
Non-Agri household	0.2910	-0.1740	0.8851
Household education	0.4294	0.0099	0.8155
Labour Constraint	0.2456	0.1888	0.9040

Annex C: Supplementary Tables

Table C.1.1: Impacts on Household Economic Activities - Baseline Bottom 50 per cent

Dependent Variable	Endline Impact (1)	Midline Impact (2)	Impact Diff (EL-ML) (3)=(1)-(2)	Baseline Treated Mean (4)	Endline Treated Mean (5)	Endline Control Mean (6)
Crop production household	0.026*	-0.012	0.038***	0.951	0.980	0.945
	(1.75)	(-0.76)	(2.88)			
Total crop harvest (kg)	63.249***	10.642	52.607**	160.372	274.995	186.683
	(4.47)	(0.58)	(2.69)			
Total crop harvest (kg) - Staples	62.296***	11.100	51.196**	155.661	263.008	177.523
	(4.28)	(0.64)	(2.50)			
Total value of crop harvest (MWK)	11,710.837***	-1,047.365	12,758.202***	26,906.869	48,332.181	30,391.480
	(2.87)	(-0.24)	(4.10)			
Raised or owned livestock	0.331***	0.192***	0.139***	0.252	0.660	0.269
	(7.91)	(4.04)	(4.33)			
TLU owned presently	0.067***	0.039***	0.028**	0.026	0.106	0.040
	(5.06)	(2.96)	(2.50)			
Household has non-farm enterprise	-0.024	-0.059	0.035	0.259	0.284	0.189
	(-0.56)	(-1.51)	(0.80)			
Number of economic activities	0.333***	0.121**	0.211***	1.462	1.925	1.404
	(5.04)	(2.11)	(3.55)			
N	5,037	5,037		794	794	885

Notes: Estimations use difference-in-differences modelling among panel households. Binary outcomes are estimated using LPM. See Table 4.1.1 for additional explanatory notes on model specification, including a list of control variables utilized. * 10% significance ** 5% significance; *** 1% significance.

Table C.1.2: Impacts on Loans and Credits - Baseline Bottom 50 per cent

Dependent Variable	Endline Impact (1)	Midline Impact (2)	Impact Diff (EL-ML) (3)=(1)-(2)	Baseline Treated Mean (4)	Endline Treated Mean (5)	Endline Control Mean (6)
Still owes on loan from 12+ months	-0.068**	0.003	-0.070***	0.075	0.096	0.174
	(-2.38)	(0.09)	(2.84)			
Took a loan in last 12m	-0.021	-0.048	0.027	0.271	0.246	0.260
	(-0.43)	(-1.16)	(0.69)			
Loan fully paid	0.036	0.037	-0.001	0.803	0.836	0.788
	(0.87)	(1.06)	(0.04)			
Purchased on credit in last 12m	-0.109**	-0.081**	-0.029	0.323	0.222	0.285
	(-2.54)	(-2.19)	(0.75)			
Credit on purchases fully paid	0.117***	0.067**	0.050*	0.807	0.899	0.808
	(3.65)	(2.62)	(1.73)			
Currently Owes	-0.139***	-0.077*	-0.063*	0.342	0.273	0.403
	(-2.79)	(-1.95)	(1.74)			
Total current debt (MWK)	-1,029.212**	-473.498*	-555.714	943.312	1,264.285	2,221.996
	(-2.57)	(-1.83)	(1.66)			
N	5,037	5,037		794	794	885

Notes: Estimations use difference-in-differences modelling among panel households. Binary outcomes are estimated using LPM. See Table 4.1.1 for additional explanatory notes on model specification, including a list of control variables utilized. * 10% significance ** 5% significance; *** 1% significance.

Table C.1.3: Credit Constraints - Baseline Bottom 50 per cent

Dependent Variable	Endline Impact (1)	Midline Impact (2)	Impact Diff (EL-ML) (3)=(1)-(2)	Baseline Treated Mean (4)	Endline Treated Mean (5)	Endline Control Mean (6)
Applied for loan but refused	-0.027***	-0.035**	0.009	0.058	0.017	0.026
	(-2.81)	(-2.59)	(0.68)			
Asked to buy on credit but refused	-0.052*	-0.007	-0.045*	0.108	0.041	0.088
	(-1.96)	(-0.25)	(1.93)			
Wanted larger loan at same interest rate	-0.035	-0.048	0.013	0.123	0.099	0.098
	(-0.95)	(-1.36)	(0.38)			
Sure to get a loan if applied	-0.053	-0.012	-0.041	0.181	0.118	0.129
	(-1.25)	(-0.36)	(1.24)			
Would apply for loan if sure can get	-0.061	-0.016	-0.046	0.153	0.094	0.146
	(-1.18)	(-0.38)	(1.31)			
Sure can buy on credit if asked	-0.020	0.019	-0.039	0.167	0.175	0.160
	(-0.50)	(0.44)	(0.58)			
Would ask to purchase on credit if sure can get	0.036	0.040*	-0.004	0.088	0.082	0.068
	(1.11)	(1.79)	(0.11)			
Loan/Credit Purchase constrained	0.035	0.034	0.001	0.873	0.902	0.896
	(1.37)	(1.25)	(0.03)			
N	5,037	5,037		794	794	885

Notes: Estimations use difference-in-differences modelling among panel households. Binary outcomes are estimated using LPM. See Table 4.1.1 for additional explanatory notes on model specification, including a list of control variables utilized. * 10% significance ** 5% significance; *** 1% significance.

Table C.1.4: Credit Use - Baseline Bottom 50 per cent

Dependent Variable	Endline Impact (1)	Midline Impact (2)	Impact Diff (EL-ML) (3)=(1)-(2)	Baseline Treated Mean (4)	Endline Treated Mean (5)	Endline Control Mean (6)
Some loan used for prod invest	0.011	-0.008	0.018	0.029	0.033	0.020
	(1.12)	(-0.84)	(1.66)			
Some loan used for consumption	-0.015	-0.047*	0.032	0.185	0.177	0.186
	(-0.39)	(-1.84)	(0.91)			
Some loan used for education	-0.008	0.002	-0.010	0.011	0.028	0.031
	(-0.67)	(0.20)	(0.88)			
Some loan used for health	-0.014	-0.015	0.000	0.053	0.074	0.069
	(-0.54)	(-0.64)	(0.01)			
Some credit used for prod invest	-0.001	0.003	-0.003	0.010	0.004	0.003
	(-0.11)	(0.38)	(0.62)			
Some credit used for consumption	-0.100**	-0.072*	-0.029	0.291	0.201	0.264
	(-2.31)	(-1.73)	(0.79)			
Some credit used for education	-0.000	0.002	-0.002	0.001	0.001	0.003
	(-0.01)	(0.63)	(0.50)			
Some credit used for health	-0.008	-0.018	0.011	0.016	0.015	0.014
	(-0.79)	(-1.67)	(0.99)			
N	5,037	5,037		794	794	885

Notes: Estimations use difference-in-differences modelling among panel households. Binary outcomes are estimated using LPM. See Table 4.1.1 for additional explanatory notes on model specification, including a list of control variables utilized. * 10% significance ** 5% significance; *** 1% significance.

Table C.1.5: Impacts on In- and Out-Transfers - Baseline Bottom 50 per cent

Dependent Variable	Endline Impact (1)	Midline Impact (2)	Impact Diff (EL-ML) (3)=(1)-(2)	Baseline Treated Mean (4)	Endline Treated Mean (5)	Endline Control Mean (6)
Any in-transfer of cash, food or labour	0.121	0.010	0.112	0.717	0.719	0.654
	(1.65)	(0.12)	(1.43)			
Any out-transfer of cash, food or labour	0.037	0.021	0.016	0.028	0.108	0.067
	(1.28)	(0.75)	(0.55)			
Total value of cash, food of labour in-transfer (MWK)	1,291.193	735.405	555.788	6,101.291	8,213.298	7,352.113
	(0.76)	(0.42)	(0.39)			
Total value of cash, food of labour out-transfer (MWK)	923.373**	228.848	694.525	520.361	1,605.166	996.184
	(2.05)	(0.60)	(1.55)			
Net transfer of cash, food or labour (MWK)	367.820	506.557	- 138.737	5,580.930	6,608.132	6,355.929
	(0.25)	(0.32)	(0.11)			
Household received Agric Implements/Inputs	0.047	-0.000	0.048	0.172	0.136	0.117
	(0.77)	(-0.00)	(1.31)			
N	5,036	5,036		794	794	885

Notes: Estimations use difference-in-differences modelling among panel households. Binary outcomes are estimated using LPM. See Table 4.1.1 for additional explanatory notes on model specification, including a list of control variables utilized. * 10% significance ** 5% significance; *** 1% significance.

Table C.1.5: Impacts on Out-Transfers - Baseline Bottom 50 per cent

Dependent Variable	Endline Impact (1)	Midline Impact (2)	Impact Diff (EL-ML) (3)=(1)-(2)	Baseline Treated Mean (4)	Endline Treated Mean (5)	Endline Control Mean (6)
Household transferred Cash Transfer	0.037	0.021	0.016	0.028	0.108	0.067
	(1.28)	(0.75)	(0.56)			
Household transferred Food/Other Consumables	0.064	0.044	0.021	0.189	0.286	0.239
	(0.83)	(0.59)	(0.39)			
Household transferred Labour or Time	-0.020	0.004	-0.025	0.119	0.144	0.186
	(-0.29)	(0.09)	(0.44)			
Household transferred Agric Implements/Inputs	-0.014	-0.014	0.001	0.015	0.022	0.025
	(-0.80)	(-1.45)	(0.03)			
N	5,036	5,036		794	794	885

Notes: Estimations use difference-in-differences modelling among panel households. Binary outcomes are estimated using LPM. See Table 4.1.1 for additional explanatory notes on model specification, including a list of control variables utilized. * 10% significance ** 5% significance; *** 1% significance.

Table C.1.7: Impacts on Social Safety Nets - Baseline Bottom 50 per cent

Dependent Variable	Endline Impact (1)	Midline Impact (2)	Impact Diff (EL-ML) (3)=(1)-(2)	Baseline Treated Mean (4)	Endline Treated Mean (5)	Endline Control Mean (6)
Any SSN benefit	-0.006	0.002	-0.007	0.672	0.616	0.586
	(-0.09)	(0.03)	(0.14)			
No. of SSN benefits	-0.234	-0.142	-0.092	1.145	0.803	0.864
	(-1.10)	(-0.79)	(0.69)			
Value of SSN benefits (MWK)	650.538	1,086.246	-435.708	8,396.757	8,920.237	8,122.398
	(0.33)	(0.66)	(0.43)			
Voucher for fertilizer	0.042	0.025	0.018	0.461	0.471	0.412
	(0.67)	(0.39)	(0.47)			
Value of Voucher for fertilizer	1,268.851	946.156	322.695	5,365.867	6,492.591	5,268.756
	(1.46)	(1.00)	(0.41)			
N	5,037	5,037		794	794	885

Notes: Estimations use difference-in-differences modelling among panel households. Binary outcomes are estimated using LPM. See Table 4.1.1 for additional explanatory notes on model specification, including a list of control variables utilized. * 10% significance ** 5% significance; *** 1% significance.

Table C.1.8: Impacts on Specific Social Safety Nets - Baseline Bottom 50 per cent

Dependent Variable	Endline Impact (1)	Midline Impact (2)	Impact Diff (EL-ML) (3)=(1)-(2)	Baseline Treated Mean (4)	Endline Treated Mean (5)	Endline Control Mean (6)
Free maize	-0.086	-0.076	-0.011	0.183	0.024	0.074
	(-0.99)	(-1.05)	(0.27)			
Quantity of Free Maize (kg)	-12.772	-13.337	0.565	25.337	0.917	4.174
	(-0.89)	(-0.96)	(0.08)			
Other free food	-0.108	-0.057	-0.051	0.171	0.067	0.117
	(-1.55)	(-0.82)	(1.31)			
Value of Other free food	95.239	115.193	-19.954	1,131.487	243.344	386.182
	(0.09)	(0.13)	(0.07)			
Food/Cash for work	0.009	-0.008	0.017	0.068	0.012	0.020
	(0.44)	(-0.34)	(0.98)			
Value of Food/Cash for work	-32.548	-139.845	107.297	308.825	63.438	84.502
	(-0.37)	(-1.31)	(1.25)			
School Feeding	-0.083	-0.043	-0.040	0.204	0.158	0.178
	(-1.11)	(-1.10)	(0.51)			
Value of School Feeding	-841.152	-403.654	-437.497	1,178.494	1,200.238	1,594.492
	(-1.15)	(-1.07)	(0.56)			
Community Based Childcare	0.007	0.003	0.004	0.040	0.036	0.019
	(0.32)	(0.09)	(0.21)			
Value of Community Based Childcare	-3.209	-67.808	64.599	182.616	193.814	86.628
	(-0.02)	(-0.61)	(0.53)			
N	5,037	5,037		794	794	885

Notes: Estimations use difference-in-differences modelling among panel households. Binary outcomes are estimated using LPM. See Table 4.1.1 for additional explanatory notes on model specification, including a list of control variables utilized. * 10% significance ** 5% significance; *** 1% significance.

Table C.1.9: Impacts on Shocks and Coping-Baseline Bottom 50 per cent

Dependent Variable	Endline Impact (1)	Midline Impact (2)	Impact Diff (EL-ML) (3)=(1)-(2)	Baseline Treated Mean (4)	Endline Treated Mean (5)	Endline Control Mean (6)
Any Negative Shock	-0.034	0.021	-0.055	0.970	0.882	0.923
	(-0.99)	(0.50)	(1.02)			
No. of Shocks	0.046	0.149	-0.103	2.619	2.372	2.414
	(0.23)	(0.64)	(0.41)			
Any Covariate Shock	-0.045	0.021	-0.067	0.940	0.854	0.909
	(-0.99)	(0.36)	(1.02)			
Number of covariate shocks	0.015	0.125	-0.110	2.200	1.853	1.845
	(0.09)	(0.53)	(0.52)			
Any Idiosyncractic Shock	0.023	0.019	0.003	0.266	0.146	0.162
	(0.45)	(0.41)	(0.09)			
Number of idiosyncratic shocks	0.019	-0.003	0.022	0.313	0.166	0.182
	(0.32)	(-0.05)	(0.56)			
Share of Positive Coping Strategies	0.354***	0.204**	0.150	0.337	0.695	0.338
	(5.71)	(2.51)	(1.45)			
Share of Negative Coping Strategies	-0.304***	-0.060	-0.245***	0.261	0.282	0.534
	(-5.11)	(-0.89)	(3.26)			
N	4,495	4,495		770	714	821

Notes: Estimations use difference-in-differences modelling among panel households. Binary outcomes are estimated using LPM. See Table 4.1.1 for additional explanatory notes on model specification, including a list of control variables utilized. * 10% significance ** 5% significance; *** 1% significance.

Table C.1.10: Impacts on Specific Shocks - Baseline Bottom 50 per cent

Dependent Variable	Endline Impact (1)	Midline Impact (2)	Impact Diff (EL-ML) (3)=(1)-(2)	Baseline Treated Mean (4)	Endline Treated Mean (5)	Endline Control Mean (6)
Drought/irregular rains	-0.064	0.042	-0.106	0.628	0.626	0.660
	(-0.82)	(0.38)	(1.39)			
Unusually high level of crop/livestock pest/disease	0.007	0.020	-0.013	0.097	0.068	0.071
	(0.21)	(0.42)	(0.32)			
Unusually high prices of food	0.041	0.003	0.037	0.878	0.707	0.678
	(0.79)	(0.04)	(0.46)			
Serious illness or accident to household member(s)	0.014	0.007	0.007	0.180	0.104	0.091
	(0.41)	(0.18)	(0.25)			
Death of household income earner(s)	-0.011	-0.009	-0.002	0.038	0.030	0.038
	(-0.66)	(-0.80)	(0.15)			
N	5,037	5,037		794	794	885

Notes: Estimations use difference-in-differences modelling among panel households. Binary outcomes are estimated using LPM. See Table 4.1.1 for additional explanatory notes on model specification, including a list of control variables utilized. * 10% significance ** 5% significance; *** 1% significance.

Table C.1.11: Impacts on Coping Strategies - Baseline Bottom 50 per cent

Dependent Variable	Endline Impact (1)	Midline Impact (2)	Impact Diff (EL-ML) (3)=(1)-(2)	Baseline Treated Mean (4)	Endline Treated Mean (5)	Endline Control Mean (6)
Did nothing	-0.113	0.027	-0.141*	0.211	0.199	0.346
	(-1.29)	(0.30)	(1.89)			
Own savings	-0.067	-0.083	0.016	0.168	0.096	0.178
	(-1.44)	(-1.36)	(0.21)			
R'ced external assistance	-0.121**	0.024	-0.145**	0.436	0.191	0.284
	(-2.37)	(0.32)	(2.59)			
More work	-0.287***	-0.237***	-0.050	0.545	0.150	0.429
	(-3.66)	(-3.94)	(0.70)			
Borrowed	-0.062**	-0.017	-0.045*	0.029	0.035	0.079
	(-2.48)	(-1.31)	(1.82)			
Household members moved out	-0.007	-0.013	0.006	0.005	0.011	0.018
	(-0.97)	(-1.49)	(0.51)			
Changed eating pattern	-0.282***	-0.108*	-0.174***	0.261	0.109	0.333
	(-4.01)	(-1.85)	(3.24)			
N	4,494	4,494		770	714	821

Notes: Estimations use difference-in-differences modelling among panel households. Binary outcomes are estimated using LPM. See Table 4.1.1 for additional explanatory notes on model specification, including a list of control variables utilized. * 10% significance ** 5% significance; *** 1% significance.

Table C.1.12: Impacts on Labour Supply - Baseline Bottom 50 per cent

Dependent Variable	Endline Impact (1)	Midline Impact (2)	Impact Diff (EL-ML) (3)=(1)-(2)	Baseline Treated Mean (4)	Endline Treated Mean (5)	Endline Control Mean (6)
Total Members FTW	0.057	-0.007	0.064	0.758	0.864	0.864
	(0.86)	(-0.09)	(1.36)			
Males FTW	0.007	-0.045	0.052**	0.256	0.336	0.334
	(0.16)	(-1.23)	(2.10)			
Females FTW	0.050	0.039	0.012	0.502	0.528	0.531
	(1.09)	(0.78)	(0.32)			
Severely Labour Constrained	-0.031	-0.017	-0.014	0.474	0.425	0.415
	(-0.95)	(-0.40)	(0.50)			
Moderately Labour Constrained	0.019	0.006	0.014	0.383	0.376	0.384
	(1.08)	(0.19)	(0.55)			
Labour Constrained	-0.012	-0.011	-0.001	0.857	0.801	0.799
	(-0.51)	(-0.30)	(0.03)			
N	5,037	5,037		794	794	885

Notes: Estimations use difference-in-differences modelling among panel households. Binary outcomes are estimated using LPM. See Table 4.1.1 for additional explanatory notes on model specification, including a list of control variables utilized. * 10% significance ** 5% significance; *** 1% significance.

Table C.1.13: Impacts on Labour Use by Activity - Baseline Bottom 50 per cent

Dependent Variable	Endline Impact (1)	Midline Impact (2)	Impact Diff (EL-ML) (3)=(1)-(2)	Baseline Treated Mean (4)	Endline Treated Mean (5)	Endline Control Mean (6)
All Chores (Hours Yesterday)	0.141	-0.395	0.536	8.867	9.094	8.765
	(0.18)	(-0.49)	(1.20)			
Own Farm Activities (Days in Past Season)	13.661	2.163	11.498	90.698	107.274	94.039
	(1.40)	(0.18)	(1.34)			
Fishing (Days in Last 7 Days)	-0.073	-0.060	-0.013	0.000	0.004	0.092
	(-1.31)	(-0.87)	(0.23)			
Non-Farm Enterprise (Hours in Last 7 Days)	-0.211	-0.878**	0.667**	1.799	1.183	0.802
	(-0.53)	(-2.30)	(2.29)			
Livestock Activities (Hours in Last 7 Days)	0.234	0.312	-0.079	0.253	0.884	0.336
	(1.32)	(1.25)	(0.32)			
Casual, Part time activities (Hours in Last 7 Days)	-3.446**	-3.190**	-0.255	9.563	6.044	10.151
	(-2.55)	(-2.12)	(0.19)			
Ganyu Work (Months in last 12 Months)	-4.697***	-4.474***	-0.223	9.709	7.723	11.521
	(-2.76)	(-2.81)	(0.16)			
Work Outside Household excluding Ganyu (Hours in Last 7 Days)	0.116	0.143	-0.027	0.112	0.064	0.257
	(0.40)	(0.59)	(0.17)			
N	5,037	5,037		794	794	885

Notes: Estimations use difference-in-differences modelling among panel households. Binary outcomes are estimated using LPM. See Table 4.1.1 for additional explanatory notes on model specification, including a list of control variables utilized. * 10% significance ** 5% significance; *** 1% significance.

THEMATIC SET

A05

MEASURING AGRICULTURAL EMPLOYMENT, LABOR CONDITIONS, CHILD/FORCED LABOR, GREEN JOBS AND HUMAN CAPITAL MANAGEMENT

Session Organizer
M. Castillo | ILO | Geneva | Switzerland

ABSTRACT

Making progress towards sustainable development and poverty reduction will require a concerted effort to promote decent work in rural areas, particularly among developing countries. It will require analysis of targeted indicators on decent work in rural and urban areas that can be used to advance national development agendas. But what do we know about rural workers and their participation in the labour market or, more broadly, about decent work in rural areas as compared to urban areas? The internationally agreed decent work measurement framework and recently adopted standards by the International Conference of Labour Statisticians (ICLS) on measuring paid and unpaid forms of work are the starting point for the measurement and monitoring of decent work. However, currently there are different criteria applied by countries to define rural areas. The paper presents the case that the lack of a harmonized international statistical definition of rural and urban areas combined with a major data gap for even a basic set of decent work indicators in many countries limits the possibility of providing meaningful analysis on decent work in rural areas at the national, regional or global levels and presents recommendations on the way forward to address the challenges.

Keywords: Decent work, labour market, labour statistics, International Conference of Labour Statisticians (ICLS), rural areas, rural workers

LIST OF PAPERS

Green jobs and rural labour markets: gendered pathways for decent work
O. Muza | Consultant | Harare | Zimbabwe
DOI: 10.1481/icasVII.2016.a05

Decent work indicators for agriculture and rural areas: conceptual issues, data collection challenges and possible areas for improvement
C. Oya | SOAS - University of London | London | United Kingdom
DOI: 10.1481/icasVII.2016.a05b

Measuring and monitoring decent work in rural areas in support of sustainable development
M. Castillo | ILO | Geneva | Switzerland
D. Levakova | ILO | Geneva | Switzerland
H. Kashef | ILO | Geneva | Switzerland
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A framework for measuring rural women's empowerment within the context of decent work: focus on economic and social advancement
M. Hillesland | FAO | Rome | Italy
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A05

Green jobs and rural labour markets: gendered pathways for decent work

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ABSTRACT

Climate change will lead to structural changes resulting from adaptation and mitigation directly, and also in the process of change from old to new jobs. Not much is known about the transition prospects of rural men and women. The ability of rural workers to cope is a key emerging transition issue which requires immediate attention in the green transition discourse, policy and practice. Using secondary information, the study maps key livelihood and labour market challenges related to climate change impacts in key sectors found in rural areas, including agriculture, forestry, fisheries, artisanal mining and tourism. The general equilibrium dashboard methodology/OECD indicators and key international instruments (ILO Solutions for Climate Action, Decent Work Measurement Framework and Canadian Labour Congress (CLC) Just Transition reveal decent work deficits in fundamental rights, employment creation, social protection and social dialogue. The study recommends gendered integrated rural labour market pathways that address greening uncertainties and promote decent work.

Keywords: Climate Change, Decent Work, Gender, General Equilibrium Dashboard Model, Green Jobs, International Standards, Labour Market, Resource Economics Rural

PAPER

1. Introduction

The primary source of income for most people in the world is returns to their labour, thus creating jobs and decent wages is essential to reductions in poverty and hunger (Norton, 2009). Important progress has been made in reducing the share of extreme working poor (those falling below US$1.90-a-day threshold, 2011 PPP) in total employment over recent decades, particularly under the Millennium Development Goals (MDGs) from 33.2 per cent to 20.0 per cent, globally, over the period from 2000 to 2015. Despite continued improvements in reducing the shares of working poverty, efforts to reduce the absolute numbers of working poor at both thresholds have stalled. In 2015, an estimated 327 million employed people were living in extreme poverty at 967 million on moderate and near poverty. The absolute number has been falling by an annual average of 4.9% (extreme poor) and whereas it increased by 0.7% (moderately and near poor) over the period 2000 to 2015. Climate change will lead to structural changes resulting from adaptation and mitigation directly, and also in the process of change from old to new jobs (Olsen, 2009). Rurality, the traditional focus of food production enters the sustainable development policy debate in three policy contexts: firstly, the international farm crisis or its global environmental and trade repercussions, secondly, domestic policies attempting to redefine rurality beyond the confines of traditional agriculture policy and third and finally, policies for sustaining rural livelihoods that focus on promoting the viability of rural communities' infrastructure, education, health, social services and intergovernmental coordination (Wimberly, 1993). Green growth is one sector that is gaining support as a way to pursue economic growth and development, while preventing environmental degradation, biodiversity loss and unsustainable natural resource use (OECD, 2010).

The concept of green jobs has evolved overtime and now recognises social equity as a key element. Bowen (2012) defines green jobs as occupations and skills with an identifiable environmental focus, but most focus is on employment in industries (or specific projects) the products of which are deemed to be of environmental benefit. Work in agricultural, manufacturing, research and development (R&D), administrative and service activities that contribute substantially to preserving and restoring environmental quality are green jobs (UNEP, 2011). Furthermore, jobs are green when they help reduce negative environmental impact ultimately leading to environmentally, economically and social sustainable enterprises and economies (ILO, 2013). More precisely, green jobs are decent jobs that reduce consumption of energy and raw materials, limit greenhouse gas emissions, minimise waste and pollution and protect and restore ecosystems (ILO, 2013). The decent work dimension of jobs in the environmental sector may be measured according to relevant indicators for instance, The Decent Work Indicators framework adopted at the International Conference of

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Labour Statisticians (ICLS) in December 2008. It covers ten substantive elements[2] corresponding to the four strategic pillars of the Decent Work Agenda (DWA): full and productive employment, fundamental rights at work, social protection and the promotion of social dialogue.

Rural workers in developing countries may be engaged in paid and/or unpaid forms of work, and their survival strategies often involve engaging in different forms of work to cope with the seasonal nature and different opportunities available as work for pay or profit. The heterogeneity of rural labour arrangements may include payment in kind (food or other goods), may involve conditional access to a piece of land, or may depend on other specified relationship between employers and workers that are determined by local customs or institutions. However, not much is known about the transition prospects of rural men and women. Literature evidence points out that the potential adverse impact of green growth policies on labour productivity and the costs of employment tend to be overlooked especially with regards to how labour markets work in different types of economies (Bowen, 2012). According to the ILO (2008) relatively little and superficial attention has been paid to the social dimension of sustainable development, in particular to the implications for employment and for decent work.

Activities in rural and informal sectors including agriculture, fisheries, forestry, tourism and artisanal mining are considered as environmental if environmentally sustainable technologies and practices are used (ICLS, 2008). However, labour market changes effected to jobs as the economy is oriented toward greater sustainability should also be assessed and measured for their decency. Firstly, what additional jobs are created, which employment is substituted, which jobs are eliminated without direct replacement and how are workers transformed and redefined as day-to-day skill sets, work methods and profiles are greened? Secondly, how are different gender groups in rural areas affected in particular women, who constitute a greater proportion of rural workers? Gender inequality in rural employment often exhibit different patterns according to social, cultural, religious and economic factors (FAO/ILO, 2010)[3]. Third and finally, is the transition process 'Just' in fulfilling the foundations of a greener and socially just economy considering issues of participation, job creation and maintenance, greening in training, education and skills, trade union rights and social protection.

Using climate change and green growth transition evidence this paper traces developments in key rural sectors including: agriculture, forestry, fisheries, tourism and artisanal mining to determine the relationship between rural labour markets and pathways to promote green growth, functionality and the implications for decent work. The rest of this paper is structured as follows: the next section presents the methodology followed by climate change impacts on key rural sectors. The pathways for green growth and transition evidence are presented next while the last section recommends key measures developed to deal with those impacts and how this will be further linked to local and international standards.

2. Methodology

Several methodological approaches are used; firstly, secondary data is used to understand the perceived effects of climate change on economic activity and employment in general secondly, using the general equilibrium dashboard methodology and the OECD's industry methodology; greening challenges in rural labour markets are outlined. Third and finally, ILO Solutions for Climate Change Action, Decent Work Measurement Framework and the Canadian Labour Congress (CLC) Just Transition methodologies are employed to argue the case for driving solutions for climate change and decent work. General equilibrium dashboard is a state in which all green jobs meet all criteria [organisational level: sector, product/service, production method, green awareness, position in the value chain and job level: occupational profile, required skills and abilities, job decency and green workload]. OECD's environmental industry definition and criteria, divides the environmental industry into 3 groups: pollution management [environmental equipment], green technology and product management group [technologies and processes for clean and efficient use of resources] and resource management group [businesses in the field of energy conservation, management and recycling]. The ILO solutions for climate action pathway guiding the development of this study posits that increased understanding of the climate change impacts on labour markets, lead to coherent climate change and decent work strategic and best practices for shared knowledge observing tripartisan and social dialogue for effective climate transition.

[2] The ten areas are: Employment opportunities (EMPL), adequate earnings and productive work (EARN), decent working time (TIME), Combining work, family and personal life (COMB), Work that should be abolished (ABOL), Stability and Security of Work (STAB), Equal opportunity and treatment in employment (EQUA), Safe Work Environment (SAFE), Social Security (SECU), social dialogue, workers and employers representation (DIAL), economic and social context for decent work (CONT). This framework has evolved since then and now includes one more area on the economic and social context (ILO, 2014).

[3] Some of them such as- the burden of unpaid work at home, lack of education and bargaining power, and limited access to assets- clearly constitute significant economic disadvantages for women compared to men, women tend to be risk averse than men when engaging in rural employment and women's heavy burden of unpaid work is one of the most important factors constraining their access to unpaid work in rural settings and gender patterns of rural employment change over time and differ across countries in response to new trends, shocks and opportunities but some deep set gender inequalities remain. Changes in international trade, migration, financial crises and diversification of the rural economy are a few of the many phenomena that play an important role in changing men and women's rural employment opportunities and roles.

3. Climate change and sectoral labour market challenges

Climate change affects work in key sectors found in rural areas including agriculture, fisheries, forestry, tourism and artisanal mining. Direct and indirect impacts effect demand in the way work is done. The ability of rural workers to cope is a key emerging transition issue which requires immediate attention in the green transition discourse, policy and practice. As shall be shown in the next sections, gender influences different rural groupings transitioning prospects and possibilities.

3.1 Gender, climate change and labour market challenges

The green economy can be an opportunity for women to make strides towards gender equality in the workplace through better paid, non-traditional jobs. A combination of innovative strategies is needed so that women as well as men can benefit from the green economy (Stevens, 2009). This involves a paradigm shift to link the environmental and social consciousness of women with the range of jobs, including manual labour and technical positions, expected to be generated from the shift to a green economy[4].

Globally, women are more likely to be affected by environmental degradation and climate change (ILO, 2012). In the developing world, climate change can intensify the pre-existing inequalities between men and women (Chagutah, 2010; Madzvamuse, 2010). Women predominate among the poorest and are disproportionately concentrated in agriculture and tourism, sectors which depend on natural resources and are often characterised by poor pay and other decent work challenges (ILO, 2012). The consequences are growing risks to rural livelihoods, declining productivity, poverty and insecurity, conflict over access to resources and rural-urban migration; factors which have underlying socio-economic risk factors leading to the vulnerability of women (see Table 1).

Table 1: Climate change, gender and vulnerability in rural labour markets

Climate impact	Underlying socio-economic risk factors	Vulnerability of women
Crop failure	A greater proportion of rural women are small holder farmers (for instance, 70% in Zimbabwe)	Strain on food provision Increased workload
Shortage of safe, clean drinking water	Gendered division of household labour	Additional time required to travel greater distances to collect water from alternative sources, which may not be clean/safe Exposed to violence/sexual abuse when travelling to and from water sources
Disease	Gender division of reproductive labour/ care given Cultural restraints on mobility	Additional time required to care for young, sick and elderly Women of all ages lack health care access
Migration	Males may contribute little to household income (e.g. remittances) Women who become de facto household heads may face difficulties in retaining control over land and other productive assets due to unequal property and land rights	Increased domestic/agricultural load Decreased coping capacity and insecurity of tenure
Disaster	Women and children often lack skills, knowledge and resources	Women and children are likely to die than men during disaster events
Displacement	Particular problems in temporary housing/relocation sites	Women and girls face higher rates of sexual abuse and violence
Resource Scarcity	70% of the world's poor are women Women have lower levels of educational attainment Women are over represented in the informal sector Women earn lower wages and have limited access to markets	Limited time and resources to invest in more resilient land and shelter Limited resources to invest in alternative livelihoods

Source: Chagutah (2010)

From a global perspective, primary sectors, including agriculture and forestry, are expected to be major beneficiaries of the transition to a low carbon economy. However, women comprise less than 20% of the global formal workforce in primary sectors and around 2% in developed countries (Stevens, 2009). The estimated share of female employees'/women in green jobs in relation to all employees in farming/fisheries/forestry is 20%, while 8% are in natural resources (including mining and quarrying). Women in green jobs are concentrated in administrative services at 68% (see Table 2).

[4] Ibid.

Table 2: Women in green job sectors

Sector	Components	Estimated share of female employees (2009)
Primary	Farming/fisheries/forestry	20%
	Natural Resource	8%
Secondary	Manufacturing	24%
	Construction	9%
Tertiary	Engineering Services	12%
	Financial and Business Services	15%
	Eco-tourism	20%
	Eco-tourism	20%

Source: Stevens, (2009)[5]

3.2 Agriculture, climate change and labour market challenges

Climate change has materialised as the leading global environmental concern of which agriculture is one of the zones most critically distressed by climate alteration (Joshia and Chartuverdi, 2013). As global temperature rises and climate conditions become more erratic posing threat to vegetation, biodiversity, biological progression they have enduring effect on food security as well as human health[6]. Doubling of the atmospheric carbon dioxide concentration will lead to only a small decrease in global crop production but developing countries are likely to bear the brunt of the problem and similarities of the effect of adaptive measures by farmers imply that these will do little to reduce the disparity between developed and developing countries[7].

A robust model of yield response to climate change for several African crops illustrates that by mid-century, the mean estimates of aggregate production changes in Sub Saharan Africa under the preferred model specification are -22%, -17%, -17%, -18% and -8% for maize, sorghum, millet, groundnut and cassava respectively (Rosenzweig and Parry, 1994). In all cases except cassava, there is a 95% probability that damages exceed 7% and a 5% probability that they exceed 27%[8]. Moreover, countries with highest average yields have the largest projected yield losses, suggesting that well-fertilized modern seed varieties are susceptible to heat related losses.

Some of the most important impacts of global climate change will be felt among the populations, predominantly in developing countries referred to as 'subsistence' or 'smallholder' (Morton, 2007). Their vulnerability to climate change comes from being predominantly located in the tropics and from various socioeconomic, demographic and policy trends limiting their capacity to adapt to climate change[9]. Morton (2007) suggests small farm sizes, low technology, low capitalisation and diverse nonclimatic stressors as increasing vulnerability but resilience factors- family labour, existing patterns of diversification away from agriculture and possession of a store of indigenous knowledge should not be underestimated[10].

Thompson and Cohen (2012) add that many of the poorest and most vulnerable people are women living in rural areas in developing countries who are wholly depended on subsistence agriculture to feed their families. Rural women, female smallholders in particular, may be disadvantaged in terms of access to key productive assets for farming and services such as land, water, rural infrastructure, technology and information, credit and extension services (World Bank, FAO and IFAD, 2008, Brody et al. 2008). These women therefore tend to have limited adaptive capacities, and are highly dependent on climate sensitive resources such as local water and food supplies (IPCC, 2007). Climate change is expected to exacerbate these gender inequalities with women being disproportionately affected by depletion of natural resources and reduced agriculture productivity (Parikh and Denton, 2002).

One effect of climate change relevant to rural employment is related to the risk of declining farm yields of which the gender-differentiated impact will depend on multiple factors, including which crops women produce, as well as their ability to adapt and respond (Cabrera de González et al., 2009). Three critical impacts on women are firstly; female farmers' ability to develop effective coping strategies might be limited compared to male farmers because of their more restricted access to productive resources

[5] Statistics provided in this table are based on ILO estimates 2007 (SustainLabour, 2009) and as such are consistent with the ICLS definition of decent jobs adopted in this paper.
[6] Ibid.
[7] Ibid.
[8] Ibid.
[9] Ibid.
[10] Ibid.

such as technology, knowledge and inputs. Secondly, climate change might worsen the conditions of the wage agricultural labourers, if in response to it; large producers expand informal employment and increase the use of pesticides. Third and finally, climate change might also increase women's unpaid workload, further reducing their opportunities for paid employment, in areas affected by desertification where time required for water collection might increase.

In general, both mitigation and adaptation policies are likely to have gender differentiated effects on employment that need to be better understood, i.e. environmental labelling, if discouraging the purchase of fruits and vegetables from developing countries, may have negative employment effects on female-intensive non-traditional export industries[11]. Climate policies can contribute to rising demand for educated and qualified workers through promoting environmentally sound technologies. However, because of women's lower levels of education in many countries, women are less likely to benefit from such demand unless the relevant training is made available to them[12].

3.2 Forestry, climate change and labour market challenges

In general, women are the primary users of environmental resources for subsistence and income generating products, yet in many cases have no say in how the resources are accessed, controlled or shared (Makonese and Tsanga, 2008). Forests can play an important role in complementing agricultural production to address ambitious global goals and reducing hunger and achieving food security and improved nutrition (Vira et al., 2015). Additionally, forests and trees can be managed to produce better and more nutritionally-balanced diets, offer greater control over food inputs and deliver ecosystem services for crop production[13]. Some 410 million indigenous people and communities depend on forests for their livelihood (ILO, 2012). Globally, 70% of forest products are sourced from 7% of the world forest, of which the latter are predominantly planted or have a planted component (Dale et al. 2009). Additionally, climate change can affect forests by altering the frequency, intensity, duration and timing of fire, drought, and introduced species, insect and pathogen outbreaks, and hurricanes.

Deforestation and land uses including degradation from mining, oil and gas concessions are reported to account 11% of annual global greenhouse gas emissions (Stevens et al., 2014). Legal protection for woodlot communities is therefore not just a land or resource rights problem, but also a climate change problem (Muza, 2016). In the context of high level of forest dependence, challenges of State and NGO-led re-greening practices are inadequate involvement of communities, poorly defined rehabilitation objectives, lack of management plans, unclear responsibilities and benefit sharing arrangements and poor structural activities (Lemenih and Kassa, 2014).

Lessons include a more active role for non-state actors in greening initiatives, more attention to market signals, devolution of management responsibility and clear definition of responsibilities, benefit-sharing arrangements, and better tenure security. It seems that market signals have led to the destruction of rainforests which have been supplanted in places like the Amazon in Brazil by cattle farming and crop production. It seems that government protection and support by civil society (researchers, NGOs) is needed to ensure sustainable forest management.

3.3 Fisheries, climate change and labour market challenges

Fisheries and aquaculture are important sources for food and livelihoods for people along the world's seashores and waterways (Smith et al., 2010), and influence the livelihoods of one billion people. Almost 45 million people worldwide are directly engaged, full time or part time, in the fishery primary sector and an additional estimated 135 million people employed in the secondary sector, including post-harvest activities (Mathiesen, 2012). Information provided to FAO from 86 countries indicates that, in 2008, 5.4 million women worked as fishers and fish farmers in the primary sector and represented 12 percent of the total[14]. In two major producing countries, China and India, women represented 21 percent and 24 percent, respectively, of all fishers and fish farmers[15]. Women make up at least 50 percent of the workforce in inland fisheries, while as much as 60 percent of seafood is marketed by women in Asia and West Africa[16]. Moreover, although comprehensive data are not available on a sex-disaggregated basis, case studies suggest that women may comprise up to 30 percent of all those employed in fisheries, including primary and secondary activities[17]. Aquaculture has been the fastest growing food production sector for the past 4 years, and supplies more than half of the world's food fish (UNEP, 2012). Excluding aquatic plants, aquaculture production reached 52.5 million tonnes representing a value of US 98.5 million in 2008[18]. It has been estimated that 52 million are employed in marine small-holder capture fisheries (and another 56 million in small-scale inland fisheries). Many involved in these sectors are recognizing that it is vital to look beyond the simplified picture of men as fishers and women as

[11] Ibid.
[12] Ibid.
[13] Ibid.
[14] Ibid.
[15] Ibid.
[16] Ibid.
[17] Ibid.
[18] Ibid.

processors and to examine the more complex picture of multifaceted relationships between men and women as boat owners, processors, sellers, family members, community members and co-workers (Mathiesen, 2012). Gender issues in the fisheries and aquaculture sector have seldom been examined, and the important role women that play has often been overlooked and, thus, not taken into account in decision-making processes and outcomes, thereby hindering development for instance:[19]

1. Men and women engage in distinct and often complementary activities that are strongly influenced by the social, cultural and economic contexts in which they live.
2. Male–female relations in the fisheries sector vary greatly and are based on economic status, power relations and access to resources.
3. In most regions, women have rarely participated in commercial offshore and long-distance capture fishing. Ocean-going boats for offshore deep-sea fishing have male crews – not only because of the vigorous work involved, but also because of women's domestic responsibilities and/or social norms.
4. More commonly, in coastal artisanal fishing communities, women manage the smaller boats and canoes that go out fishing. Women are also involved in gathering shells, sea cucumbers and aquatic plants in the intertidal zone. They also contribute as entrepreneurs and provide labour before, during and after the catch in both artisanal and commercial fisheries. In addition, they are often responsible for skilled and time-consuming onshore tasks, such as net making and mending, processing and marketing catches, and providing auxiliary services to the boats.

Climate change will affect fisheries availability, stability, access and utilization (Labour S., 2013). Availability will be impacted as aquatic foods will vary through changes in habitats, stocks and species distribution. Stability of supply will be impacted by changes in seasonality, increased variance in ecosystem productivity and increased supply variability and risks. Access to aquatic foods will be affected by changes in livelihoods and catching or farming opportunities and utilization of aquatic products will also be impacted and, for example, some societies and communities will need to adjust to species not traditionally consumed. Aquatic foods have high nutritional quality contributing 20% or more of average per capita animal protein intake for many poorer countries. Climate change will affect food quality as food resources come under greater pressure and the availability and access to fish supplies will become an increasingly critical development issue. Climate change is a compounding threat to the sustainability of capture fisheries and aquaculture development (Cochrane et al., 2012), see also Table 3.

Table 3: Climate change effect on fisheries livelihoods and labour market challenges

Climate change effect	Livelihoods/Labour Market Issues
Less predictable rain/dry seasons-decreased ability to plan livelihoods activities-e.g. farming and fishing seasons	Increasing vulnerability of riparian and floodplain households and communities Livelihood strategies will have to be modified, for example, with changes in fishers migration patterns due to changes in the timing of fishing
More droughts or floods- damage to productive assets (fish ponds, weirs, rice fields etc and homes)	Increasing vulnerability of riparian and floodplain households and communities
Changing levels of precipitation where rainfall decreases reduced opportunities for farming, fishing and aquaculture as part of rural livelihoods systems	Reduced diversity of rural livelihoods, greater risks in agriculture greater reliance on non-farm income. There are particular gender dimensions, including competition for resource access, risk from extreme events and occupational change in areas such as markets, distribution and processing, in which women currently play a significant role Displacement of populations into coastal areas leading to influx of new fishers
Water stress and competition of water resources	Affect aquaculture operations and inland fisheries production, and are likely to increase conflicts among water-dependent activities
Extreme events	Impact on infrastructure, ranging from landing and farming sites to post harvest facilities and transport routes. They will also affect settlements, with communities living in low-lying areas at particular risk
Changes in distribution species	Composition and habitats will require changes in fishing practices and aquaculture operations, as well as in the location of landing, farming and processing facilities

Source: Chagutah (2010)

3.4. Tourism, climate change and labour market challenges

Travel and tourism's impact on the economic and social impact of a country can be enormous: opening it up for business, trade and capital investment, creating jobs and entrepreneurialism for the workforce and protecting heritage and cultural values (Mowforth and Munt, 2015). Travel and tourism generated

[19] Ibid.

US$7.6 trillion (10% of global GDP) and 277 million jobs (1 in 11 jobs) for the global economy in 2014[20].

Tourism is a climate-dependent industry and so many destinations owe their popularity to their pleasant climates during traditional holiday seasons (Amelung et al., 2007). The Tourism Climatic Index (TCI) reveals that the locations of climatically ideal tourism conditions are likely to shift poleward under projected climate change[21]. Tourism is currently considered among the economic sectors least prepared for the risks and opportunities posed by climate change and is only now developing the capacity to advance knowledge necessary to inform business, communities and government about the issues and potential ways forward (Scott, 2011). At a global scale, climate change will ultimately lead to welfare loss, unevenly spread across regions (Bigano, 2004). Tourism is increasing contribution to climate change, especially through the use of air travel (Becken, 2007).

According to the UNWTO, women make up the majority of the tourism workforce, but they tend to be in the lowest paid, sometimes even un-paid, and lowest status jobs. Strong associations persist in the popular imagination between tourism and prostitution (Ferguson, 2009). Indeed for many, this is the extent of gender issues in tourism[22]. Certainly, the sexual exploitation of women and children is a serious issue that needs to be addressed and the emerging phenomenon of sex tourism in developing countries has been extensively researched by feminists (Pettman, 1997; Jeffreys, 1999). Sexual exploitation of children in tourism occurs in multiple tourism destinations and even in places which do not have any real tourism infrastructure (ECPAT, 2008)[23]. Many African countries have encouraged tourism to attract foreign investment and to fund infrastructure development[24]. While this, coupled with a renewed focus on Africa from tourist-sending countries has sparked tourism growth on the African continent, this growth has predictably, been accompanied by an increase in child sex tourism (CST). Victims of CST are often caught in poverty, from minority groups, dependent on seasonal economies, working children, children living on the street and children abused or neglected in the home and AIDS orphans.

Scholars within tourism studies have long argued that tourism is a highly gendered industry (Kinniard et al.,1994; Kinniard and Hall, 1994). Research has identified a clear segmentation of men's and women's work in tourism. The majority of women's work is concentrated in seasonal, part time, low paid activities such as retail, hospitality and cleaning (Sinclair 1997; Chant 1977). Global gender inequalities are embedded within the promotion and marketing as tourism destinations (Ferguson, 2009). There are 2 distinct ways in which gendered assumptions operate in tourism development policy; implicitly (gender blind) and gender aware[25]. Gender blind involve how macro-level tourism development policy relies on gender inequalities embedded in processes of restructuring of the global economy. Gender aware aspects of tourism development policy; focus on policies which openly seek to affect change in gender equality or promoting women's empowerment.

3.5. Artisanal mining, climate change and labour market challenges

Mining is an important economic activity in many developed and developing countries. The formal mining sector employs more than 3.7 million workers. In addition, more than 20 million people work in artisanal and small-scale mining (ASM) (Hentschel, 2002). In 2010, 1.5 million people were employed in the mining sector in developed nations, and 2.2 million in developing/emerging nations (Hruschka and Echavarria, 2011). The number of people working in mining jobs dropped significantly during the 2008 recession, although many of these jobs have since returned[26]. In addition, artisanal and small-scale mining employs an estimated 25 million people worldwide, and indirectly supports more than 150 million people[27]. Mining takes place in more than 100 countries, with more than 50 regarded by the World Bank as "mining countries" because of the importance of mining to their exports, domestic markets, or to employment.

A changing climate presents physical risks to mining and metals operations because these industries are often located in challenging geographies, relying on fixed assets with long lifetimes, involve global supply chains, manage climate-sensitive water and energy resources, and balance the interests of various stakeholders (International Council on Mining and Metals, 2013). A key transition issue is around the opportunity to turn the industry into an agent of change and solution providers, rather than a generator of unsustainable lock-ins and a resisting force (Mont Masson-Clair, 2015). While the impact of climate change on large scale and small scale mining may vary in terms of scale, the impact on workers is more or less the same. Natural disasters pose immediate health and safety risks, while warmer temperatures may attract worker recruitment, retention, safety and productivity by increasing risks of accidents, creating or exacerbating food and water shortages and causing greater prevalence of disease (Table 4).

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[20] Ibid.
[21] Ibid.
[22] Ibid.
[23] http://www.ecpat.org/wp-content/uploads/legacy/cst_faq_eng.pdf.
[24] Ibid.
[25] Ibid.
[26] Ibid.
[27] http://www.miningfacts.org/Economy/How-many-jobs-depend-on-the-mining-industry/.

Table 4: Climate change effect in mining labour markets

Climate change effect	Labour Market Issues
Rising temperatures flooding, natural disasters, and drought	Increases the risk of heart-related illnesses and inhibit decision-making increasing the likelihood of injuries, accidents, and fatalities and decreasing productivity.
	Underground cooling systems may be inadequate to handle changes in temperatures and availability of water and energy
	Increase the incidence, prevalence and geographic reach of tropical diseases such as malaria, yellow fever, cholera and schistosomiasis with consequences for workforce health Flooding and rising temperature will increase the spread of tropical diseases that affect community health
	Undermine food security and rising temperatures will exacerbate water shortages, undermining worker health and productivity
	Increased requests for financial and employee support, in response to natural disasters in host communities
	Damage to livelihoods and poverty will elevate the need for basic services and restoration of economic activity. If these are also home communities for employee and contractor workforces, such incidences will directly affect worker health attendance and productivity
	Increased requests for financial and employee support, in response to natural disasters in host communities
	Drought, extreme weather, and flooding may decrease food security, worsen poverty, induce mitigation, contribute to civil unrest and increase conflict over resources
	Community water infrastructure and watershed restoration projects may be required to mitigate reputational risks and to meet needs of all users
	Force migration of coastal peoples, whose movement to new areas may exacerbate social problems and conflicts in host communities

Source: Adapted from International Council on Mining and Metals, 2013

Due to the illegality of their operations, artisanal miners cannot access official markets and depend on intermediary traders[28]. Their minerals are also deemed unattractive by fair trade organizations due to their environmentally degrading activities. They face the constant risk of being arrested too. In essence, artisanal miners face many risks and challenges only to make less money than the people they sell their minerals to. Not only are they at the risk of rock-falls, shaft collapses, water-borne diseases, animal attacks and injury, they also fall victim to turf wars and harassment from peers. They work on low-value ore-bodies while using labour intensive equipment and inefficient processing techniques which result in very low recoveries. They lack adequate geological knowledge of the ore-bodies and do not possess adequate mining skills. They have very little knowledge of the economic principles that govern the extraction industry and as a result their operations are run on a 'Gambler Mentality'.

The vulnerability of artisanal miners and women in particular is high during droughts or economic crises (Muza, 2009). In Zimbabwe for instance, women, who constitute 30% of artisanal miners also face some gender-specific challenges[29]. They are harassed by male counterparts including gold dealers in the sector. Although all artisanal miners suffer police arrests, the women's situation is worse in that because of the family care roles they play, they are sometimes forced to negotiate for 'lighter' charges outside the law. This is perpetuated by structural inequalities and stereotypes that discriminate against women, especially the misconception that the mining sector is a preserve of men. This is so despite the fact that women are disproportionately overwhelmed by negative impacts of mining, such as loss of agricultural land, unequal employment opportunities, increased incidences of Sexual Transmitted Infections (STIs), teenage pregnancies, access to clean and safe water and climate change which has affected subsistence farming, ultimately removing the guarantee of putting food on the table.

4. Pathways for green transitioning in key rural sectors: the case of Zimbabwe

Zimbabwe is severely vulnerable to climate change and its vulnerability is set to increase between 2010 and 2030 (DARA; Climate Vulnerability Monitor, 2012). It is ranked 156th on the Human Development Index (UNDP; Human Development Index, 2014). Zimbabwe's CO2 emissions are 0.7 tonnes per capita, while the global average is 4.9 tonnes per capita (World Bank; World Development Indicators: Energy dependency, efficiency and carbon dioxide emissions, 2010). There are consequences of not changing the current policies for industries with a greater environmental impact. Green growth pathways in Zimbabwe have largely focused on climate adaptation and mitigation strategies in ecotourism, reforestation, land and water management, organic agriculture, the development of clean sources of energy, recycling of green waste, green mining and green growth fisheries and aquaculture.

28 https://projekt263.wordpress.com/2013/09/24/formalising-zimbabwes-artisanal-mining-sector/.

29 http://www.zela.org/index.php/latest-news/46-engendering-policy-in-the-artisanal-and-small-scale-mining-sector-in-zimbabwe#_ftn2.

4.1 Organic agriculture

Organic Agriculture (OA) initiatives in Zimbabwe are mainly developed by farming communities similar to those in Kenya and South Africa (Parrott and Elzakker, 2003). While increased uptake of OA on food supply and food security depend on geographical and socio-economic conditions and on the scale considered (Halberg et al. 2006), ethical concerns are significant drivers of integrated crop protection (IP) and organic farming (OA). However, animal manure shortage, slow organic matter decomposition and high labour requirements constrain OA (Svotwa et al. 2009). Evidence from the Organic Conservation Agriculture (OCA) project shows a high proportion of women (65.5%) engaged in the OCA project, despite not having used affirmative processes to increase participation which points to a number of factors, including the organic appeal to women producers (combined OA with TK); a higher proportion of women in the communal areas due to work opportunities for the men-folk; and or the majority of men in the household are watching to see if OA offers opportunities before fully engaged (McAllster, 2012). Of the engaged OCA farmers, 66% of the household are male headed households, 44% are female headed with a small number of child headed households. One of the most successful associations is led by a woman. In most cases, the females heading households are either widowed or divorced. However, the highest percentage of women actively participating in OA are within traditional family structures, with their lack of control over resources, asset and income being a key limiting factor, and posing a challenge for them expanding their enterprises.

Through a Global Environment Facility's biodiversity thematic area[30] implemented in two phases from 2006 and 2011, 400 members from Makoni Organic Farmers Association (MOFA) have received organic farming skills training in the application of crop rotation, livestock and green manure, composting, mulches and cover crops. The project links farmers efforts to upstream policy measures such as the national waste strategy and biodiversity strategies, the forestry based and wildlife land reform policies, as well as the environment and natural resources strategic plan for the period 2011 – 2015[31]. The 450 member project won coveted Equator Prize 2014. Research on unlocking the organic potential of Zimbabwe suggests key recommendations addressing some decent work indicators including firstly, a national agricultural policy which provides for organic farming, organic farming training, budgetary support and loan facilities. Secondly, an educational policy that provides for curricula on organic farming education at all levels. Thirdly, national organic promotion, processing and marketing policies linked to international (IFOAM), regional (CAADP), sub-regional (RISDP), and national (ZOPPA, SAZ); Fourthly, affordable registration costs and efficient processes and fifth and finally quality relationships between key stakeholder groups that include policy makers, policy implementers, research institutions, private sector as buyers, technology suppliers and NGOs.

4.2 Recycling of agriculture waste, land and water management and clean energy sources

Provision of clean energy sources, recycling of agricultural waste, land and water management are other pathways for greening the Zimbabwean economy. Reduction of green house gas (GHG) emissions emerges as a key mitigation factor in rural economies. Livestock generate GHG mainly in the form of methane emissions arising from digestion processes and nitrous oxide emissions arising from excretions. The cultivation of crops contributes to the concentration of greenhouse gases mainly by requiring the use of fertiliser as well as emitting nitrous oxide from crop residues reintroduced into the ground. Mining pollutes water and land and also contribute to GHG emissions. Forestry emissions are driven by deforestation for agriculture land and forest degradation due to fuel wood consumption as well as formal and informal logging. Tourism increases contribution to climate change, especially through the use of air travel (Becken, 2007). The global air travel tax emerged as a realistic compromise between restricting travel and achieving emissions reduction.

A new recycling company Clean and Green Zimbabwe was launched with a vision to maximize on recyclable recoveries. The company has directly created more than 70 jobs dire directly and indirectly unemployed youth are earning an income by selling their waste to the organisation. The company has so far collected 350 tonnes of waste[32]. The country's waste management strategies employ the traditional closed system which focuses only on the collection, transportation and disposal of waste. The system is failing to cope with the large amounts of waste being generated and noted that there was need to employ a more sustainable approach anchored on the reduction and recycle principles. Another arganisation, Environment Africa (EA) is pushing the concept of waste separation at source, use of colour-coded bins and liners for waste separation and ultimately recycling. Waste is segregated according to type and recyclability from the waste stream at point of generation or source. Recyclable wastes include paper, glass, plastic, polystyrene, cans or tins and biodegradable waste[33]. Enterprising young minds from Sakubva a high density suburb in Zimbabwe's Mutare city came together to venture into an indigenous waste management company called Mutare Plastic Recycling Centre. It is the first of

[30] Supported by the Global Environment Facility's Small Grants Programme (GEFSGP) of UNDP, the farmers are leading the way in environmental conservation and sustainable use of resources for livelihood improvement and poverty reduction.

[31] http://www.zw.undp.org/content/zimbabwe/en/home/ourwork/environmentandenergy/successstories/sky_s-the-limit-for-new-crop-of-organic-farmers-in-zimbabwe.html.

[32] http://www.hararenews.co.zw/2014/07/clean-and-green-zimbabwe-new-recycling-initiative-launches/.

[33] https://www.newsday.co.zw/2013/10/19/zimbabwe-waste-management-strategies-new-wine-old-skins/.

its kind in the city. The youths are not yet able to add value to the recycled plastic, so they sell it mainly as pellets or raw plastic to companies mostly in Harare, where it is used to make irrigation pipes, plastic bags, lunch boxes and other plastic products[34].

In rural areas of Zimbabwe, 80-90% of people are heavily dependent on wood fuel, light their homes with kerosene, and carry out essential food processing tasks, such as milling grain, using diesel-powered systems. Total electricity generation in 2009 stood at 7,900 GWh, of which 53.3%, or 4,303 GWh, was produced from renewable sources. Electricity consumption per capita in 2009 stood at 1,022 kWh (REEEP, 2012)[35]. Zimbabwe could move forward to a renewable revolution and create job opportunities by improving access to financing new renewable energy technologies and realizing Zimbabwe's capacity to create job opportunities in renewable energy sector (IRENA, 2014). According to IRENA, in 2014 an estimated 7.7 million people worked directly or indirectly in the sector, with an additional 1.5 million in large-scale hydropower. Solar PV is the largest employer, with 2.5 million jobs. Zimbabwe has abundant sunshine throughout the year and has a high potential in Solar PV[36].

4. 3 Eco-tourism

In 2014, travel and tourism's direct contribution to employment was 181.000 jobs while total contribution to employment was 426 200 (Mowforth and Munt, 2015). With decreasing rainfall and rising temperatures, significant declines in biodiversity are expected to occur in most parts of the country especially the western regions where most of the estates are located. Ecotourism is defined as 'responsible travel to natural resources areas that conserves the environment and sustains the well-being of local people' (Stevens, 2009). The ecotourism green pathway in Zimbabwe stresses community participation in decision-making processes in relation to eco-touristic ventures and subsequent benefits derived from such ventures flowing back to local communities (Muzvidziwa, 2013). Eco-tourism places emphasis on conservation through utilisation, instead of emphasising preservation only. It helps conservation of natural environment and enhances the socio-economic lives of the local community. It is a strategy with potential to mostly benefit locally disadvantaged and marginalised communities living near or around tourist areas. Primary school curriculum and traditional conservation methods strengthen ecotourism (Marunda and Chaneta, 2014). Good governance, positive international relations and policies remain major factors in determining the overall viability and sustainability of the ecotourism sector, hence facilitating sustainable development (Chiutsi, 2011).

In order to promote gender equality, support opportunities for women and end violence against women, it is important to empower women as a first step[37]. Women are involved in eco-tourism through the preservation of forests, rivers and lakes and also participate in responsible nature industries. Amagugu International Heritage Centre in Bulawayo whose motto is 'where culture and nature meet' promotes women enterprises including crafts making and participatory cultural activities[38]. The tourism industry can contribute to this effort by creating opportunities for women and spread awareness of gender issues. Having economic opportunities and education is one of the most important ways for women to empower themselves to seek a better quality of life for themselves, their families and their communities[39].

4.4 Reforestation.

In Zimbabwe, women need environmental resources and in particular forest produce like fruits, roots, leaves and insects for food and medicine, firewood for heating and lighting, grass for thatching their huts and many other uses (Makonese and Tsanga, 2008). Protecting and re-establishing forests for their economic and ecosystem services including carbon stocks is a key green pathway. 66% of Zimbabwe's land area is under various forest types compared with 27% which is under cultivation. Exotic plantations occupy about 156 000 ha of land of which over 90% is in the Eastern Districts. The heaviest concentrations of forests occur in the gazetted state of forest areas, national parks areas, the eastern highlands and large scale commercial farms. On the other hand, the woody vegetation cover in most communal areas is low and variable with heavily populated districts such as Mutasa and Chivi having only 26% and 30% covered respectively. Though woodlots establishment is gaining momentum as a key rural sector providing employment to rural men and women (Muza, 2016), key decent work indicators would need to be recognised, especially improving security of tenure for women.

4.5 Green Mining

Up to 2 million people are affected by artisanal mining in Zimbabwe. These people are mostly involved in the extraction of gold, diamonds, tantalite and chrome. 500 000 people are directly involved in artisanal mining with over 150 000 of them being children and women. The World Economic Forum ranked

[34] http://www.thezimbabwean.co/2015/03/youths-live-off-plastic-recycling/.
[35] http://www.reeep.org/zimbabwe-2012.
[36] https://www.newsday.co.zw/2015/07/31/zims-potential-to-move-towards-a-renewable-clean-energy-revolution/.
[37] https://www.ecotourism.org/news/tourism-and-gender-how-can-tourism-help-empower-women-and-promote-gender-equality.
[38] www.amaguguheritage.org.
[39] https://www.ecotourism.org/news/tourism-and-gender-how-can-tourism-help-empower-women-and-promote-gender-equality.

Zimbabwe 88 out of 135 countries in its Gender Gap Index 2011, a position relatively consistent with its gender blind policies in key economic sectors like mining[40]. The misconception that the mining sector is a preserve of men has further undermined policy responsiveness to gender-specific challenges faced by women in mining who now constitute 30% of artisanal miners in Zimbabwe[41].

Green mining activities involve, shutting down illegal and unregulated mines, choosing environmentally friendly general mining processes, implementing recently discovered green mining technologies, cleaning up the sites of shut-down mines, re-evaluating cut-off grades and research and development of green mining technology[42]. Two major methods of implementing green mining reform are governmental regulation and innovative technologies[43]. Poor governance practices in the mining sector precipitated hazardous mining practices with severe ecological damages and human rights violations on communities living in mining areas. In Manicaland Province for example, alluvial diamond and gold mining activities in Chimanimani, Marange and Penhalonga has exposed communities to environmental degradation, water pollution, forced dislocations and loss of livelihoods (CRD Report, 2014). Attempts by communities living in mining areas to fight for their rights to a secured environment has been met with brutality by mining companies leading to loss of life in some instances[44].

Apart from direct labour market impacts related to mining activities in general, landmines also threaten rural livelihoods, Zimbabwe has one of the densest minefields in the world, with about 5 500 landmines per kilometre, according to the Halo Trust, which did the Mukumbura demining project.[45] Since independence, in 1980, more than 1 500 people and 120 000 livestock have been killed in landmine accidents[46]. In Gonarezhou National Park, a 53 kilometre stretch of landmine field, 300 people have lost their lives in that area alone since 1980. More than 400 cattle and over 500 wild animals have also been killed by mines[47]. Previous attempts to formalise artisanal small-scale mining ignored the concrete needs of women and thus did not effectively improve the status of women[48]. This gender blindness persists in the prevailing illegality policy which perpetuates structural inequalities, worsening the women's situation as they are forced upon arrest to negotiate for 'lighter' charges outside the law to cater for the family care roles they play[49].

4.5 Green growth fisheries and aquaculture

Conventional fisheries and aquaculture production methods exploit renewable natural resources with a substantial potential for environmental degradation if the industries production practices are not sustainable a feature that are uncommon (Pualy et al. 2003). The industries are important users of energy with significant carbon footprint (Acshe, 2011). As far back as possible Tyedmers et al., (2005) estimate that the world's fishing fleets are using 1.2% of the global oil consumption, primarily as fuel, and by a rough estimate this number will increase to 2% if aquaculture is included. Green growth initiatives in the fisheries and aquaculture sector include harvesting, growing and trading with efficient and sustainable use of natural resources, ensuring that economic benefits from fisheries and aquaculture are equitably distributed and socially beneficial and reducing the carbon footprint of the fishery and aquaculture sectors (including production, processing and trade) and pursuing opportunities to use coastal and marine ecosystems as carbon shocks (UNEP, 2012). Aquaculture Zimbabwe is partnering with established fish farmers, donor agencies, international agencies and government departments to help subsistence farmers in Zimbabwe to diversify crop and livestock production with climate sensitive methods and using locally available inputs and feeds. Women are the majority of subsistence farmers in Zimbabwe; hence the initiative is expected to benefit more women.

5. General equilibrium dashboard model with OECD indicators and the case for just transition and decent work

While green growth involves economic, environmental and social contributions, the current focus of green pathways (discussed in section 4) is economic and environmental efficiency at the expense of social contributions in particular, the decent work agenda. As shall be illustrated in this section, there are key transition uncertainties and decent work deficits. The 11 general equilibrium dashboard transition indicators scored against the green pathways transition evidence (illustrated in section 4) show that labour markets are very certain (VC) about the green pathway sectors, products/services, production methods, green awareness and land and water management issues. However, rural labour

[40] Economic Forum. Retrieved from World Economic Forum Gender Gap Index Report (2011) http://www3.weforum.org/docs/WEF_GenderGap_Report_2011.pdf.
[41] Newsday Article on Artisanal Mining Must Be Regulated (2014) Retrieved from https://www.newsday.co.zw/2014/10/14/artisanal-mining-must-regularised/.
[42] http://web.mit.edu/12.000/www/m2016/finalwebsite/solutions/greenmining.html.
[43] http://web.mit.edu/12.000/www/m2016/finalwebsite/solutions/greenmining.html.
[44] Ibid.
45 https://www.newsday.co.zw/2016/02/11/prioritise-awareness-on-demining/.
[46] https://www.newsday.co.zw/2016/02/11/prioritise-awareness-on-demining/.
[47] http://www.herald.co.zw/zimac-needs-47m-for-de-mining/.
[48] http://www.zela.org/index.php/latest-news/46-engendering-policy-in-the-artisanal-and-small-scale-mining-sector-in-zimbabwe#_ftn2.
[49] http://www.zela.org/index.php/latest-news/46-engendering-policy-in-the-artisanal-and-small-scale-mining-sector-in-zimbabwe#_ftn2.

markets are also very uncertain (VU) about the green pathways position in the value chain, occupational profiles, required skills and abilities and job decency. Labour markets are also certain (C) about the development of clean sources of energy, pollution management group, resource management group and green technology and management group pathways (See Table 6).

Table 6: General Equilibrium Dashboard Transition Gaps

General Equilibrium and OECD Indicator	OA/Clean Sources of energy and recycling/Green growth fisheries and aquaculture/Reforestation/Eco-Tourism
Sector	VC
Product/Service	VC
Production Method	VC
Green Awareness	VC
Position in the value chain	VU
Occupational Profile[50]	VU
Required skills and abilities[51]	VU
Job decency[52]	VU
Development of clean sources of energy	C
Green Workload[53]	VU
Land and water management	VC
Pollution management group	C
Resource management group	C
Green technology and management group	C

VC=Very Certain C=Certain U=Uncertain VU=Very Uncertain

Evidence from Table 6 supports that green activities have significant job creation potential (OECD, 2011) and can be the new engine of growth (UNEP, 2011). However, there is much that still needs to be understood and investments in research and development will inform key stakeholders on how to transition smoothly. There is still reasonable uncertainty that all jobs generated will be decent and will eliminate persistent poverty. Current knowledge and practices are developed in the context of labour requirements for production and not from the perspective of working conditions and decent work for instance, employment opportunities expected in agriculture, fisheries, forestry, artisanal mining and tourism are clearly outlined. Missing from the green pathways are decent work indicators for instance how the work will lead to adequate earnings and productive work, decent work time, combining work and family life, work that should be abolished, stability and security of work, equal opportunity and treatment in employment, safe work environment, social security, safe work environment, social security, social dialogue, workers and employment representation, economic and social context of decent.

While human resource procedures in the formal sector seeking gender equity clearly articulate most decent work indicators in employment search, recruitment, training, equitable pay and getting organised, activities in resource based sectors remain informal and are currently not integrated in rural policies for the creation of green jobs. Yet conventional rural sector practices exhibit decent work deficits for instance, family labour mentioned as a resilience factor to the extent that it involves child labour is not consistent with the values of decent work. New skills required in renewable energy, conservation and other climate-sensitive tasks may require long hours of training for women away from their families and might also require them to pay. In mining for instance, green technology and equipment require technical know-how which most informal miners especially women currently do not possess. Lack of rules and laws to protect workers in informal employment exposes them to decent work deficits including loss of property and jobs during crisis contexts (Muza, 2009) and also in the process of change from old to new jobs.

Green policies also based on such conventional rural sector practices miss out key elements of decent work and in such instances 'potential is overestimated and environmental policies may have much less attractive labour market consequences' (Morris et al., 2009). In this case, 'job creation has

[50] Refers to the nature or purpose of the job, irrespective of the sector it is performed in. Almost any occupation can be considered green as long as it contributes to reducing harmful impacts of human activity on the environment either directly/indirectly. As a result, occupations ranging from managers, workers to labourers can all at some point be considered as being green.

[51] Certain jobs require worker to possess certain specialized green skills and abilities. Determining whether a job can be considered as being green can in some cases be done based on the necessary skills and competencies required to perform it.

[52] The UNEP and ILO have both stressed the fact that green jobs which offer adequate wages, safe working conditions, job security, reasonable career prospects and workers (UNEP 2006, p.4). The Apollo Alliance has also taken up this dimension in its definition of green job stating that 'if a job improves the environment; but doesn't provide a family-supporting wage or a career ladder to move low-income workers into high-skilled occupations, it is not a green collar job'. Job decency is therefore a key dimension of green jobs.

53 Some workers may do some of their work in green areas and some of their work in traditional areas (Connection Research, 2009.p. 17). In this case, it is important to adequately measure the part of the workload that is officially dedicated to green tasks in order t determine if the job can be considered as green.

no merit as a basis for judging decency' (Hughes, 2011) and policies to promote green jobs maybe 'terribly counterproductive' (Alvarez et al., 2010). Again, it is highly questionable whether a government campaign to spur 'green jobs' would have net economic benefits (Michael & Murps, 2009). In this case, 'green jobs do not automatically constitute decent work, as many are "dirty, dangerous and difficult for instance, employment in industries such as recycling, waste management and biomass energy tend to be precarious and low-paid' (ILO, 2012).

6. Towards a gendered integrated pathway for decent work

The gendered integrated pathway for decent work is based on four pillars of fundamental rights, employment creation, social protection and social dialogue, also acknowledging gender equity in the sense that women constitute the majority of the rural labour force and also have high environmental awareness and are important partners in green transitioning. Equitable access to more and better opportunities in rural areas enable rural women to become effective actors and engines of growth; as well as to produce or acquire the food, water, fuel and social services their families need (Cabrera de González et al., 2009). This pathway follows appropriate labour standards that promote both men and women's interests and operationalises the decent work indicators and the general equilibrium dashboard concerns, gaps and opportunities. It recommends targeted policies that improve the livelihoods of rural women in resource-based economies.

6.1 Green jobs and fundamental rights

As illustrated in the preceding discussion, rural workers in informal labour markets work under difficult and unpredictable conditions and more often, their rights are violated. Because, they are not recognised formal workers and are often not protected by law, the integrated pathway recognises fundamental rights at work including the right to green jobs collective bargaining, eradication of forced or compulsory labour and abolishing of child labour. Existing rural groupings including commodity associations, village groups, farmer field schools or other can be used as vehicles for local organisation to enhance collective bargaining. Different rural groupings from agriculture, fisheries, forestry, tourism and artisanal mining will advocate for green jobs issues through District Councillors or Ward Committees who will then lobby governments and employees for decent work in informal labour markets. The decent work and Just Transition maps can feed into the natural resources strategic plans.

6.2 Green jobs and employment creation.

Employment creation under an gendered integrated pathway addresses key four emerging issues regarding jobs created, jobs substituted, jobs eliminated without direct replacement and worker transformation and redefinition. In all scenarios, worker skills will be revised; though some will be made redundant others will be acquired. However, decent work will only be realised if investments in accompanying green technologies are time and labour saving and thus create more time for women to participate in other productive work and also have quality family life. Gender-sensitive financial programmes and packages that empower women to develop and nurture complementary green spaces relevant for sustainable and productive green employment are introduced.

6.3 Green jobs and social protection

Transitioning to the green economy means new ways of doing work as well as new environments for doing work. To feed to the gendered integrated pathway, green jobs promoted in the rural informal sector are safe and provide security, observe healthy and safety regulations, provide sufficient income for a person to live and the work is dignified and offer prospects for personal development. It is linked to some form of social security that provides protection if the worker is unable to work. Because rural sectors are resource-based and sensitive to climate change, the green pathways adopted to create green jobs promote safe working conditions for women and their children. Green playing spaces may be provided for young children to enable women to carry out their work productively. The work spaces for women could be developed to provide shelter and cover against harsh climate conditions. Health and safety regulation trainings and information can be provided on the job or during other community meetings. Green profitable value chains for women and the requirements for success in such endeavours can be recommended for women in informal markets so that women can earn more and also provide the scope for their personal development.

6.4 Social dialogue

The gendered integrated pathway recognises social dialogue for green transitioning as critical in formalising informal workers concerns and feed into the country's green discourse, policy and practice. Informal workers in resource based rural activities have direct experience working in rural economies. Consultation of rural informal workers and encouraging them to express their concerns contributes to decent work at all levels. Particularly for women, who are the majority and have direct experience in environmental practice. Their views are important in policy formulation.

Environmental advocacy through the relevant ministerial portfolios for instance the Ministry of Labour and Social Welfare, the Employees Council, the Workers Union the green transition needs of informal workers can be presented for motion. Environmental advocacy through the private sector ensures that new technologies introduced are in line with local needs and expectations and also address gender issues. Environmental Advocacy through international governmental organisations also ensures that funding and humanitarian assistance is channelled for actual community needs and gaps.

Improved rural social dialogue (involving employers, workers and government representatives) that involves greening experts and gender advocates support a more balanced policy and research agenda. Additionally, other approaches to understanding the greening transition gaps that take into account decent work and gender equality issues may be considered. Perhaps a complementary monitoring framework (for example, to complement the decent work indicator framework) may be proposed to meet the gendered integrated pathway for decent work in rural areas concerning green jobs and fundamental rights, employment creation, social protection and social dialogue.

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A05

Decent work indicators for agriculture and rural areas: conceptual issues, data collection challenges and possible areas for improvement

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ABSTRACT

This paper aims to achieve three main objectives. First, to assess the relevance of concepts and indicators of Decent Work (DW) for rural areas and employment in agriculture, especially in low-income countries, where coverage, data availability and reliability are particularly problematic. Second, to examine some of the main reasons for the lack of data on DW for rural areas and agriculture, particularly with reference to problems with data collection, such as: the scarcity of employment-focused surveys; sampling challenges that lead to some categories of the working poor to be missed out or under-represented; questionnaire design issues; challenges in survey implementation from selection to training to supervision of interviewers. Third, the paper proposes a selection of more relevant indicators as well as some ways to improve data collection and their quality to better capture the realities of DW, especially in low-income countries (LICs). In this regard the paper presents options for the integration of DW indicators in existing national agricultural surveys, noting the main practical challenges and possible solutions.

PAPER

1. Introduction

This background paper aims to achieve three main objectives. First, to assess the relevance of concepts and indicators of Decent Work (DW) for rural areas and employment in agriculture, especially in low-income countries, where coverage, data availability and reliability are particularly problematic. Second, to examine some of the main reasons for the lack of data on DW for rural areas and agriculture, in terms of problems with data collection, particularly: the scarcity of employment-focused surveys; sampling challenges that lead to some categories of the working poor to be missed out or under-represented; questionnaire design issues; challenges in survey implementation from selection to training to supervision of interviewers. Third, the paper will attempt to propose a selection of more relevant indicators as well as some ways to improve data collection and their quality to better capture the realities of DW, especially in low-income countries (LICs).

The first Section of the paper focuses on three problems and tensions in the implementation of a DW agenda in developing countries and especially in the measurement challenges this agenda raises. By looking at the available lists of Decent Work Indicators (DWIs), their conceptual origins, their availability from existing data repositories, ideas about alternative indices, debates about their applicability to different contexts, and a critical appraisal of the quality of what is available, this section highlights three basic problems with DW concepts and indicators:

1. Context specificity is important for relevance of concepts and indicators. A long and rigid list of DWIs may reflect aims for universalism and the imperative of international comparability. However, while all dimensions DW are desirable, not all indicators are relevant and applicable to all contexts, so there is an external validity problem if an extensive list of DWI is used. As a result, there is a danger of focusing on too many indicators/dimensions many of which suffer from very poor coverage in terms of countries, i.e. some countries with only a very limited set of available data for some very broad background indicators for economic opportunities (employment rates, for instance).
2. Many of the available indicators in several low-income countries, especially in Africa, are basic employment indicators that serve as 'background information' (how many people are active, or employed in rural areas, or the employment rate) but do not provide any indication of 'quality' and key indicators of quality (returns to labour, frequency of employment i.e. underemployment rates, non-wage conditions, etc.) are often missed from agriculture/rural datasets. Especially in agriculture a proper measurement of overall working conditions (including quality job aspects) is crucial. In this sector, the employed population tends to have specific employment conditions which tend to be structurally different from other economic sectors. Standards DWIs might therefore result inadequate to measure job quality in agriculture.
3. Generally the quality of available labour statistics for rural areas in developing countries, especially

in low-income countries (LICs) in Africa, is very poor and may contain biases that would require some rethinking of survey design issues as explored in more detail in Section 2 of this paper.

The scarcity and low quality of labour statistics for agriculture and rural areas stem from two main factors:

(a) Scarcity of employment-focused surveys, since labour force surveys (LFS) are not sufficiently frequent or not focused on rural areas, and most household budget surveys (HBS) cover too many topics, contain extensive and time-consuming modules on consumption, and are focused on welfare indicators (education, health, consumption) rather than on employment and earnings;

(b) Inadequate survey design to capture the realities of rural employment, especially in LICs, including sampling and non-sampling problems.

Section 2 of this paper discusses some of these problems, especially issues of survey design. It also proposes a number of possible areas for improvement, in relation to the most suitable DWI as well as to survey design options. The main alternatives would require:

1. Some more selectivity in DW indicators, i.e. trying to focus on a smaller but more relevant set of indicators, including some that are not currently being collected (for example, detailed data on returns to labour, whether self- or wage-employment, as well as more precise measures of underemployment and occupation multiplicity/multiple job-holding).

2. Better survey designs for greater rural employment focus, including longer modules on DW indicators, alternative sampling methods, better design of questionnaires and questions, and far more training and supervision of interviewers and data collectors.

The paper will particularly focus on the types of countries that are more affected by the scarcity and inadequacy of rural labour statistics, namely low-income countries, especially in Africa. There will be therefore more use of examples from Sub-Saharan Africa, in order to better inform pilot exercises in Burkina Faso and Togo, coordinated by FAO in collaboration with the ILO.

2. From concepts to indicators: the meaning and measurement of DW in rural areas

This section offers an overview of some conceptual issues, how the concept of 'DW' has been built and the dimensions attached to it, as well as some tensions between its holistic character and its applicability in a wide range of contexts and situations. It will be argued that its applicability is variable across contexts and that many dimensions of DW indicators may not be fully relevant or feasible in LIC contexts, where agriculture represents the main source of livelihood (as own-account or wage work) and most people reside in rural areas. This section will particularly focus on dimensions of quantity (measures of employment and underemployment for different types of employment) and quality (especially on returns to labour and non-wage benefits).

Based on work previously done at FAO (ESS)-ILO, and on knowledge of existing databases (ILOStat as an international repository of various national sources, and FAO-RIGA databases, which are based on LSMS[1] datasets) a broad assessment of data availability will be provided and some priorities suggested. This section is organised around a number of themes and main arguments, some related to conceptual questions and some more strictly linked to data issues, as summarized below:

a. In the absence of a simple and universal definition of DW, the choice has been to conceive multiple dimensions, but without a clear sense of what is most important or relevant for different contexts. Some of the dimensions and DWI, while desirable in themselves, are only applicable to particular labour markets and country contexts. As a concept, DW, should work in different contexts, but a rigid set of dimensions may not make the concept internally and externally valid.

b. The evidence base is weak, especially because of problems of data availability and coverage, especially for LICs. The majority of indicators available are basic labour market indicators, or what can be considered 'background' employment information, i.e. the DW pillars of 'socio-economic context' and 'employment opportunities'.

c. The second concern with regards to data problems is that what is available is not always reliable because some of the most conventional indicators may suffer from biases. It is the case of the distinction between 'self-employment' and 'wage employment' and the quality of data on returns to labour.

d. Conceptually and statistically, an important challenge is the fact that occupation multiplicity (when a person combines two or more jobs) and underemployment are pervasive realities in many LICs and especially in rural areas, but they are not sufficiently captured by official statistics, because of reliance on problematic notions of 'main occupation' and the way 'employment status' is conceptualized and measured. An implication is that statistics of employment status are often problematic, as a result of the above, and rural wage employment is frequently underestimated and limited to a particular set of wage

[1] Living Standards Measurement Surveys.

jobs (typically more formal and stable).

The concepts and definitions of DW have gone through a lengthy period of development and operationalisation. The ILO has developed a set of guidelines and a working definition that has been evolving in the last 10 years. DW has been broadly defined by the ILO as being productive work for women and men in conditions of freedom, equity, security and human dignity. The definition rests on basically four pillars, namely employment creation and enterprise development (Pillar I); social protection (Pillar II); standards and rights at work (Pillar III); and governance and social dialogue (Pillar IV). The most challenging task has been to operationalize the concept in all its dimensions through a series of indicators. Only in 2012 a manual[2] for concepts and definitions was published (and further developed in ILO 2013a), although many years before a substantial literature on 'DW' and its measurement had been generated (note, in particular, the special issue of the International Labour Review in 2003). This reflects the difficulties in achieving a universally applicable set of concepts as well as in finding a sufficiently robust set of indicators. In this respect, according to Sehnbruch et al. (2015), the concept of DW has been less successful than the UNDP-linked concept of human development for various reasons. First, it is not sufficiently embedded in a long and well established theoretical tradition that has had great impact on development thinking (i.e. Sen's capability approach). Second, complex and sophisticated dashboard indicators such as those proposed for DW are harder to communicate and diffuse than methodologically simple and easy to understand indices, such as the UNDP HDI, despite its unavoidable reductionism. Third, these authors also rightly suggest that the 'empirical operationalization of the DW approach is probably its biggest sticking point' and reflects the challenge of finding consensus about a simple synthetic indicator because of the tripartite nature of the main promoting organization, the ILO[3]. Furthermore, these challenges compound the already perceived neglect of employment issues in the international development agenda (besides an ex-post inclusion of 'DW' under MDG1b), while the new proposals for Sustainable Development Goals do not advance a significant improvement in the visibility of the DW agenda[4].

2.1 Too many indicators and dimensions? The applicability of the DW concept to rural employment in LICs

The process of conceptualization and measurement development around DW has led to the proliferation of indicators, which try to encompass its various dimensions. The current list of DW indicators includes 4 pillars and 11 dimensions. Each dimension contains a number of indicators, some about basic background information on employment (like employment rates) and some more specifically focused on questions of employment 'quality'. The list is long, with 60 indicators (see ILO 2012 and 2013a for a full explanation of these dimensions and each indicator). The dimension on 'economic and social context', including 12 indicators, provides very general background statistics, such as inflation rate, labour share of GDP or GDP per capita or some education variables. The dimension on 'employment opportunities' includes 11 indicators, most of which are general background employment indicators (such as active population, labour force participation, employment rate, unemployment rate and so on). The other dimensions (adequate earnings, working time, work to abolish, stability/security, etc.) are more focused, contain a smaller number of indicators and are more relevant to issues of employment 'quality' so, in a sense, many of the indicators in these dimensions should be critical for a good measure of DW deficit[5]. These are in fact the kinds of indicators that are often quoted in relation to DW deficit in OECD countries.

In sum, this long list includes all indicators that would be desirable for a full picture of DW situation, including general and specific aspects of employment as well as quantity and quality indicators. The problem is that some indicators, despite universal commitments to DW, may not be relevant across widely different labour market contexts, where employment realities reflect varying levels of economic development, productive structures, social structures and institutional development. For example, the unemployment rate is an important indicator of labour market performance, but it loses meaning and significance in poor countries where most people cannot afford to be unemployed due to the absence of any social protection system[6].It is therefore not surprising that most LICs and indeed many countries in SSA register relatively low unemployment rates in their single digits, especially in rural areas (Baah-Boateng 2013).

[2] Decent Work Indicators; Concepts and definitions. Available at http://www.ilo.org/wcmsp5/groups/public/---dgreports/---integration/documents/publication/wcms_229374.pdf.

[3] Although the ILO is the driving institution and the hub for the development and implementation of the DW agenda, this has also been appropriated by the UN system more broadly as reflected in the commitment of the 2005 World Summit of the United Nations General Assembly later reaffirmed in July 2006 at the high-level segment of the substantive session of the United Nations Economic and Social Council (ECOSOC).

[4] DW is diluted in its joint inclusion with sustained economic growth in just one of the 17 Goals. See Goal 8 https://sustainabledevelopment.un.org/sdgsproposal . It is also true that the multiplication of goals and instruments make most goals less visible than in the original MDG agenda, so 'DW' is not the only victim of this proliferation of goals.

[5] The notion of 'deficit' attached to DW can be inferred from the indicators given their wide range. So, for example situations with higher incidence of child labour, more under-employment, or more excessive working hours, higher proportion of low earnings, higher proportion of working poor, less union density, more occupational hazards, higher gender wage gaps or higher rate of precarious employment could all be interpreted as contributing to DW 'deficits'.

[6] Unemployment rates are typically low in very poor LICs and especially in rural areas compared to urban areas, despite the obvious fact that rural working conditions are generally less decent than urban ones.

Attempts to construct rankings on the basis of even smaller sets of indicators are fraught with problems precisely because of the different relevance of these indicators to different contexts. For example, the special issue of the International Labour Review 142(2) in 2003 included a number of articles proposing DW indices, based on selected indicators, which could help classify countries according to DW deficit. One of these attempts, by Bescond et al. (2003), selected 7 indicators and devised a method to rank countries with the use of the trimmed mean of available indicators (meaning that the two extreme values are dropped). Different country indices would therefore be based on different sets of indicators. While the overall ranking made some sense since richer countries scored better than poorer developing countries, there were anomalies such as a relatively high ranking for Tanzania compared to countries like Mauritius and Spain. The main reason for this anomaly was precisely the low unemployment rates in Tanzania and low female-male labour participation rate gaps, which reflect the fact that most people, including women, simply cannot afford to be unemployed or inactive. It is however hardly plausible that the DW situation in Tanzania is better than in Spain and Portugal. In a nutshell, if understanding DW deficit in Denmark requires 40 or 50 indicators because of the nature of labour markets and social and employment structures there, this does not mean that the same indicators should be applied to Burundi for the sake of international comparability. Insufficient coverage and too many missing values already make international comparability very difficult[7].

These examples and a close inspection of the applicability of several DW indicators to situations of informal, irregular employment and absence of social protection systems, underscores the importance of context specificity to analyse labour market performance and the problems with approaches that seek universal concepts and indicators and give primacy to international comparability. Many of these dimensions and indicators may be desirable in themselves but not applicable to some contexts. Some may be non-negotiable as is the case of the core labour standards, namely (a) no child labour, (b) no forced labour, (c) freedom of association and right to collective bargaining, and (d) no discrimination (across various dimensions). A DW agenda cannot ignore these even in poor countries, as it is a rights-based framework and, despite operational difficulties to enforce some of these rights, the effort to measure them cannot be avoided. The question is what other indicators are most suitable and relevant, knowing what is available, what data are collected with more reliability and what relevant indicators are missing in order to build a more realistic and effective DW agenda for rural areas in LICs.

2.2 What is available and from what sources?

A simple inspection of the available data in specialized international repositories like ILOSTAT-KILM shows that many of the available indicators in most low-income countries, especially in Africa, are basic employment indicators that serve as 'background information' (how many people are active, or employed in rural areas, or the employment rate) but do not provide any indication of 'quality', as key indicators of quality (returns to labour, employment below a desired capacity i.e. underemployment rates, non-wage conditions, etc.) are often missing from national agriculture/rural datasets.

A recent exercise conducted by staff at the FAO-ESS department tried to assess the coverage of 26 selected basic DWIs worldwide[8]. The assessment of available DWIs was based on the collection and classification of indicators according to data sources (ILO-STAT, World Development Indicators and World Trade Organization Statistics), availability/coverage, and disaggregation of data. Approximately 66 percent of the total DWIs for rural areas fall under Pillar 1 (employment creation), i.e. basic background information on employment for indicators such as employment ratios, total employment, unemployment rates, or labour force participation rate. Although important for the first pillar of DWI, these indicators only provide a very superficial picture of the DW deficit in a country and say little about the quality of actually existing employment.

In the main international repository for labour statistics (ILOSTAT and KILM), the coverage of the indicator for employment status, which is essential to distinguish between self-employed and wage-employed, is limited, particularly at a disaggregated level (rural vs urban). For example, for all African countries, most of which are low-income, employment status data are available for 73 percent of countries at aggregate level but only for 24 percent for rural areas (Table 1). For another sample of 7 non-African LICs, 4 out of 7 have aggregate statistics for employment status but only one of these 4 countries has disaggregated data for rural areas. In addition, some countries have disaggregated rural/urban information for wage employed people, but coverage is limited because the surveys these are based on are youth-focused only[9].

Recently, the ILO has been committed to collecting youth DW related statistics through dedicated LFSs, namely school-to-work transition surveys (SWTSs)[10]. Such surveys, administered in more than 25 countries (both developing and in transition), were designed on the basis of the ILO statistical framework. The ILO project towards the collection of youth statistical indicators represents a first

[7] The MDG agenda included the target 1b 'Achieve full and productive employment and decent work for all, including women and young people' but this in practice did not translate into a single indicator of DW with comparable data for all countries.

[8] An internal working paper with this material will be published soon. I had access to early drafts.

[9] These were school-to-work surveys, and thus they had a very specific purpose when they were conceived.

[10] http://www.ilo.org/employment/areas/WCMS_234860/lang--en/index.htm.

attempt to expand labour market information for the world of youth, including information on rural characteristics of the labour market. Indicators collected through these surveys are in general well-suited to inform about urban labour market difficulties faced by youth in the transition from school to work. Nevertheless, labour market indicators for rural areas may require context-specific information whose reliability might be undermined if collection is done through a standardized labour module, as generally designed for urban areas.

Table 1: Employment status –availability by number of countries (Africa)

Availability	**(number of countries)**	**%**
For rural	43	73%
Overall aggregate	14	24%
Total	59	100%

Source: Own elaboration from ILOSTAT data

Most of the indicators pertaining to the four pillars of DWIs that are not of a 'background kind' or related to the notion of 'employment opportunities' are missing for rural areas and agriculture[11]. Arguably a basic indicator of DW is the level and trends in agricultural wages, an area where major DW deficits are found. A recent check in ILOSTAT database showed that only 7 out of 59 African countries, and only one out of 7 non-African LICs, have data for agricultural wages. Disaggregated wage data for rural/urban strata are even scarcer, which shows the extent to which a key measure of DW is missing from available official datasets. Although this indicator is not directly included in the list of priority DWI prepared by the FAO-ESS paper, it should be considered of high priority. This is because the working poor in many LICs may be more dependent on casual wages in agriculture so information about their levels and trends is critical for any assessment of DW deficits in rural areas (Oya and Pontara 2015). Likewise, information on the incidence of migrant and seasonal/casual employment is virtually non-existent in Africa and most LICs in international data repositories (WB, ILO, FAO) but in some cases could be potentially calculated from HBS and LFS when available and if employment modules include questions on time-use. The shortage of statistical information for basic DWIs in agriculture/rural contexts is therefore alarming. Knowing the degree of underemployment is also probably a priority in contexts where full-time permanent employment is the exception and irregular employment the norm. However, a simple inspection of available statistics in ILOSTAT-KILM shows that in SSA there are only 6 countries with some data, only at aggregate level. And even for these countries the reliability is dubious since most have very low levels of recorded underemployment, i.e. below 10 percent of recorded employment, which is not particular plausible (e.g. less than 4 percent in Zimbabwe in 2004). Again, this indicator can be estimated for some countries where HBS and LFS produce time-related data, but it cannot be assumed to be available whenever a HBS or LFS is accessible.

Most of the data available are derived from Population Censuses, which are low frequency (typically every 10 years), Labour Force Surveys (LFS), which are relatively scarce especially in LICs, and, in the absence of these sources, what can be calculated from Household Budget Surveys (HBS) that collect some basic information on employment. One problem with LFS and HBS, as noted in the FAO-ESS paper, is that 'while LFSs cover a wide array of DW related issues, they may exclude the agricultural sector… [HBS] usually fail to provide detailed statistics on all the pillars of the DW Agenda' (p. 19). Also, only a fraction of countries are covered and sometimes with low frequency, so data may be easily out-of-date.

In sum, a major challenge is the scarcity of 'rural employment'-focused surveys in most low-income countries and generally in many developing countries. This is partly because of scarcity of LFSs, because agricultural surveys are essentially focused on production and land statistics, and because other national household surveys are focused on consumption and social welfare indicators (LSMS-type surveys, household budget surveys – HBS -, Demographic and Health Surveys – DHS – to name the best known). This means that (rural) employment issues have been basically falling between the cracks and explains the large number of missing values in international data repositories for employment statistics. The other major challenge is that not all the indicators available are sufficiently relevant/applicable to LIC contexts whereas key DWI seem missing, as will be argued in the next section.

2.3 Are the available rural employment data sufficiently reliable and relevant?

Generally the quality of available labour statistics for rural areas in developing countries, especially in low-income countries (LICs) in Africa, is very poor and may contain biases that would require some rethinking of survey design issues, as explored in more detail below[12].

[11] Detailed information on the pillars and different dimensions of the DW measurement framework can be found in the ILO manual (2013a) - Available at: http://www.ilo.org/wcmsp5/groups/public/---dgreports/---stat/documents/publication/wcms_223121.pdf.

[12] See Jerven (2013), who also provides compelling evidence of the unreliability of basic macroeconomic indicators

There are also issues with relevance. The discussion of multiplicity of DWI in the previous section argued that some of the key indicators of the labour market are not particularly appropriate or useful to understand labour market performance especially in rural settings of poor countries. The World Bank seems to agree with this argument: 'the typical indicators of labour force participation (for example, the employment-to-population ratio, the unemployment rate, main occupation and sector of activity) derived from the standard questions about the "main activity" are generally inappropriate to capture employment patterns such as these which tend to be significantly more complex' (emphasis mine)[13]. Thus it is not surprising that unemployment rates vary enormously across developing countries, even within Africa (particularly comparing Southern African countries with the rest of SSA), thereby reflecting problems of applicability and data collection[14].

There are other indicators like employment status, which establish rigid categories, which may work in contexts where a single well-defined (and regular) activity per individual dominates, as in developed countries, but are less reliable to describe the complexity of rural employment, where there is typically occupation multiplicity, seasonality, irregular employment and generally substantial heterogeneity of rural livelihoods. This has been captured by an abundant literature on the 'rural non-farm economy' (RNFE) (Reardon 1997; Davis et al. 2010), but diversity and multiplicity of roles also happens within agricultural activities. In this sense, as will be argued in more detail in section 2.3.3, and especially but not only in SSA, an activity that is often badly captured is rural wage employment, especially agricultural wage employment.

Part of the problem with relevance and reliability lies in the applicability and operationalization of the most basic definitions. By 'employment', or what the World Bank has recently called 'jobs' (World Bank 2012), statisticians and data users usually mean 'work performed for pay or profit', which can be remunerated in a variety of ways, in cash or in kind[15]. Some analysts call this a 'market oriented' job, because there is some market transaction involved, but the participants in the transaction can be of many different types and contracts may vary widely (Belchamber and Schetagne 2013)[16]. To be sure, there are many types of work that are not explicitly remunerated in any way, but the boundaries between existing categories of 'work' are sometimes blurred, especially in the rural areas of poor countries. What the ILO now calls 'unpaid trainee work' (Belchamber and Schetagne 2013),16 for instance unpaid apprenticeships, are in fact very precarious, and common, forms of employment in the so-called 'informal sector' (more below), since the skills and knowledge acquired by a trainee could be classified as a 'wage'. Moreover, an activity that generates goods that may have a market value but that are consumed within the household can also be considered and is indeed normally considered 'employment', as in the case of what is called 'subsistence agriculture'. Nonetheless, in reality most rural people, even the poorest, have some engagement with markets (output and factor markets) so it is really hard to find purely 'subsistence' households.

Definitions of categories for employment status are also harder to operationalise in poorer countries, particularly for 'wage employment' and unpaid 'contributing' family workers. The notion of 'wage employment', and more generally the 'wage contract', may seem obvious in most countries in the world, and defined by ILO statistical conventions where an employee-employer relationship is assumed, but is actually hard to properly operationalize in rural areas of developing countries, especially in poor countries, characterized by widespread poverty, casual work and occupation multiplicity (section 2.3.3). There may for example be disguised domestic workers also classified as 'unpaid family workers, if there is no explicit cash remuneration and there is some family tie with the worker. There may also be many young people who 'help' in the household farm but also engage in multitude of other casual remunerated activities but are classified as 'unpaid family workers, a category that absorbs a very large proportion of the reported employed population in most LICs.

The key prefix 'rural' attached to employment is not without its challenges either, particularly when comparing countries at very different levels of development and with very different labour structures. Many studies on rural employment in low-income countries tend to take the 'rural' for granted. Researchers sometimes forget that the boundary between the rural and urban differs widely particularly when demographic criteria are used. For example, the cut-off point ranges from 200 inhabitants in Denmark to 50,000 in Japan, and two neighbouring African countries like Senegal and Guinea use very different cut-off point to define urbanity (10,000 and 1,500 respectively) (Dirven et al. 2011). Moreover, in the real world of households and individuals, often characterized by substantial intra-annual and intra-household mobility the rural-urban boundaries may be even more blurred (Breman 1996). Lerche (2010)

in Africa, like GDP, often used in econometric analysis, and documents the major challenges faced by national statistical agencies to produce enough and good-quality data on various aspects of development.

[13] See website at http://go.worldbank.org/KAI66PHUY0.

[14] See Luebker (2008b), for an illustration of this point in the case of Zimbabwe. He shows that, in Harare, almost one half of those considered employed by ILO definition thought of themselves as unemployed. See also Baah-Boateng (2013).

[15] The 19th ILS conference defined work as 'any activity performed by persons of any sex and age to produce goods or to provide services for use by others or for own use'. http://ilo.org/wcmsp5/groups/public/---dgreports/---stat/documents/normativeinstrument/wcms_230304.pdf.

[16] See also ILO (2013b) at http://www.ilo.org/wcmsp5/groups/public/---dgreports/---stat/documents/event/wcms_175150.pdf.

and many authors writing on labour in India focus on the increasing fluidity of employment patterns straddling the urban-rural divide. In China this is a particularly important issue, as the rural-urban interconnections are as important to understand household and individual patterns as what happens within defined 'rural' areas (Zhang 2015). While multiple occupations can be found in 'rural' areas, typically 'rural' occupations like agricultural wage employment may also attract urban-based workers, for example in Latin America, as shown by Ortiz (2015) in relation to both coffee and citrus harvesters who live in town and cities not too distant from the farms. And there are plenty of other examples. The point is that it may be increasingly difficult to define employment and DW in terms of their 'rurality' and this may lead to a greater focus on sector- or activity specific employment indicators beyond the rural-urban divide. The next four sub-sections extend this discussion to four central questions:

a. Centrality of seasonality and irregular rural employment in LICs.

b. Whether notions of 'formal' and 'informal' would help us capture DW deficit in rural areas of LICs.

c. Neglect and statistical invisibility of rural wage employment, especially in African countries.

d. Challenges in capturing the employment features and DW deficit of small-scale producers.

2.3.1 The irregularity of rural employment

A key challenge in the application of DW concepts and indicators is the fact that most employment in rural areas tends to be irregular, or does not conform to the patterns typically associated with 'permanent' or 'regular' employment (the latter, for example, is the preferred term in the Indian context for workers with permanent contracts who work full-time)[17].

Employment status categories (e.g., paid employee, own-account worker, employer, unpaid family worker, and so on) derive from the 'labour force approach', which is usually linked to notions of wage employment that are primarily relevant for developed countries and designed to contribute to national account statistics and unemployment figures (Standing 2006; Breman and van der Linden 2014). Breman and van der Linden (2014) link this approach to the notion of 'Standard Employment Relationship', i.e. regular salaried employment subject to regulations and a variety of forms of protection. At least, this is the way many national statistical agencies, the interviewers they hire and many respondents tend to interpret the concept. The concept needs to be carefully operationalized with a broad enough definition and the consideration of a variety of scenarios. Section 3.2 on questionnaire design explores this.

When the norm is irregular, seasonal and casual employment, i.e. a vast majority of rural people do not depend on one full-time activity with high frequency (duration in terms of months of work and frequency as hours per week), their livelihoods in reality hinge on two basic aspects of work:

a. The effective number of 'days' (8-hour equivalent days) they manage to work in any given calendar year with explicit or implicit remuneration (i.e. both returns to self-employment and to wage employment in cash or in kind, including self-consumption).

b. The explicit or implicit returns to those activities (per day of work).

Therefore, in these contexts, the big issue is time-related underemployment, which is perhaps one of the most relevant and useful DWI for rural areas in LICs. One of the main reasons for underemployment (as one key element of labour underutilization[18]) is seasonality of agricultural activities, which tend to dominate many rural settings despite the increasing rise of non-farm rural incomes (Davis et al. 2010 and 2014). In contexts of low-technology, low-productivity agriculture, most agricultural activities are highly seasonal, at times erratic, because of their reliance on vagaries of weather, and uncertain in terms of returns, due to high risks of crop failure or low productivity. In the case of semi-arid areas in Africa, the agricultural season may not last more than 4-5 months, from the time of land preparation to the harvest, with slack periods in between. Apart from the uncertainty of natural environments, farming is characterized by the fact that production time exceeds labour time to respect the natural rhythm of plants and animals, so employment in farming is quite different from employment in factories or in other non-primary activities, (Mann and Dickinson 1978; Bernstein 2010). These contexts thus generate obstacles for the development of capitalist agriculture and more permanent agricultural activities, and are exacerbated by the dependence on rainfed farming systems and limited availability of irrigation in most LIC contexts. As a result, rural people either remain idle without engaging in gainful economic activities or try to complement what they do with other non-farm activities. As an abundant literature has shown, the latter is the norm rather than the exception (Davis et al. 2010 and 2014; Reardon 1997). In fact, it may be the case that an individual is 'irregularly' employed in two or three different activities, but the sum of days of work accumulated in the different activities over a given year equates to almost

[17] Winters et al. (2008) prefer to use the term 'permanent' or FYFT (full-year full-time) to distinguish from other forms of employment that may be 'full-year' but are only part-time or full-time but only for a period of time in a year (such as a season). Both terms 'regular' and 'permanent' are often used interchangeably.

[18] The other elements are unemployment and 'potential labour force', as defined by the 19th ILS resolution. See footnote above. http://ilo.org/wcmsp5/groups/public/---dgreports/---stat/documents/normativeinstrument/wcms_230304.pdf.

a 'regular' or full-time status. In such contexts employment statistics derived from questions with short reference periods, such as the conventional 7-days, may lead to biases depending on whether the survey took place at the peak of the agricultural season or during the slack period. Therefore, a 12-month reference period is more suitable to capture the true extent of underemployment. This is why it is important to collect detailed information on effective time in work, so that distinctions can be made between different degrees of 'irregularity' and underemployment.

Pervasive underemployment and irregular jobs can happen amidst instances of 'overemployment' especially in the form of 'excessive working hours', another important DWI. Since most employment in rural areas of developing countries is not protected by labour legislation on maximum number of hours, the duration of a 'day of work' can vary widely from one job to another from one period of the year to another. This situation is particularly important at times of peak labour demand for agricultural activities, such as weeding or harvesting. Given the importance of harvesting on time, or sowing shortly after the rains, as in much of rain-fed semi-arid areas, farmers are forced to use their family and hired labour intensively, implying more than 10 hours of work per person in any given day. This can also entail the use of child labour, whether during school holidays or not. A lot of casual wage jobs in agriculture are defined in terms of tasks even when the mode of payment is daily. So, a worker will be asked to perform a task and, depending on his/her productivity. This task could take half-day or even require extra time the following day. At the same time, there are also people who work excessive hours because during certain periods of time they have to work in multiple jobs and extend the day of work to very long working hours. Thus, someone may start very early and work in the farm until midday, then go to work in the market and perhaps add another casual job later in the evening. This can be particularly burdensome for women when they combine productive and domestic/reproductive activities at times when productive activities are very demanding. In sum, a scenario of underemployment coupled with excessive hours of work (overemployment) is possible:

a. A worker may be effectively 'active' working in agricultural tasks (as self-employed or wage employed or both) for a fraction of the year, say 120 days, which would mean 'under-employed' in that activity.

b. However, the hours worked in some of these 120 days may be 10 or 12 or more, in which case there is over-employment or 'excessive hours of work'. The question is whether 'over-time' (rather than over-employment) is compensated or not and whether the worker would prefer to work fewer hours, which might mean less income if payment is task-based or piece-rate. All this is obviously hard to ascertain in situations where the labour relation is inherently 'informal', i.e. no contract, no hours stipulated, just tasks to be completed.

In sum, for the purposes of relevant and realistic DWI in relation to employment regularity, data on the number of effective days of work per year, for all recorded occupations would be needed in contexts where 'regular' employment is the exception. Moreover, estimates of instances of 'excessive hours' of work, which may happen in particular periods, are also important for a more encompassing consideration of DW in relation to time-use.

2.3.2 Definitions: do "formality" and "informality" help?

The irregularity of employment, multiplicity of jobs, variable hours and remuneration would suggest that this is a context of widespread 'informality'. Indeed, most of the employment in rural areas of LICs is 'informal' according to the usual definitions of informality, whether 'legalistic', scale- or productivity-based. The problem is that the dichotomy formal-informal means different things to different people and is defined and operationalized in multiple ways (Maloney and Arias 2007 – in Perry et al., chapter 1; Maloney 2004), and may create problems of applicability to diverse contexts as it happens with some DWI. Sometimes, the nature of the labour contract is emphasized, whether workers have formal contracts, receive benefits or pay taxes, for example. Other times, 'informality' is equated with the type of employer and especially its scale of operations, so a 'shortcut' is devised whereby enterprises are considered 'informal' if employing less than 10 workers and thus these workers may be classified as 'informal' by virtue of the scale of their employers rather than the nature of their labour relation. This can create biases insofar as there is a possibility of small-scale operators (especially in services) that may formally employ people and be 'formal' in the legal sense.

The ILOSTAT-KLM statistical repository only includes 18 countries in SSA with some data, often dated, on the proportion of informal employment in non-agricultural employment at aggregate level and in some cases coverage is limited to urban areas or to the capital city. This type of information is almost impossible to find in these compiled databases for rural areas and agriculture. The ILO technical notes point out that 'information for the indicator is often based on national definitions and users are advised to review definitions carefully when attempting to assess country comparisons', so there does not seem to be one universal definition in use. There are multiple layers in the definition and therefore multiple choices for national agencies to opt for one or a different combination of elements. The ILO combines categories of employment status with the 'legalistic' definition of their labour relations, and the type of employer ('productivity' definition), but has moved towards the 'legalistic' definition, focused on the nature of labour relations and contracts, to accommodate situations in which the employment relation is 'informal' even if it happens within 'formal' units[19]. This combination of layers of formality creates multiple situations of 'informality' as illustrated by Maloney and Arias (2007). In some cases a combination that is adapted to a country context may result in a definition that is more operational but that excludes some groups. For example, in India informal work/employment (clearly distinguished from 'informal economy' and the 'informal sector') is defined as: 'Unorganized workers consist of those working in the unorganized sector or households, excluding regular workers with social security benefits provided by the employers, and the workers in the formal sector without any employment and social security benefits provided by the employers' (NCEUS 2009: 3). The inclusion of formal sector workers who do not enjoy the benefits of formality is important. The 'unorganised' sector is defined in relation to ownership (individuals and households) and scale (less than 10 workers), including 'all agricultural activities undertaken on agricultural holdings', quite a common option in most developing countries, where 'informality' is restricted to the nature of the employer and its scale.

Although knowing the extent to which an employment relation is 'informal' or takes place in an 'informal' setting may be useful, the applicability of the different definitions creates its own problems. In fact, the rigid guidelines applied make the concept of 'formal' largely irrelevant to the agricultural sector in LICs, especially when casual wage work and what is called 'subsistence agriculture' (more precisely 'own-use production work') dominate. However, this does not mean that there may not be employment that conforms to some of the definitions of 'formality', i.e. large-scale plantations where some workers may be deducted taxes on their pay, who have written contracts, albeit temporary, and where some statutory benefits (sick leave, annual leave, etc.) are available (Wendimu and Gibbon 2014, for an application in an Ethiopian context).

Given the challenges discussed above, leading authors like Breman (2006) and Wuyts (2011) have questioned the usefulness of the 'formal'-'informal' distinction and especially its inconsistent operationalization across contexts. They argue that what matters is knowing the dimensions and conditions that characterize a given employment and report them separately for different topics. Trying to establish an indicator of 'informality' is akin to the production of a composite DW index from the various dimensions it is supposed to encompass. As argued by Breman (2006) among others, what really matters is the nature of the employment relation or the form of work rather than the scale or productivity of the employer/producer irregular employment, no written contract, no benefits or rights, lack of formal registration, etc.).

For small-scale producers, the issue becomes even more irrelevant and complicated since they would not qualify as 'formal' either in relation to the nature and scale of the production unit (the small-scale own-account farm, for example) or to the nature of their employment (nor formally protected or registered, irregular, with uncertain remuneration, etc.). Moreover, rigid classifications may obscure a continuum of degrees of 'informality' among small-scale producers, from those with less market involvement (as sellers and buyers) to those who are primarily market-oriented producers[20]. As Wuyts (2011) argues, the trouble is also that the application of rigid notions of 'informality' (i.e. that the self-employed are 'informal' by definition and that some 'informal' activities are therefore correspondent to self-employment) may lead to biases in the representation of employment status, inflating self-employment and underestimating wage employment (see more below in 2.3.3).

In light of these challenges and tensions, it may be advisable not to apply rigid formal-informal distinctions in the context of rural employment in developing countries, but rather focus on key central dimensions of DW and measure them properly without recourse to broad categorizations and dubious composite indices. Therefore, indicators of time-related underemployment, security, protection, registration, taxation and benefits, may be better to analyse separately and comparatively instead of being pooled and diluted in an aggregate index/classification of more inconsistent applicability, particularly when there are distinct categories of work (small producers, more or less market-oriented, casual wage workers, seasonal workers, etc.). What is at stake is their applicability to rural/agriculture contexts and not whether they can be combined in any meaningful 'reduced' composite index.

2.3.3 Rural/agricultural wage employment: biases and challenges[21]

According to the 2013 World Bank World Development Report on 'Jobs' (World Bank 2012, 6): 'a job does not always come with a wage'. In fact, Figure 1 in that report suggests that, on aggregate, employment is usually dominated by non-wage employment (a combination of own-account farming and non-agricultural self-employment). In most SSA countries and in many LICs the category of 'wage employees' category usually represents between 2 and 10 percent of the total employed population,

[19] See, for instance, definitions for informal employment by the ILO, at http://www.ilo.org/wcmsp5/groups/public/---dgreports/---stat/documents/normativeinstrument/wcms_087622.pdf and http://ilo.org/public/english/bureau/stat/download/papers/def.pdf and http://ilo.org/wcmsp5/groups/public/---dgreports/---stat/documents/meetingdocument/wcms_223918.pdf.

[20] Moreover, in some cases and increasingly so small-scale producers may operate within cooperatives or producer organisations, also with varying degrees of integration, and therefore part of a different employment category beyond their degree of 'informality'.

[21] The arguments and evidence in this section draw from Oya (2013) and Oya and Pontara (2015), which include more details.

the vast majority being classified as either self-employed or unpaid family workers, but there are some exceptions like the richest African countries as well as those located in Southern Africa (Oya 2010, Table 2). Beyond Southern African and African Small Island States the official statistical picture consistently shows very low incidence of wage employment in aggregate terms and especially in rural areas. For example, in the 2004-05 LFS in Ethiopia, a country with a large population, only 2.3 percent of rural people employed were paid employees by private companies, NGOs or individuals (including 0.5 percent of domestic workers). Anyone with some fieldwork experience in rural Ethiopia would question these figures, as wage jobs are very common and people working for wages far from a small minority. As will be argued below, the problem lies in the conventions of 'main occupation' and the way large-scale surveys are conducted.

There are important differences between regions and countries. The incidence of agricultural wage employment, in rural Africa is less than 3 percent in aggregate, compared with 22 percent of men and 11.4 percent of women in South Asia, and 21 percent and 2.3 percent respectively in Latin America (World Bank 2007). In addition, non-agricultural rural wage employment applies to only 9 percent of men and 3 percent of women in most African countries, whereas it represents a much higher proportion South Asia, Middle East and North Africa (MENA), East Asia and Latin America (World Bank 2007, 205 Table 9.2). Despite these figures, the Bank acknowledges that 'Making the rural labour market a more effective pathway out of poverty is…a major challenge that remains poorly understood and sorely neglected in policy making'.

Based on the RIGA databases and selected countries, a study by Davis et al. (2010), reporting income sources, confirms these contrasts by region and gives evidence of some large and possibly inconsistent discrepancies in findings between African countries[22]. In Latin American countries, rural labour market participation rates (based on questions of having worked as wage workers, not about the 'main activity') are quite high, while the three African countries considered present a very inconsistent picture in Africa: 55 percent of rural people having worked for agricultural wages in Malawi, compared to 3.7 percent in Ghana and 3.8 percent in Nigeria.

This neglect or apparent invisibility of rural wage workers is a serious challenge if we are interested in DW in rural areas. Indeed, research shows that most often the poorest rural people tend to depend more on casual wage employment (Sender 2003; NCEUS 2007; FAO-IUF 2005; Kevane 1994). A particularly problematic omission is paid domestic work, as opposed to domestic work tout court. In most countries there are either no statistics at all on this category or the values are almost insignificant as shown in the example above in Ethiopia. For example, in Zimbabwe and Botswana, 'wage employment in private households' (i.e. domestic workers) is quite a significant employment category in official statistics, at almost 5 percent of total employment in both countries (Luebker, 2008a: 32, and Central Statistical Office [Botswana], 2008: 20). In contrast, in other countries this category of workers seems invisible from official statistics. It is plausible that even in rural areas of poor countries thousands of domestic workers are employed in the houses of people employed by 'formal' enterprises and certainly in those of civil servants. It is precisely in these kinds of jobs where the potential DW deficit is greatest (see Cramer et al. 2008, for evidence from Mozambique). Hence the biggest priority should be to capture the true significance of this kind of employment in rural areas of LICs in order not to underestimate the extent of DW deficit in a country. The reasons for these low recorded levels of rural wage employment may be variegated, as different hypotheses have been considered by the literature, namely:

a. high land/labour ratios and low population densities coupled with low productivity, which reduce the incentive to hire labour and also constrain wage labour supply (Berry 1993, Barrett et al. 2005, Mellor 2014)[23].

b. Small-scale producers' resistance to become proletarianized and their protracted attachment to their land and own-account farming[24]. While there is some contested evidence on this occurrence, total avoidance of market compulsion to work for wages is unlikely (Bernstein 2010)[25].

c. This thesis is complemented with the idea that most labour hiring in African contexts takes the form of reciprocal labour exchange in the form of collective workgroups[26].

d. The hypothesis of 'resistance' would be consistent with some evidence that households participate in agricultural wage employment because of liquidity constraints, so they may pull out and focus on

[22] The RIGA (Rural Income Generating Activities) programme and database (http://www.fao.org/economic/riga/riga-database/en/) is an attempt to extract more detailed labour statistics and specifically wage employment data from existing national household surveys (LSMS-HBS). Davis et al. (2010) and Winters et al. (2008) report the key findings.

[23] See Oya (2013, 254 and Table 2) for a critique of this hypothesis.

24 See Hyden (2006, 138-160) on the idea of 'uncaptured peasantry'. For criticisms of this position see Kitching (1989), Sender and Smith (1990), and Mueller (2015).

[25] See also Zhang (2015) on China.

[26] See Whitehead (2006) and Swindell (1985, chapter 5) for an analysis of the nature, decline and persistence of cooperative/reciprocal labour exchange and the extent to which collective workgroup may conceal disguised forms of wage labour, when reciprocity is not demonstrated and some individuals tend to benefit much more than others.

their own farm activities when improved access to social protection and/or finance reduces the need to rely on casual wage employment, such as ganyu in Malawi (Bryceson 2006)[27].

Among these hypotheses, one of the most convincing is that many low-income African countries still have underdeveloped capitalist sectors and have the lowest incomes per capita in the world. Historical evidence suggests that convincingly that as income per capita increases, the proportion of reported self-employment is substantially reduced (Gindling and Newhouse 2012).

However, none of these hypotheses questions the quality of data. So, a plausible alternative hypothesis is that some of this evidence essentially derives from the fact that data collection systems are inadequate and have failed to capture the significance and nature of rural wage employment, at least on the basis of more conventional questions (Oya 2013, Mwamadzingo 2003, 31; White et al. 2006; Cramer et al. 2008; Zhang 2015). This has partly to do with definition issues and their operationalization, as discussed in section 2.3 and 2.3.1 above. The reason this hypothesis is suggested is two-fold. First, the problems of reliability of rural labour market and agricultural statistics more generally have been shown through basic consistency checks, comparisons and some survey experiments (Carletto et al. 2015; Jerven and Johnston 2015; Sender 2003). Second, abundant micro-level labour surveys show a very different picture.

Various studies published in Oya and Pontara (2015) illustrate this point. For example, Mueller (2015), writing on Tanzania, finds in the West Usambaras Mountains, that around 60 percent of rural households had at least one member engaged in wage employment, in contrast with an official figure of 11 percent from national Integrated Labour Force Surveys (ILFS) in 2000/01. Around 22 percent of rural adults work for wages during the reference period of his study, compared to the 3.3 percent of waged or salaried workers in the economically active population based on the same ILFS. Although Mueller's and the ILFS methods are different and questions are not the same, the discrepancies suggest that we miss an important part of the picture of the rural labour market precisely because of how questions are formulated. Other studies (Petit and Rizzo 2015) also document the pervasive practice of agricultural wage labour, especially among the poorest households, in countries like Ethiopia and Rwanda where official estimates of the incidence of wage employment in rural areas do not exceed 10 percent[28]. Other contributions on South Africa and Lesotho also point to the extent to which self-employment is overstated and how migrant labour is insufficiently captured (Pons-Vignon 2015; Johnston 2015). But these problems are not limited to LICS in Africa. Even in countries where labour statistics are relatively good, such as India, biases and underreporting occur, as Jha (2015) argues especially in relation to seasonal migrant labourers. In China the problems are even more serious. As indicated by Zhang (2015), one major challenge there is that 'hired agricultural workers' do not exist as an official statistical category. The use of costs of hired labour inputs is also fraught with problems (Zhang 2015), including the conflation of very diverse forms of wage employment. Rizzo et al. (2015), writing on Tanzania, argue that the limited evidence on informal employment, especially for non-agricultural activities, is largely due to many forms of wage employment being mistakenly reported as self-employment. The importance and dynamism of rural and agricultural labour markets may however be partly captured by analysing specific questions sometimes contained in nationally representative surveys, like LSMS. A recent study (Dillon and Barrett 2014) , based on data from LSMS and ISA surveys led by the WB, looks more specifically and in detail at questions about hiring (employing) labour for agricultural activities. When these questions are asked (rather than 'your main occupation in the last 7 days'), a picture of important and dynamic agricultural labour markets emerges. According to this study, the incidence of labour hiring (in terms of farmers employing hired labour) ranged from 30 percent in Ethiopia to almost 50 percent in Niger, for a sample of 5 countries and various agricultural operations. This shows that LSMS-type surveys can potentially be used to extract this kind of information as long as employment modules contain the relevant questions.

To account for the discrepancies between official statistics and micro-level survey evidence as well as with qualitative research, methodological problems in data collection must be debated. This will be done in more detail in the discussion of survey design (Section 3). In previous research (Oya 2013), I have suggested four reasons why rural wage employment data are unreliable and scarce in most of Africa and many other non-African LICs:

a. Lack of labour force surveys (LFS) focusing on the rural sector and small-scale enterprises;

b. Growing marginalization and simplification of questions on labour and employment in nationally-representative household surveys (HBS), which are unsurprisingly biased towards the collection of consumption data for poverty indicators;

[27] However, this may apply in relation to the worst forms of casual wage employment in agriculture, which may be seen as 'last resort' but (a) not all forms of rural and agricultural wage employment are of this kind and (b) the likelihood that access to finance and assets might improve for the vast majority of small-scale producers in poor countries is very low because governments and NGOs have limited resources to substantially expand the outreach of these kinds of interventions. There is also evidence that cash transfers programmes in Malawi relax the labour constraint faced by poorer farming households and even allows them to hire ganyu for their own farms. See http://www.fao.org/economic/ptop/programmes/malawi/en/.

[28] See also Erlebach (2006) a rare in-depth study of rural wage employment in Rwanda, which confirms the huge importance of wage jobs for the poorest rural people.

c. Inadequacy of some statistical conventions, definitions and survey practices, some already explored in previous sections of this paper;

e. Issues about the definition and boundaries of the 'household'.

Section 3 will discuss the last three points. On the first point, the relative scarcity of LFS in Africa and LICs can be inspected by looking at existing survey inventories at the ILO and the World Bank[29], especially in comparison with Latin America and Asia (Mwamadzingo 2003). Generally, since the 'poverty reduction agenda' started dominating the international aid agenda HBS of the Living Standards Measurement Surveys (LSMS) type have overtaken traditional labour force surveys as sources of basic labour data in terms of frequency (Rizzo et al. 2015; Johnston 2015). The paucity of rural wage employment data in these countries has a knock-on effect on published research, which depends heavily on the use of international repositories and data from national household surveys, so that results in scarcity of published research too. In contrast, research on small-scale farming is abundant and, yet, data are not sufficiently rich so as to capture DW dimensions to be applied to these quantitatively important but highly diverse group.

2.3.4 Accounting for decent work among small-scale producers

This section focuses on some of main methodological and conceptual challenges in the definition of 'smallholders' and in the operationalisation of DWI in the situations of self-employment in agriculture.

In many parts of SSA and many LICs, most rural dwellers have some access to land, so they are liable to be recorded as agricultural producers, given their attachment to such land. This, however, does not mean that they depend primarily on their land-based activities as much of the RNFE literature has shown. The issue is that, as a group/category, is excessively heterogeneous, even if it concentrates a significant proportion of the 'rural poor' according to much of the literature. If a survey collects enough background information about farm households or small-scale farmers at least a continuum of cases can be devised along the set of the categories below:

a. Small (agricultural) producers who consistently employ labour and for whom the only relevant questionnaire is the module on 'agricultural production' (and sales), including information on the labour they hire, possibly obtaining relevant information for DWI. Although it is not ideal to obtain DW data from employers (in this case small-scale producers), this route may be better than failing to sample the casual workers employed by them. Relevant DWI that could be collected from this category are agricultural wages, incidence of labour market participation in poorly paid casual agricultural jobs, and non-wage aspects of the employment relation.

b. Small (agricultural) producers who employ labour but also frequently or significantly work for others (in farm and non-farm sectors), in which case it is equally important to collect detailed information about agricultural production and wage employment. Information on wages, non-wage conditions (benefits) and time-related under-employment can be collected from this category.

c. Small (agricultural) producers who may not or only sporadically employ labour and mainly rely on family labour and who do not work outside their farm, in which case detailed information about their agricultural production' work done on the farm and agricultural sales is necessary. Here the focus of DWI data collection can be on the irregularity and levels of earnings (farm income), time-related underemployment, child labour and excessive hours during peak periods.

d. Small (agricultural) producers or landless workers who essentially depend on their wages (agricultural and non-agricultural) and for whom the key modules would be one on wage jobs. The focus of data collection would be on the quality of jobs accessed as well as on time-related underemployment.

Small-scale producers will be normally situated along the continuum of those categories. Note that the same 'profiles' may also be engaged in own-activities in non-agricultural sectors, for which a questionnaire ought to include a specific module too. This heuristic classification serves to illustrate the fact that 'small-scale producers' as a single category may be too ambiguous and broad. To tackle this issue there are three main conceptual and methodological challenges that need to be addressed in order to better capture DW among small-scale producers:

1. Defining the 'smallholder' as an agricultural producer, in terms of scale, use of labour and other attributes.

2. Distinguishing 'smallholders' from other groups of people in the 'rural sector', especially from wage workers.

3. Distinguishing different classes of smallholders.

[29] http://www.ilo.org/global/statistics-and-databases/lang--en/index.htm http://go.worldbank.org/JF4LVHJBS0.

2.3.4.1 Defining a 'smallholder' or self-employed small-scale producer

As with other labour categories, the definition of small-scale producer may not be as straightforward as that of simply 'own-account worker' in the agricultural sector. A key issue is what is meant by 'small', as references to farm size only may result in some inconsistencies and bias.

Dixon et al. (2004), in an FAO book/report (Smallholders, globalization and policy analysis), note that 'the definition of smallholders differs between countries and between agro-ecological zones. In favourable areas with high population densities, they often cultivate less than one ha of land, whereas they may cultivate 10 ha or more in semi-arid areas, or manage 10 head of livestock. Often, no sharp distinction between smallholders and other larger farms is necessary.' The quote reflects the confusion around the meaning of 'smallholder'. The Ethical Trading Initiative (ETI) Smallholder Guidelines (2005) explicitly state that 'the definition of smallholder differs significantly according to crop, and to the social, cultural, economic and political context' (p. 13). As an alternative to definitions based on farm size the ETI opts for a definition that encompasses a number of well-established criteria whereby 'smallholder farmers' or small-scale producers:

a. produce relatively small volumes of output on relatively small plots of land;

b. may produce an export commodity as a main livelihood activity or as part of a portfolio of livelihood activities;

c. are generally less well-resourced than 'commercial-scale' farmers;

d. are usually considered as part of the 'informal economy' (not be registered, excluded from aspects of labour legislation, limited records);

e. may be men or women;

f. may depend on family labour, but may hire significant numbers of workers;

g. are often vulnerable in supply chains.

These multiple criteria refer to production scale, market orientation, relative resource endowment, levels of 'informality' and labour use. These are common to many other definitions and often implicitly assumed more than explicitly stated. In relation to 'scale' a challenge is whether farm size should be preferable to farm capitalisation or business scale (e.g. annual turnover). This is particularly important in the light of bad measurement of land size in contexts of scarce resources for data collection (Carletto et al. 2015; Hannertz and Losch 2006). Moreover a particular farm size means different things depending on the crop, the technology and the production system. For example, in Ethiopia, compare a 2ha technologically sophisticated flower farm that may require US$ 1 million of start-up investment with a cereal (teff) farm of equal size that can be started with a few hundred dollars to start up or even less. In large agricultural producing countries in Latin America, such as Argentina, the definitions are on a completely different scale. An institutional report in 2007 (Scheinkerman et al. 2007) defined 'small producers' in terms of labour use and some farm size ceilings, usually set at 500ha (!). As Berdegué and Fuentealba (2011) note in relation to Latin American smallholders, 'the "2 hectare" definition is a measure of our ignorance and not of our understanding of smallholder farming, nor of what is needed for well-designed strategies and policies'. However it is widely used in the literature (cf. Wiggins et al., 2010; Hazell et al., 2010; IFAD, 2010). Many surveys tend to concentrate on (badly) measuring land, when they could more systematically collect up-to-date data on investment and capitalization. Furthermore, given the fact that in many contexts (such as India) land can be used under multiple tenancy systems it makes sense to talk about 'cultivated land' rather than owned land.

The definition of 'small-scale' producers/farmers also hinges on data collected on labour use. Bernstein (2010) suggests that typically small-scale producers are defined as those whose farm size is determined by the availability of family labour and often conflated with the idea of 'subsistence production'. Thus in its 'pure' form, a small farmer would only use family labour on a relatively small farm, size-wise, and without selling labour in the labour market, i.e. without being a wage worker as well. The Fairtrade Labelling Organisation (FLO) also defines a smallholder as a producer who is dependent on family, as opposed to non-family, labour. However, it is well known that small-scale agricultural production heavily depends on casual wage labour inputs, and the exclusion of this category therefore introduces another serious bias in the definition (Cramer et al. 2014).

As with other labour categories, context matters also for the operationalization of definitions of small-scale farmers. The key lesson from this discussion is that surveys may start with a broad 'international' definition based on a combination of criteria (relative production scale and labour use patterns), but then will have to adapt such definitions to each context in terms of: country, crop and technology. In other words, universal criteria such as 'less than 2 hectares' or 'only using family labour' should be avoided. Surveys ought to collect more and better information on business scale (production scale, investment) and on the use of labour (whether family or hired, permanent, seasonal or casual), i.e. directly by asking small-scale producers.

2.3.4.2 Distinguishing smallholder farmers from other people in the 'rural sector'

The problems in defining 'small farmers' have an impact on the distinction between 'small farmers' and 'wage workers' in rural areas. This distinction may be problematic in rural contexts of LICs, characterized by occupation multiplicity, insofar as many smallholders could also be considered 'wage workers'. In many parts of SSA, South Asia and elsewhere, large segments of the 'smallholder population' straddle occupations between different forms of wage labour and their own-account farming, in addition to petty non-farm business. They frequently combine the 'places' of capital and labour, which makes their treatment in analytical and statistical terms rather complicated (Bernstein 2010). Whether they are more reliant on their own account farming or on wage employment is an empirical question that many household surveys fail to adequately ask and probe, resulting in biased representations of what people do in rural areas and underestimates of the incidence of rural wage labour as argued in section 2.3.3.

A couple of practical examples may help illustrate these ambiguities, which require careful survey design:

Box 1. Employment status: ambiguities and diversity. Case 1

Case 1. Border between Senegal and Mauritania, semi-arid context

Mr Diop has a 1ha farm along the bank of the Senegal river in Senegal. He combines the cultivation of a small plot of irrigated rice for commercial purposes and millet and vegetables for own family consumption and some for the market. He and members of his family travel across the border to find employment in a horticultural plantation named GDM, which employs hundreds of casual labourers on a daily basis especially during harvesting times. Diop and his family use the money obtained with their seasonal work to buy fertilizers, complement the purchase of food (some of which is cheap imported rice) and to pay for irrigation costs. Mr Diop has been a member of the state-promoted rural cooperative for the past 20 years and is now member of a small GIE (*Group d'Interet Economique*), set up by a number of wealthier farmers of the area to attract NGO funding and credit. They use the GIE also to lobby the government for more support in irrigation facilities and more remunerative marketing arrangements. None of the Diops is member of a trade union on the Mauritanian side to look after their interests as employees of GDM.

NOTE: DIOP & FAMILY COULD BE EASILY CLASSIFIED AS SMALLHOLDER RICE FARMERS, SINCE THEIR LOBBYING INTERESTS AND FARM CASH INCOME DERIVE FROM RICE FARMING AT A SMALL SCALE, BUT THEY ARE ALSO WAGE WORKERS INSOFAR AS THEIR EMPLOYMENT IN A NEIGHBOURING PLANTATION ACROSS THE BORDER IS CRUCIAL FOR THEIR LIVELIHOODS AND THE SURVIVAL OF THEIR SMALL FARM. **A CATEGORY SMALLHOLDER/MIGRANT WORKER WOULD BE RELEVANT TO THIS CASE.**

Box 2. Employment status: ambiguities and diversity. Case 2

Case 2. Tobacco outgrower farmer in Manica, Mozambique

Mr Bolacha is a small outgrower tobacco farmer in the province of Manica, central Mozambique. Bolacha is a Mozambican citizen and return migrant from Zimbabwe after the events of the fast track land reform in 2000. He managed to get some land in his family village and used his contacts with tobacco farming companies to obtain an outgrowing contract with one of them, farming 1.5 ha of tobacco, in addition to 1.5 ha of maize and vegetables. He also owns three cows. Mr Bolacha has invested much of his savings from years of work as farm labourer in Zimbabwe in his own-account farming. He employs family labour in his tobacco and food crop fields although his son has recently migrated to neighbouring provincial capital Chimoio to work in private transport as a driver.

Bolacha depends enormously on the support of his tobacco buyer, in terms of credit, technical assistance and access to fertiliser. He has also joined an association of tobacco outgrowers to lobby for better contractual conditions.

Bolacha employs one permanent worker as his family labour is not sufficient, especially for highly time demanding operations in tobacco cultivation and basic processing. At the time of harvesting he also routinely employs 5-10 casual daily workers from his village and surroundings.

NOTE: **THIS CASE WOULD BE CLOSER TO A SMALLHOLDER-EMPLOYER** WITH TYPICAL COMMERCIAL FARMER INTERESTS AND LOBBYING NEEDS VIS-À-VIS CORPORATE AGRIBUSINESS/BUYERS. HIS PAST AS A FARM LABOURER COMPLICATES HIS SELF-REPRESENTATION AS HE SEES HIMSELF AS A 'SIMPLE HARD WORKER' AND NOT AS AN EMPLOYER.

These two illustrations shows the potential for bias if the two cases are simply classified as 'small farmers' with implications for a proper understanding of DW deficit in each of these cases. Therefore, when collecting information on people who may be generally classified as 'small farmers.', it is important to work with context-specific categories that contemplate the possibility of non-overlapping definitions and which would allow a more precise distinction, for example between 'small-scale agricultural own account workers' and 'people who mostly depend on casual agricultural wage incomes for their own and their families survival'. Both may have land and farm but are not affected by the same DW deficit issues.

2.3.4.3. Distinguishing among different 'classes' of small-scale producers and generating DW deficit estimates for small producers

Assuming that a distinction between categories can be established, the next challenge is to account for heterogeneity within these categories. In the case of small farmers who mostly depend on their own-account farming to live, how do we account for wide differences in assets, vulnerability, farm practices and labour relations among them? How do we account for the differences between a 'small farmer' who barely produces surplus for the market from one who is strongly commercially oriented and largely depends on markets for his/her survival with much higher returns to his/her labour and capital? The constraints they face may be different and their aspirations and priorities may also differ.

Much of the agrarian political economy literature works with such distinctions. For example, in the literature on India it is common to see a distinction between: poor (marginal) smallholders, middle farmers and richer farmers (NCEUS 2007). These distinctions may be articulated in terms of relative DW deficits. For a self-employed farmer, the key issues in terms of the quality of this employment would be:

1. Time used in the activity (given a level of farm income, less time is better than more time, and particularly avoidance of excessive hours during the peak season).

2. Returns to labour time, in terms of net returns to the farm business but including the returns to the household labour employed (Samphantharak and Townsend 2012), which requires imputing monetary values to hard-to-estimate agricultural production (Carletto et al. 2015).

3. Volatility of farm income, determined by the volatility of production, especially in contexts of rainfed agriculture, and the volatility of farm prices in the contexts of liberalization. Uncertainty and vulnerability are indeed issues that affect the DW status of small producers.

4. Assets consumed/used, new assets acquired (investment) and an estimate of returns to capital, by considering the opportunity cost of assets used (especially land) – (Carletto et al. 2015).

5. Access to producer organizations or forms of associational power that may help them manage risk and vulnerability.

6. OSH (occupational safety and health) hazards, including possible pesticide poisoning or attacks from wild animals, and availability/access to mechanisms to prevent such hazards.

7. Access to social protection mechanisms, which can enhance income security and reduce need for last-resort low-paid activities (usually characterised by high DW deficit).

Collecting accurate information on the 7 above aspects, especially on the first and the second, will provide the basis for a realistic account of DW status among small-scale producers and will allow for identification of classes of small farmers that are more severely affected by DW deficit. The challenge will be to define, if necessary, any benchmarks whereby a DW 'deficit' is established. This is unlikely to work ex-ante unless a measure of minimum returns, related to ongoing minimum wages, average agricultural wages or to the national poverty line can be accepted as suitable benchmarks to assess returns to small-scale farming. For both under-employment and excessive working hours, weekly or monthly benchmarks could be also applied if time-use is accurately measured. Whether producers access cooperatives or other forms of collective representation may be used as benchmark, but such indicator would not tell us the extent to which individual producers do benefit from or are active in these organizations. Finally, far more difficult is to find benchmarks for aspects 3 and 4. However, a maximum level of farm income volatility (as coefficient of variation), informed by knowledge of national realities, could be devised, particularly through simple questions on maximum and minimum farm incomes over different periods; also, the acquisition or not of new assets could be used as benchmark for DW deficit in relation to assets, or any evidence of asset depletion (sales, loss) as a qualitative measure. This would be however harder to operationalise. An option may also be to find a benchmark for business incomes and asset use in other sectors/areas and assess the relative distance between these and the results for agricultural producers, as a proxy for DW deficit.

Meanwhile, data for OSH are likely to be hard to find in available surveys and the range of hazards may be large, which can complicate the choice of key risks for measurement purposes, especially when hazards vary a lot from one agro-ecological context to another. Access to basic social protection measures may be relevant in some cases and not in others, but it is not advisable to miss out such possibility, since it does have an impact on DW standards.

To be sure, obtaining accurate information on the above indicators/issues is a major challenge in LICs, given the measurement problems with basic agricultural data and incomes in smallholder population settings (Carletto et al. 2015), which will be briefly discussed in the section on questionnaire design.

2.4. Towards a more relevant and operational set of DWIs in low-income countries

Based on the detailed considerations on various aspects of the relevance and reliability of DWIs in rural areas, and considering some of the specific challenges in dealing with irregular employment, 'informality', capturing wage employment and devising specific DWI for small-scale producers, this section briefly selects a set of indicators that may be more relevant to the rural contexts of LICs and contain a more consistent mix of key aspects of DW in these contexts. Considering what was said in section 2.1 on the excessively long list of dimensions and indicators, a more limited and necessarily more selective set would make operationalization easier and would also allow for a concentration of efforts and resources in improving the reliability of the data for these indicators and adding new dimensions that have not been properly accounted for. The table below shows a selection from the list of 'main' and 'additional' DWIs as devised by the ILO (2012). This is followed by a shortlist of additional indicators that do not feature in the main ILO list but are related to some of the 'main' ILO DWIs. The additional indicators would be helpful in terms of complementing and improving the evidence collected for the main DWI. They are designed to capture the particular vulnerability of certain groups of workers whose employment experience is characterised by irregularity and by the need to straddle multiple casual activities in order to survive. The incidence of employment remunerated in kind is also an indicator of precariousness and casualization. Finally, and given problems with capturing child labour a particular indicator can be added to capture child labour that is performed for pay and someone else, which is important

Table 2: DW Indicators: priority selection from available lists

Indicator from DWI list (and ILO link)	Sources	Comments and possible adjustments
Children not in school (%) – CONT1	Census, UNESCO, DHS	Key issue will be to use consistent sources since there can be discrepancies between official data and DHS-type data
Employment by status(%) – EMPL8	Census, LFS, HBS	Problematic if 'main occupation' and 7-day question apply
Labour underutilization or Time-related underemployment (%) – TIME4	LFS, HBS	It should not be limited to hours within last 7 days but extended to 12 months reference period – Ideally surveys should capture total number of days of work per year effectively done
Working poor – EARN1	HBS	Relies on good estimates of poverty lines and needs to be disaggregated by employment status
Low pay rate (below 2/3 of median) – EARN2	LFS, HBS?	Requires detailed wage data across different activities and including casual workers and especially in agriculture where the worst paid jobs tend to concentrate
Average real wages (especially in agriculture) or an 'agriculture wage index' –adaptation of EARN4 and EARN6	LFS, HBS?	Special focus on agriculture and wages paid to casual workers – since these are the most likely to be over-represented among the working poor and the poorest of the poor
Excessive hours (in relation to week) –TIME1	LFS, HBS	Not easy to operationalize when there is no minimum for rural / agricultural employment but important especially for peak agricultural labour periods when working days can be very long (10-14 hours)
Child labour (with disaggregation) – ABOL1	LFS	It may be hard to apply in situations of 'disguised child labour'
Forced labour – ABOL4	LFS	Hard to operationalize and requiring various probing questions in a questionnaire
Precarious employment rate –STAB1	LFS, HBS	Criteria for 'precarious' need to be discussed by context
Casual workers in agriculture / rural (% total employment) – as part of STAB1	LFS, HBS	Needs a suitable concept of 'casual' – less than 6 months and less than 20 hours per week?
Occupational segregation by sex – EQUA1	LFS, HBS	Question is benchmark especially in contexts where activities are highly gendered
Occupational injury frequency rate, fatal and non-fatal – combination of SAFE1, SAFE2 and SAFE3	LFS	Hard to find consistent and complete data across rural sectors
Labour inspectors per 10,000 employed persons – SAFE4	LFS	Possibly available at aggregate level but less so for agriculture / rural areas
Trade union density rate – DIAL1	LFS	Not likely to differentiate between LICs as all characterized by very low densities

Table 3: DW Indicators: new additional indicators for consideration

Additional indicators	Sources (potentially)	Comments and possible adjustments
Number of days per year effectively worked	LFS, HBS and micro-surveys	The main challenge is to obtain an accurate indicator when several casual activities predominate – the use of an employment matrix can help
Longest period of time without any remunerated work	LFS, HBS and micro-surveys	This complements the previous indicator and helps identify groups of workers particularly vulnerable to periods of lack of work
Occupation multiplicity (total number of reported economic activities)	LFS, HBS and micro-survey	As above – the use of an employment matrix can help address this need
Paid child labour (excluding unpaid contributing family labour)	LFS, HBS and micro-surveys	This requires a distinction between child labour performed as 'contributing family workers' and child labour for someone else, sometimes involving direct payment
Percentage of wage workers paid in kind (including small-scale producers)	LFS, HBS and micro-surveys	This can be an additional percentage indicator to complement previous indicators on precarious employment and casual work and particularly important in rural areas of LICs
Occupational safety and health – specific agriculture specific indicators	LFS, HBS, Agricultural surveys, and micro-surveys	This is part of the core DW agenda but can be adapted to realities of agricultural contexts and be applied also to own-account producers and contributing family workers. Examples are: 1. Incidence of hazards per worker such as snake bites, infections, and so on in any given year 2. Use of pesticides and other hazardous material/equipment (per worker per year)
Farm income volatility	HBS, Agricultural surveys	Considering the challenges in obtaining reliable indicators of returns to labour in own-account farming, data on volatility may be especially important, since the variation in remuneration via farm incomes is a major driver of poverty and seasonal shocks. This indicator can be constructed through questions on highest and lowest farm incomes in a given year and comparing three years, if a measure of continuous farm income over 12 months is hard to obtain
Association/producer organisation density rate	HBS, Agricultural surveys and micro-surveys	While trade union density can only apply to wage employees, a measure of collective bargaining and associational power may also be relevant for self-employed producers, particularly small-scale farmers. The indicator can be similar to the trade union density but referred to producer organisations (instead of trade unions) and small-scale farmers (instead of wage workers)

and perhaps a form of child labour even more alarming than child labour within a family operation (farm, non-farm business).

The key DWIs listed above can potentially assist in establishing a framework that is particularly relevant for rural areas and LICs in particular. DW deficits in these realms are critical and can provide a consistent picture of labour market performance and the realities of employment in poorer countries. They are also particularly important for agriculture and also apply to small producer.

3. Survey design challenges and options

The previous section has provided an extensive discussion of key conceptual and methodological challenges in the applicability of a DW statistical agenda for rural employment especially in LICs and in SSA. One of the key arguments advanced in that section is that methods and the way data are collected matter a lot for the achievement of this difficult aim. There is an increasing awareness that collecting household and individual-level information on employment, production, and incomes is marred by difficulties and practical challenges, and results in the misapplication of international conventions. In short, survey design matters for all kinds of data. And it matters particularly for key data on agricultural production, poverty and indeed labour, particularly, but not only, in LICs.

The World Bank and its Surveys and Methods team have engaged in recent years in an ambitious programme of data quality experiments. Some have been conducted to assess issues of survey design and effects on employment data[30]. For example experiments were conducted in Tanzania which 'assess the effect of different ways of collecting labour statistics. It uses two different modules, a long module and a short module, and administers each to either the person him/herself or to someone else in the household answering on their behalf (a proxy respondent). Both proxy respondents and self-reporting respondents are sampled randomly from the roster of household members[31].

The central concern of all data collection activities should be exposing the 'truth' and the avoidance of any systematic biases. In reality, it is impossible to make socio-economic observations that are entirely free of biases – the real world is not a laboratory. That said, it is important to attempt to prevent the worst forms of bias, and particularly systematic biases. There are different types of biases that can lead to measurement error in labour surveys: cultural and wealth differences between respondent and interviewer leading to under-reporting or exaggeration of activities; application of inadequate categories/conventions on key concepts/ indicators; language issues, especially when translation is needed and key terms have not been properly translated; expectations of benefits and incentives on the part of the respondent, leading to responses driven by how the respondent thinks answers could increase benefits.

Some of the points made in this section and the recommendations provided are based on extensive experience in conducting rural labour surveys and in the associated literature of micro-level case studies that have developed and implemented similar methods (see Oya 2013, Oya and Pontara 2015, and various references therein). By and large, many of these case studies make use of mixed methods in micro-level surveys, and place emphasis on capturing occupation multiplicity and the specificities of each type of labour relation in each context[32]. Research methods in these studies are in some ways innovative, especially in their attempt to better capture nuances and concealed aspects of labour relations, labour market participation and workers' mobility. A careful integration of quantitative surveys and in-depth qualitative research focused on longitudinal aspects of employment histories, is a demanding but rewarding approach. In addition, qualitative research can contribute to better survey design by ascertaining key terminologies and concepts, and give insights into the perceptions and aspirations of different categories of rural people. Common to this research is some differences in the design of the questionnaires, the sampling decisions to capture the 'hidden populations', the selection and the training of interviewers, as compared to large-scale nationally representative surveys. The point here is that national surveys could indeed learn from the micro-survey experience and scaled lessons up, even if perhaps not all innovations are equally feasible in the context of a large-scale nationally representative household survey.

The challenge of integrating such innovations into established frameworks for national household surveys cannot be underestimated. There is of course a need for embedding the improvements in the collection of rural labour data into the national statistics strategies of developing countries. Sometimes compromises may be necessary as it is impossible to have the 'ideal' questionnaire or survey design. There is currently an ongoing process of revisions in data collection systems. Many African countries are revising their GDPs, for example (Jerven et al 2015), and generally both aid agencies and governments in most developing regions are working to tackle some of the challenges discussed in this paper (see, for example, AFRISTAT and Paris21 Secretariat 2008 and http://www.copenhagenconsensus.com; Glassman and Sandefur 2014 and their work at the CGD). The main argument is the need to make sure that some of the efforts at improving the measurement and statistical capacities especially of LICs are sustainable over the long run through their institutionalization in data collection systems and protocols. In that regard, the recommendations in this paper and the tools to be subsequently piloted at country level should provide a basis to inform and influence national strategies for data collection. It is foreseen that for that to happen, countries should allocate sufficient funding for the collection of the relevant data, as well as to strengthen their NSO capacity for collection and tabulation/ analysis. Unfortunately much of the data collected is never really tabulated and analysed, especially at more disaggregated levels.

While there are far too many survey quality issues that could be discussed, this section will focus on the most salient aspects that may affect the quality of DWI in rural areas of LICs.

3.1. Sampling issues

There are various sampling issues and decisions that are central to any survey design. First is the sample size and whether the data are planned to be statistically representative of a population. For statistically representative data a key question is the level at which inference is to be made (national, provincial, district) and the degree of heterogeneity of the target population. In cases where the whole rural population is the target then heterogeneity is likely to be a challenge and detailed information is needed for adequate stratification (by administrative area, agro-ecological zone, density, gender, age, production scale, socio-economic status, etc.). Thus, required sample size may be large if substantial heterogeneity is anticipated. Second, when the goal is not broad national-level statistical inference but capturing a particular issue (wage variation and determinants in agricultural employment) or a particular population (child labour, seasonal migrant labour), sample design must take into account the challenges of finding relevant respondents (especially for 'hidden populations') in the absence of adequate sample frames. Related to this is whether sampling is based on a residence-based

[30] See http://go.worldbank.org/KAI66PHUY0.
[31] Look for SHWALITA (Survey of Household Welfare and Labour in Tanzania) http://edi-global.com/publications/.
[32] See also collection of papers in forthcoming Oya and Pontara (2015).

framework or on a job-based one. In contexts where significant numbers of workers (especially in agriculture, harvesting) are resident in urban areas and work seasonally in agriculture, a job-based framework may be more suitable, or simply a framework where seasonal migrant labour is captured regardless of the 'permanent' residence of respondents (see also discussion of household roster below).

National household surveys aim to obtain statistically representative data for the overall population. While this aim is justifiable the conventional methods used to attain sometimes come at the expense of little or biased coverage of some particular groups, which can be considered in sampling terms as 'hidden populations'. Seasonal migrants, children at work, people subject to human trafficking, people not residing in 'normal' residential units or not being part of official household lists at village level. There are many cases and all relevant for an accurate picture of rural DW deficits. This underscores the need to rethink sampling methods to make sure hidden populations are included even in nationally representative samples.

In this regard, seasonality is a related aspect that has implications for sampling. In section 2.3.1 the paper has discussed the centrality of 'irregular' employment in LIC contexts and how some activities are concentrated in particular periods compared to other activities. This means that the time of the survey matters and that sampling may have to be adapted to make sure all relevant activities are captured. Although this is possible through 'good recall'[33], the reality is that misreporting of details of activities may be due to interviews taking place when the activity is not ongoing. In contexts of multiple occupations the time of the survey may thus lead to under-reporting of some activities, especially if they are of a casual nature. There are also implications for some of the 'hard-to-reach' populations who may only be available at a particular place during a particular period of time. Therefore, in contexts where migrant labour (for agricultural and non-agricultural employment) needs to be captured, survey designers will need to identify the periods when this 'population' can be found for interview purposes. Missing the right period may mean missing these specific groups altogether. The main mechanisms to circumvent these challenges are twofold. First, survey designers may decide to organize data collection in different rounds within a given year (as it is done for HBS) once seasonal patterns have been identified. Second, questionnaires can be designed to provide full information on all activities for a 12-month reference period, making sure interviewers are well trained to probe answers and make sure there is not any activity that goes unreported.

Another issue is sample size. Most national household surveys have a large enough sample size for statistical representitivity at fairly aggregate levels (national, rural/urban, provincial/regional). However, this works in contexts where there is sufficient population homogeneity within these aggregate strata. If multiple distinct groups who are not randomly distributed exist in a given context, then the risk of missing them out or under-sampling is great. For example, agricultural wage workers and migrant labourers may be concentrated in particular pockets of dynamic export agriculture (Ejido in Spain, Sao Francisco Valley in Northeast Brazil, flower producing areas in Ethiopia, etc.). In addition, the different categories of small-scale producers may also be more concentrated in some places and harder to find in others without any random pattern. Information about more conventional groupings by gender or age-groups is also necessary to make sure stratified random sampling works well. These situations require not only a larger sample size but also 'pre-survey scoping research' to attempt to identify whether there may important 'hidden groups' in a given national context, and where these 'hidden groups' concentrate or in what kind of residential units they tend to live to adapt sampling methods to capture these groups while keeping the core probability sampling techniques. What do we mean by 'pre-survey scoping research'?

Essentially the combination of carefully designed qualitative scoping research to reveal some of the patterns mentioned above, in addition to consultation with experts with extensive fieldwork experience in the rural areas of a given country.

In addition to the scoping research implemented to improve the sampling process, when data collection starts, there are also other options for serious consideration:

1. Conducting a fresh full census to construct an up-to-date sample frame, including residential units that may house temporary migrants or people without fixed residence, as well as areas where child labour and forced labour are known to be present.

2. Including additional stratification in the sampling stages to be able to capture some of the hard-to-reach groups.

Cramer et al. (2014) elaborate on the first point. Their argument is that official household surveys in African countries (and one could argue also in other developing countries) such as Ethiopia and Uganda are based on samples drawn from lists of rural households provided by village-level authorities[34]. The problem is that sometimes these lists are politically manipulated, i.e. often used as the basis for the distribution of scarce resources such as food aid, or subsidized agricultural inputs and credit., which may lead to potential biases in

[33] Good recall refers to the capacity of respondents to remember activities in which they have engaged in the reference period. For example remembering all activities for a 12 month-period would be very good recall compared to just remembering activities in the past 7 or 30 days.

[34] See also a related example on 'hidden' migrant populations in peri-urban areas of Vietnam (Pincus and Sender 2008).

reporting if authorities have an interest in excluding particular groups[35]. Fieldwork experience also suggests that, apart from potential systematic exclusion of some marginalized groups, many of these lists are far from up-to-date and may exclude newly arrived individuals or households[36].The alternative adopted by the FTEPR research (Fair Trade Employment and Poverty Reduction project www.ftepr.org), documented by Cramer et al. (2014), and which can be proposed in the FAO pilot surveys, is to create a sample frame on the basis of a new and complete census of all types of housing structures discovered in the research sub-sites that have been previously selected for the survey. The definition of the 'Residential Unit' is broad enough to minimize biases towards more 'established' households, hence worded as any structure in which at least one person was sleeping. This would mean that a very basic structure, even without a roof, where squatters sleep (likely to be temporary migrants), could be considered for the sampling frame. A challenge would be whether this method can be 'mainstreamed' in national surveys, since these follow long-established sampling frameworks, household-based lists (rather than simply residential units) and use the same methods over long periods of time to ensure comparability over time. In principle, the advantages of the proposed innovations probably outweigh the possible logistical constraints but one cannot underestimate the potential resistance to such changes. However, one possibility, assuming that there is a sufficiently recent population census, would be to combine existing official sampling frames, especially if countries have renewed and updated the local registers, with ad-hoc additional lists prepared by fieldworkers for potential respondents who are temporarily in the area (e.g. migrant workers, people without fixed residence etc.) but fail to be included in official registers. Such combination of sources would not be too onerous and would substantially improve the coverage.

The above innovation is at the heart of debates about operationalizing the concept of the 'household'. Trying to work with a universal concept of the 'household', which is central to most surveys, is in fact a major challenge, but frequently ignored by survey designers and data users. There is increasingly substantial research, including survey experiments, which highlight some of the challenges and biases derived from the uses and misuses of the concept of 'household' (O'Laughlin 1995; Randall and Coast 2015). In the next section on questionnaire design, we elaborate further on this, looking in particular at the questionnaire requirements for an adequate identification of household rosters for the purposes of measuring DWI.

However, as advanced above, rigid definitions of the household may lead to exclusion of key groups. Carr-Hill (2014) notes how population censuses and household surveys routinely 'omit by design' or under-report mobile 'footloose' populations, particularly nomadic or pastoralist populations, internally displaced people who may have lost their homes, and institutional populations (such as but not only care homes, factory barracks, hospitals, the military, refugee camps, etc.). In practice, he argues, surveys also tend to miss out fragile, disjointed or multiple occupancy households, people living in slums, and areas that pose some security risks. To this it could be added that in situations where child trafficking, forced labour and child labour happen, conventional surveys are unlikely to capture them because they get misreported as de facto 'contributing family workers' at their employers' households[37].

With regards to 'fragile, disjointed or multiple occupancy households' and similar cases, Randall and Coast (2015) discuss evidence from Tanzania and Burkina Faso, where 'households' may be of different types and organised in different ways, defying the application of rigid household definitions, and requiring new typologies, like the one they propose of 'open' and 'closed' households. Accounting for pastoralist groups is quite difficult because of their mobility but also because of the social organisation and the different prevailing notions of 'household'. For example, official surveys tend to split-up Masai 'open' households ignoring their preference to consider themselves to be one economic unit of production and consumption. Part of the problem is also survey logistics and the difficulty of dealing with loosely extended households. When these nuances are not captured at the design stage, the implication is that (often poorly trained) interviewers are left to decide who to include and why in a given household roster, reflecting the power of interviewers in translating these complex concepts into something meaningful in both small- and large-N surveys (Randall et al. 2013).

Taking into account the challenges with rigid definitions of the household and the fact that a lot of the DWI apply to the level of the individual, an important sampling issue is whether the key unit of observation is the household or the individual. In reality this dichotomy is problematic since both are interrelated. However, for practical purposes and given that labour indicators normally refer to the individual, the anchor unit of observation should be the individual as long as an appropriate system to define the household roster is adopted (see section 3.2.1). This is important especially when own-account activities involve the pooling of family labour, especially in farming and the analysis of the activity could be done at 'household level'. However, in practice it is possible to collect household-level evidence (including on the 'farm enterprise') even when the anchor unit of observation is the individual who acts as 'principal respondent' and from whom a household is empirically defined. Then individual- and household-level information can be linked through identifying codes. What matters is that enumerators are well trained to know when they need to ask at the level of individual and when at household level.

In sum, although it is a challenge to question well-established and deep-rooted conventional sampling methods, the issues discussed in this section are serious and should provide the basis for some re-thinking,

[35] See, for instance, related ethnographic work in Ethiopia by Bishop and Hilhorst, (2010) cited in Cramer et al. (2014).

[36] See examples in Cramer e t al. (2014).

[37] See, for example, Anyidoho, N. and P. Ainsworth (2009) on West Africa.

and notably to consider:

a. Measures to capture 'hidden' or 'hard to reach' populations (like the ones mentioned here, such as avoiding official lists or including different types of residential units).

b. The operationalization of a more flexible definition of 'households', to accommodate a variety of circumstances that may be important in any particular national and local context.

c. The focus on individuals as anchor units of observation for DWIs, while context-relevant and empirically observed household units are also addressed in the data collection process, resulting in three types of data: individual, household (including a 'family activity') and job/activity. What matters is that the three levels are consistently linked and no relevant information is missed out.

3.2. Questionnaire design

This section focuses on key aspects of questionnaire design that can have an impact on the quality of data for DWI. The discussion is also based on available survey experiments (especially at the World Bank), relevant literature on survey methodology and especially the author's own survey experience. The focus is on two key issues: the household roster, or who is included in the list of household members and the information collected therein; employment modules and labour data issues. A key message is that the consideration of alternative definitions (household roster), the re-organization of employment modules to avoid typical biases, and the precision and context specificity in questions and wording are key to obtain higher quality data.

3.2.1. The household roster

Who is included or not in a household roster matters a lot for indicators of well-being, which are frequently collected at household level but then normalized per individual, consumption and income being leading examples.

Recent survey experiments with alternative definitions of the household and different ways of preparing a household roster show a significant impact on survey outcomes. According to Beaman and Dillon (2012) slight changes in definitions of the 'household' lead to significant variations in both household size and household composition, with important implications for the measurement of basic outcome variables, such as per capita consumption expenditure, asset statistics and per adult equivalent agricultural output measures, which may affect any analysis of DW deficits. The conundrum is that, on the one hand, a consistent and easy to interpret household definition is required for time and population comparisons, but, on the other hand, over time and for a given population, 'the definition must also identify the correct economic or decision making unit, which may in fact differ according to the research question'.

Leone et al. (2010) and Randall and Coast (2014: 6), reporting on various case studies, show that 'children move between households on a weekly or longer-term basis' rendering multiple households 'open'. Therefore, the decision of where to include a child is not straightforward if the criterion is one of residence and/or consumption. Akresh and Edmonds (2010), in another experiment, show that that households are extremely fluid, and characterized by substantial mobility of some of their individuals with 10 percent of individuals spending some time away over a three year period, averaging 16 of the 36 months away. This phenomenon is not randomly distributed across household members but affects specific categories such as the youth, hence leading to potential bias and miscounting if rigid definitions of residential status are applied. Avoiding this kind of bias would require consideration of different and less stringent residential criteria or using alternative criteria such as 'economic linkages' regardless of residence patterns as suggested in the paragraph below.

In light of the rigidity and potential bias of standard 'residential' definitions of the household (such as being resident for over 6 months in past 12 months), Cramer et al. (2014) and the FTEPR research (FTEPR 2014) opted for an 'economic' definition of the household roster to avoid the bias of missing out key individuals who may be important to understand the wellbeing of the household. The concept of a list of 'economically linked' individuals offers additional and extremely useful information on labour market participation and the other characteristics of individuals usually considered 'absent' (according to strict residential definitions) and therefore irrelevant to an analysis of the welfare of rural populations[38].

The implication of this discussion is that a more detailed and thorough measurement of household composition in multi-purpose household surveys is essential to avoid systematic biases in the estimation of key outcome variables. In addition, some changes in definitions could be contemplated, such as the option of using 'economic linkages' between members and not simple residential rules. The main possible drawback

[38] The four following categories of linked individuals could be thus identified and surveyed (directly or through proxy respondent): (1) those who live permanently with the principal respondent and who share income and expenditure; (2) those who, even if not sharing residential accommodation on a regular basis, make significant economic contributions (in cash or in kind) to the expenses of the household/respondent; (3) those who, even if not sharing residential accommodation, regularly depend on economic contributions in cash or in kind from the respondent or others in the RU; (4) those who, even if not resident at all in the same place as the respondent, either can be relied upon by the respondent, or receive contributions from the respondent.

is related to training. Applying an economic definition of the household is less straightforward and therefore more training time-consuming than a conventional residential definition. Sometimes the criteria for 'economic linkage' may be ambiguous and sometimes may result in unmanageable household rosters. These problems, however, can be tackled through careful selection, training and supervision.

3.2.2. Employment modules

An important question for good quality DWIs is measurement error. Some indicators are particularly vulnerable to this kind of non-sampling error. There are different areas in which quality particularly matters for DWI:

1. Identification of economic activities in which an individual has been engaged in the past 12 months, and the key characteristics of each of these activities.

2. Collection of sufficient information on each of these activities, with priority given to the ones that contribute most to the livelihood of individual/households.

3. Avoiding large measurement errors in time-related questions as well as in questions on returns to labour (whether self-employment or wage employment).

4. Capturing child labour and forced labour in contexts where respondents may want to conceal such practices.

3.2.2.1. Accounting for occupation multiplicity and accuracy in the definition of occupations/activities

This is by far one of the key challenges and one of the reasons why some key indicators of the labour market (employment rate, employment status, sector of employment etc.) are particularly sensitive to what questions are asked and how. LFS and some HICES and MICS include questions on 'secondary' job holding, but virtually all headline statistics refer to the 'main' job. While it is best practice, even by ILO standards, to use an activity list to determine whether somebody was employed and the nature of each job, this is not systematically applied or analysed (Oya 2010).

The usual reliance on the tricky notion of the 'main job-holding', designed to give a single classification for every individual surveyed, is problematic even if the goal is an aggregate picture for international comparability. Unfortunately, in contexts of occupation multiplicity, irregularity and strong seasonality, the interpretations and use of the concept of 'main activity' are influenced by the biases of both respondents and interviewers. Moreover, conventional reference periods are problematic[39]. Many countries still rely on standard questions with a seven-day reference period (designed to generate internationally comparable statistics) which, in contexts of strong seasonality, irregularity of activities and occupation multiplicity, can lead to significant statistical biases and thus turn to be meaningless for international comparisons. The use of relatively short timeframes tends to compound the biases introduced by the reliance on notions of 'main activity' when this is defined in terms of time. As practiced in India, a combination of different reference periods (12 months, 30 days and 7 days) applied to same or different questions may help reduce this bias.

Properly identifying and capturing different kinds of activities is also challenging. This is because certain types of activities, and indeed many wage jobs that are particularly relevant for the most deprived rural people – characterized by severely exploitative conditions, even forms of bondage – are highly stigmatized and can, for that reason, easily be under-reported and overlooked. Mueller (2015) provides examples of the most widely terms used for casual wage work (kibarua) in Tanzania, an activity that can be often under-reported or unreported altogether. Oya (2015) also finds particular activities like charcoal making and trading in rural Mauritania of going under-reported because of official bans on them, thereby leading to biases if not enough probing is done, since this is one of the most important sources of accumulation and survival for many rural people in remote areas of the country[40]. , as shown in his comparison between official statistics and micro-survey data. Oya (2013), Chand and Srivastava (2014).

An adequate identification of all the economic activities of individuals and households also requires appropriate wording. Much is lost in bad translation as suggested in section 2.3.3. For example, key terms like 'salary' or 'wage', 'gainful activity' or 'remunerated activity' may be linked by design and practice to limited sets of activities and jobs because of what respondents (and interviewers) usually understand by those terms (Rizzo et al. 2015). Oya (2015) on Senegal, and Rizzo et al. (2015) provide concrete examples of instances in which a poor translation or a misinterpretation of key terms leads to measurement error and bias[41]. The issue is not only adequate use of local terms and preparing suitable

[39] There are differences across surveys in this respect though.

[40] See also Oya (2013) and Chand and Srivastava (2014) for other examples of 'stigmatized' activities that result in under-reporting of female employment.

[41] Rizzo et al. (2014) provide detailed examples of the problems of questionnaire design and specifically how questions on employment are 'lost in translation' in the context of Tanzania, leading to a biased characterization of employment patterns for informal labour, and to wage employment being classified as self-employment. Oya (2015) documents a variety of terms normally used in rural vernacular Wolof in Senegal for concrete occupations in the broad spectrum of casual wage work. By contrast, inadequate translations because of bad guidelines to interviewers result in these specific relevant terms not being used to capture wage jobs and therefore missing them altogether.

glossaries for enumerators, but also the importance of systematic and careful probing, which in some surveys is often overlooked because of time constraints and wrong incentive systems.

Adequate wording and probing of course require conceptual clarity, as survey designers need to clearly train interviewers about what each key concept means. Although this may seem obvious, fieldwork experience is often compounded by a biased conceptualization of key terms. For instance, this is the case with the distinction between wage employment and self-employment, with the result that a particular occupation (e.g. street vendor) is automatically related to a given status (e.g. self-employment) without the required probing (Oya 2015). Huang (2013, 349), in the context of China, argues that Chinese statistics reduce wage workers to '[a] high-status category of regular "employees-workers" that excludes the great majority of the labouring people of present-day China'. Wuyts (2011), Rizzo et al. (2015) and Breman (2006) provide other similar examples concerning large segments of 'informal workers' The solution is a theoretically and empirically grounded definition that avoids strict boundaries: thus 'wage employment' refers to any form of work for another person or entity in exchange of any kind of compensation whether in kind (including land, for example) or in cash. If the 'employer' provides all or the bulk of the means of production (i.e., land, working capital, equipment, seeds, and so on) the labour relation is characterized by a wage-contract even if in a disguised form, e.g., as labour tenancy or sharecropping (see Banaji 2010).

Probing is also critical to capture a range of forms of child labour, forced labour and to understand the gendered nature of labour markets and various forms of occupational segregation. Since these are sensitive issues, the wording in standard questionnaires may not be the most suitable, hence interviewers must respond by adapting the wording or finding ways of circumventing the sensitivity about these topics by using the most appropriate and least 'threatening' terms as well as maintaining a fluid conversation during the interview, which may put at ease the respondent.

What matters is to get a full picture of the employment situation of an individual in these heterogeneous and fluid contexts is the accurate enumeration of the complete set of economic activities in which individuals engage over an extended period of time (e.g., 12 months) and the relative importance of each of them for their subsistence. The RNFE literature not only systematically documents the importance of occupation multiplicity and livelihood diversification, but also the contingency of the dominance of one particular activity or another. In China, most rural people are engaged in more than one activity—farming and off-farm employment but, as Huang maintains (2013, 359) their final classification hinges on what activity they are engaged for more than 6 months a year. In many African countries, characterized by relative land abundance and proliferation of small-scale producers (whether viable or not) the idea of 'main occupation' may be particularly misleading, resulting in either respondents or enumerators emphasizing own-account farming (because it reflects property attachment as well as a more 'regular' activity regardless of its returns) at the expense of other more irregular but perhaps more remunerative activities.

The alternative to the use of 'main activity' is clear: a full enumeration of all relevant economic activities in the past 12 months, whether in the form of self-employment or wage employment or other employment status categories. In practice, this information can be collected through a carefully designed and context-specific (in order to capture key local activities and key local terms) 'employment matrix' (example in Appendix A1). The list can be designed based on prior research in the country and a context-specific knowledge of the most important types of employment in rural areas. This matrix does not only include a checklist of all context-relevant activities in which the individual has participated, but can also include information on duration and frequency of each activity, their seasonal pattern, the location and whether they performed the activity accompanied by a child or not. The latter can be an important question for DW evidence. Even if it does not entail child labour (it could be a woman carrying a baby on her back while working) it shows the burden of a combination of productive and reproductive tasks on women and can feed into evidence on occupational gender segregation.

3.2.2.2. Tailoring questionnaires to specific types of employment

Once we are confident all activities and their duration and frequency have been identified, we need accurate information on each of these activities, especially the most important ones in terms of returns (remuneration), security (duration and frequency), and other conditions related to the quality of employment, whether in terms of health & safety, collective bargaining, gender (or other type of) discrimination, or additional non-wage benefits. The challenge is that each activity has its own specificities so questions should be tailored to each type. Therefore, rather than using a single set of standard questions for each of these activities, separate modules can be prepared to collect relevant information in each case. As the GIRM-WB (2007) report shows, specifically designed modules work well for own-account farming, wage employment in agriculture, own-account non-agricultural business, wage-employment in non-agricultural activities, and questions specific to contributing family workers. Therefore, a combination of the sector of activity and employment status can be used to devise specific questionnaire modules to collect detailed information on each of the key activities listed. Within each sub-module there may be reporting of more than one instance, e.g. two or three jobs as casual wage worker in agriculture, or two different non-agricultural businesses. Depending on the number of questions included, this can be operationalized by adding different rows per question (one row corresponding to one job) or by applying the same sub-module separately for each job (this may be too cumbersome in cases where the number of activities and jobs reported is very large).

Each type of activity entails its own challenges. Own-account farming and generally household business require accurate data on aspects such as: production, sales, input costs, use of hired and household labour, assets, land measurement, credit, associations, etc. The problems in accurately measuring each of these items are dependent on the type of crop or type of business, so context specificity does matter. Carletto et al. (2015) and Samphantharak and Townsend (2012) present detailed accounts of the main challenges some of which will be explored in more detail in the section below.

Wage employment requires accurate data on different aspects: the nature/type of employer (scale, 'formality' or not; relations, etc.), types of contractual arrangements, whether only labour is provided (and not tools or land), payment methods, levels of remuneration, frequency, non-wage benefits, issues of harassment and conflict, trade unions, etc.

Likewise, questionnaires should contain specific questions that may help shed some light on DW deficit for small-scale producers, following the examples and recommendations made in section 2.3.4. In particular good estimates of returns to labour, farm income trends and volatility, and of underemployment as well as overemployment will be very useful for a pictire of DW for this group. In addition, other measures of quality of employment, related to hardship and risks associated with small-scale farming, as well as indications of associational power can provide additional elements for a more complete picture of DW among small-scale producers.

These are just illustrations of the sorts of issues that the survey design must tackle in order to prepare sufficiently detailed employment modules that will be necessary if DWI are to be improved.

3.2.2.3. Minimizing errors in estimates of returns to labour – understanding remuneration systems

The accuracy of some of the data needs mentioned in the previous section is crucial. In particular, and for contexts of rural areas in LICs, the accuracy of measures of underemployment and overemployment can be addressed with carefully designed employment matrices (Appendix A1). In addition, good quality data on returns to labour should be ensured in any system for DW measurement in agriculture and rural areas. However, the reality is that this kind of information is often missing or fraught with measurement errors. Generally there is a major evidence gap on labour returns, especially for rural wage employment. Sender (2003, 414) notes in particular that:

'[In] most developing economies no efforts at all are made to collect time-series data on the wages of those employed in small-scale farm and non-farm rural enterprises, especially on the wages of those who are irregularly, seasonally, or casually employed.'

Collection of reliable information on wages is particularly challenging in rural areas of LICs, especially in agriculture because payment systems vary and are sometimes complex (Hatlebakk 2004; Rogaly 2005). For example, in agriculture, payments can often be in the form of either a daily wage (following local 'norms'), a piece-rate wage (e.g. monetary rate per kg of output harvested) or, more typically, a task-based wage (clearing x area of land; sowing x number of rows, or pruning x number of trees). To complicate matters, in some workplaces workers may receive a daily wage but they must complete a task so the payment becomes de facto task-based. As argued by Cramer et al. (2008) 'the literature on piece-rate systems and farm wage differentials attempts to explain marked differences between how workers are paid, even when they are doing similar things and in comparable locations'.

Other authors have documented substantial variation, and particular forms of labour market segmentation that are related to complex labour relations (Bardhan and Rudra 1986; Rogaly 2005; Ortiz 2015; Cramer et al. 2008). There may be great variation even within the same local context, depending on crop, type of employer, type of sector, season, and market conditions. This underscores the need for detailed modules with sufficient number of relevant questions. It is therefore quite possible that a full questionnaire page must be devoted to capture the nuances of these payments and make sure that all relevant data is collected in order for data users to estimate comparable and reliable daily wages. For example, if a casual worker is employed by the task, detailed information about the task is needed, especially with regards to the time to complete it. Sometimes casual workers are paid daily but they need to complete a task. In case this is not completed, they may need to continue the day after, in which case the payment is not daily but task-based (see FTEPR 2014; Wendimu and Gibbon 2015). Another complication that requires attention is the use of –in-kind payments and methods to impute value to the goods offered in exchange for labour. The quality of these estimates is crucial for any DWIs related to earnings.

The challenges in capturing earnings are not limited to those working for wages. Indeed, a measure of earnings/ returns to labour for the self-employed, especially small-scale producers, may even be more difficult. In fact, recent literature suggests that for small-farming activities the quality of the data collected in large-scale surveys leaves much to desire. For example, net farm income for smallholder farmers is hard to measure for different reasons. The fluctuations in farm revenues, the deliberate misreporting of production, consumption and sales, recall problems in relation to precise quantities of consumption items or to labour time use, the complicated valuation of opportunity costs (own or family labour or equipment depreciation), and many other problems mean that questionnaire design, training of interviewers and their supervision are crucial for good quality data. Samphantharak and Townsend (2012), based on a survey experiment in Thailand, emphasize the importance of four important challenges for household enterprises (including farming):

a. Distinguishing and measuring accrued vs cash incomes and between purchased and used inputs.

b. Measuring the implicit compensation of household labour, which can be done with different alternatives of shadow wages depending on whether the household workers also participate in the labour market or not.

c. Paying attention to gifts and transfers, including labour exchange, which should also be valued

d. Dealing with valuation and depreciation of assets.

With regards to the last point, the collection of relevant information on assets, both productive assets (such as irrigation equipment, motorbike, tractors, etc.) and consumer durables is certainly an important task, whether to estimate long-term returns to household enterprises or to adequately characterize the socio-economic status of respondents, whether self-employed or wage employed. Assets and durables are generally easier to observe and verify (thus less potential for measurement error) than current consumption And, as they provide a measure of long-term wealth, such information may be used to complement data on earnings, which tend to fluctuate every year due to the nature of the activities involved (Howe et al. 2012). Both smallholder farmers and rural wage workers may be substantially differentiated in terms of available assets and this can be a reflection of having been exposed to more DW in the medium-long term.

More specifically in relation to own-account farming, Carletto et al. (2015), writing on SSA, confirm that the evidence base about farm size, productivity, and contribution of agriculture to welfare is very poor. The problems are, however, not uniformly distributed across types of farmers and crops (hence the importance of identifying these categories ex-ante as suggested in section 2.3.4.3). Carletto et al. (2015) document a number of specific problems:

a. Accounting for inter-cropping, which substantially affects measures of returns to farming. Depending on the pervasiveness of the practice and the level of production in question, it is advisable to consider all crops mixed in an inter-cropping arrangements. There may be recall problems for some harder-to-measure agricultural products, thus making inter-cropping estimates somewhat unreliable. The priority is to capture orders of magnitude first to then choose the crops that are more important for the team.

b. Land measurement and problems with recall and administrative data. The alternative of GPS-based measurement is increasingly applied and is not without its problems but clearly reduces potential measurement error on a very important indicator. It is recommended that, to the extent possible, enumerators probe respondents' reporting of land area by randomly choosing plots and measure them with GPS devices.

c. The production of some crops is harder to measure than others: generally root crops and 'fast crops' (onions and vegetables), which may be harvested continuously are far more negatively affected by recall bias than other annual crops characterized by one (or perhaps) two key harvest seasons and also often marketed. This would require rethinking questions and measurement methods to capture the volume of harvested output with higher frequency data perhaps. Therefore, questions about production/harvest in cotton will have to somewhat differ from questions about production/harvest of cassava. An option is to obtain rich qualitative information on production and harvesting patterns for these crops. The questionnaire can make a particular distinction between crops that generate cash and crops that are consumed by the household in large proportions. For the latter a shadow market price can be applied to provide a monetary value to the physical production estimates.

d. Regardless of the type of crop, a common problem is the use of non-standard measurement units (banana bunches, heaps of cassava, '50kg sacks, etc.), which translate in inconsistent weights and introduce non-random biases on production estimates, which are crucial to estimate returns to labour in own-account farming. The methodological option is to calculate accurate conversion factors to specific non-standard units encountered in the survey and using CAPI to facilitate this process and input context-specific conversion factors.

e. Imputing monetary value to self-consumption when relevant price data are not available. This would require more adequate information on relevant (local) prices for agricultural products consumed within the household, taking into account the importance of seasonality in these prices.

The discussion in this section suggests that the only way to minimize the measurement errors identified in the literature on economic activities / employment is to add detailed questionnaire modules and design activity-specific questions to obtain consistent estimates of earnings. Generally, detailed information on farm budgets should be collected separately in order to obtain more accurate measurement of returns to labour in family activities, entailing a detailed farm budget module with the net data then being compared to the less detailed agricultural revenue information collected through an employment module, for example.

Detailed modules have a substantial (positive) impact on the quality of data. Experimental research on poverty-related questions indeed suggests that 'equivalent as well as same households answer the same questions differently when interviewed with a short questionnaire vs. the longer counterpart', which suggests a potentially serious bias in short questionnaire-surveys for complex issues like poverty and employment (Kilic and Sohnesen 2015). A long questionnaire, in turn, raises issues of sequencing. For this purpose there are a couple of rules of thumb that can help. First, the key questions for the high-priority DWIs, e.g. earnings and underemployment, should not come too late in the questionnaire as respondents may be tired at the end of it and these questions require attention and use of memory. Second, there should be a logical flow between different questionnaire modules. So, the employment matrix should come first for all employment-related (DW) questions, followed by relevant modules for each key type of activity (own account activity, agricultural wage employment, non-agricultural wage employment, etc.). The end of the questionnaire should include questions that are complementary to the main focus (DW – employment) but not essential.

The challenges and recommendations included in this and other sections above suggest that there is an advantage in developing longer employment modules and generally longer questionnaires. There is however a trade-off between lengthening questionnaire and practical, financial and logistical constraints. Long interviews, if conducted in one go, may also affect the quality of the information collected in each case, if respondents and interviewers get tired. However, available evidence from survey experiments suggests that the pros of more detailed and longer questionnaires outweigh the cons, as in the case of poverty indicators (Kilic and Sohnesen 2015).

3.3 Selection and training of interviewers

It is not enough to improve questionnaire design and adopt more flexible sampling approaches. The quality of DW indicators highly depends on careful selection of interviewers, much more intensive training than usual (including conceptual training on key concepts) and close supervision, particularly in pilot and early data collection phases.

For example to be able to capture the nuances of distinctions between self-employment and wage-employment; the particularities of remuneration methods for different occupations; the characteristics of the 'household'; the different types of small producer; the OSH issues; instances of child labour and forced labour; forms of discrimination; to name a few key issues, interviewers would have to be carefully trained to understand these conceptual and methodological differences and work with plenty of concrete examples from the country where the survey will take place. For example, addressing child labour is not straightforward in contexts where the use of child labour is pervasive even if not always resulting in out-of-school children. Enumerators and supervisors may not see this as 'child labour' and will need to be carefully trained so that they can consistently capture it and make sure they use the right terminology (local terms) and deal with existing sensitivities in a suitable way. Preparation of training will therefore require substantial scoping research to understand context specificity and better communicate concepts to interviewers. The conduction of careful scoping research processes may be done before a large-scale survey is conducted and ahead of training and questionnaire design. This is an important investment, the results of which can be carried forward to different rounds of similar surveys. However, it should not be simply seen as a one-off investment, insofar as conditions and context also evolve. If survey rounds follow a 5-year frequency, for example, some updates of the scoping work may be needed although the time taken may be less than during the first core round. Survey designers will assess the main changes in context between surveys and decide on the kind of scoping needed, particularly on the focus of the scoping as there may just be come issues to focus on (migration patterns, new activities emerging and so on). The scoping work required to improve survey design should be institutionalized, i.e. not simply contracted out to external consultants. While the latter could assist in the process, national data collection agencies should have focal points to conduct this scoping research so that practices are not externally driven.

Scoping and deeper training are critical factors contributing to better probing skills. Well-trained interviewers certainly have to probe to make sure they understand in which category the respondent is, or what kind of wage contracts the respondent has been involved in, for example. In some instances there may be 'social desirability bias' among respondents, whereby own-account activities are seen as morally superior or desirable compared to 'working for others', or where certain activities are deemed demeaning and not worth reporting. Therefore the probing will have to be particularly careful to make sure the respondent is not under- or un-reporting wage work activities, or any activities that may be considered illicit in some contexts (e.g. charcoal making, smuggling), various forms of discrimination, and activities that should be abolished under the DW agenda (child labour, forced labour). In order to make sure interviewers do enough and good probing three basic conditions generally apply:

a. Adequate incentive systems, so for example avoiding piece-rate payment (per questionnaire) which may lead to excessive urgency and speed in administration.

b. In-depth training on the key concepts and indicators, turning interviewers in quasi co-researchers, making sure there is substantial 'buy-in' for the survey among them. This means that periodic/ annual training for annual agricultural surveys, for example, should not be simply limited to 1-2 days of work going through the questionnaire but should include some time for basic conceptual discussion around indicators and how probing can be done for the most challenging questions, all this complemented with more days of pilot work.

c. Close and sustained supervision in the field, especially in the early stages, to make sure that any systematic errors are avoided and that different situations are tackled with the help of supervisors.

3.4. Survey implementation

Once design, selection and training are completed a key issue is implementation. Below are a number of key recommendations that may work in most contexts although survey designers will have to understand the context of the survey to address any particular practicalities.

a. **Survey teams**. Normally it is better to work in smaller teams, each guided by an experienced and very well trained supervisor. A smaller team of about four enumerators may be easier to manage especially when internal conflict arises (between enumerators or between supervisor and enumerators) as discipline is critical in situations where fieldwork is physically and mentally demanding. A close supervision is critical, and being able to go through questionnaires and different scenarios in the evenings is also highly advisable, to make sure any corrections can be made on the spot. Another possibility is having smaller teams or even individual enumerators who spend long periods of time in the same village and administer the different questionnaires to be used. This would facilitate the familiarization of the enumerator with the context or could be compatible with the reliance on a locally-resident enumerator with adequate training. The composition of teams is also important. First, a good mix of experienced and less experienced but highly skilled enumerators is advisable. Having only very experienced enumerators may be problematic if new concept or new forms of implementing the survey are important for the study. Enumerators with excellent interpersonal and communication skills and good capacity to understand new concepts brought by training are essential. Particularly with a long and detailed questionnaire it is imperative to find interviewers who can turn the sequence of questions into a conversation, which requires them being engaging. Second, it is preferable to have with direct experience in rural areas of the sampled zones and a high command of the key languages spoken in each area, bearing in mind the possible presence of migrants from other parts of the country. This means that each candidate should be thoroughly tested on the relevant languages before embarking on fieldwork. Overall, however, the main priority is to conduct intensive and in-depth training, followed by sufficient pilot-testing (a few times in two or three different sites for at least one week) and a system of close supervision with regular inputs from main survey designers.

b. **Place of interview**. Places where respondents potentially are not free to talk should be avoided. These include public areas where others can overhear and in particular the workplace where the presence of employers or supervisors or even other workers may intimidate respondents. Generally, all interviews should be conducted in private and without the possibility of external interference. Survey teams should also stick to sampling targets and avoid being driven to particular respondents by 'gatekeepers', such as village chiefs or other local authorities.

c. **Survey technologies**. Survey design also needs to consider the ways in which available technologies can help better implementation, faster data processing and minimisation of interview errors. An increasingly popular option is the use of computer assisted personal interviews (CAPI) instead of conventional questionnaires on paper. The main advantages are: (a) reducing the potential number of data entry mistakes by a set of filters and consistency checks; (b) substantially cutting or even eliminating data processing time, since data are automatically entered into a database as enumerators fill in tablet questionnaires; (c) as data are 'live' and arrive 'just in time' researchers and survey designers can cross-check consistency and run some analysis as survey goes on, without having to wait until the survey has been completed. Appendix A2 considers the main pros and cons of this option.

4. Summary of key recommendations

The discussion in this background paper has tried to (a) assess the relevance of concepts and indicators of Decent Work (DW) for rural areas and employment in agriculture; (b) examine some of the main reasons for the lack of data on DW for rural areas and agriculture, in terms of problems with data collection; and (c) propose a selection of more relevant and suitable indicators as well as some ways to improve data collection.

The main implications of this analysis are:

1. The concept and indicators of DW present problems of applicability and relevance in rural contexts of LICs, especially in SSA. Context specificity is indeed important for the relevance of concepts and indicators. A long and rigid list of DWI may reflect aims for universalism and the imperative of international comparability. Therefore it is proposed that more selectivity is a applied to the choice of DWI, i.e. trying to focus on a smaller but more relevant set of indicators, including some that are not currently being collected (for example, detailed data on returns to labour, whether self- or wage-employment, as well as more precise measures of underemployment and occupation multiplicity/multiple job-holding). Since not all dimensions/indicators may apply equally across countries, it may not be possible to have a single set of DW deficit indicators that is internationally comparable. Section 2.4 provided a list of DWIs that could be the basis for a primary attention if rural and agricultural sectors, particularly in LICs, are the main focus of analysis.

2. Despite advances in the conceptualization of labour categories and conventions, there are tensions and challenges that should be addressed and not ignored. Distinctions between categories of employment status need to be operationalized more carefully, so that the true incidence of self-employment and wage employment is adequately captured through a variety of methods and questions. This is important as there are different options of DWIs to be applied to self-employment vs wage employment situations. Distinctions in terms of levels of 'formality', given variation in definitions and applicability, may obscure more than reveal about DW deficit in rural employment. Thus, dimensions normally associated with 'informality' should be spelt out and reported separately.

3. More precise estimates of the degree of underemployment and 'overemployment' by individual as well as by type of activity (job) are needed for a more accurate picture of time-related DW deficits, which are crucial especially for the working poor who frequently straddle different irregular jobs.

4. Better survey designs for greater rural employment focus, including:

a. Suitable sampling methods to ensure coverage and inclusion of 'hard to reach populations' (seasonal migrants, child labour, forced labour, people in less accessible areas, etc.)

b. Longer and better designed modules on employment questions, e.g. the use of employment matrices, separate sub-modules with specific questions for each type of activity, and careful design of questions on returns to labour, both for self-employment and wage employment

c. Context-specific questions for aspects of DW not related to earnings, thus OSH, access to social protection and gender-related discrimination.

5. Improvements in sampling and questionnaire design will be insufficient if the quality of those who participate in surveys (from designers to supervisors, interviewers and data users) does not improve. There needs to be conceptual clarity and methodological awareness among all these groups. Careful selection and training of interviewers and field teams, as well as appropriate incentive systems are crucial for success in data collection.

Finally, it is clear that most of these recommendations can be applied in the context of independent micro-level surveys that operate with some degree of freedom over design choices. However, an important objective is also to 'mainstream' these methods into existing nationally representative household surveys. In other words, some of the 'solutions' proposed here could be incorporated in the design of such large-scale surveys. My own experience is that this is challenging because (a) of resistance from national statistical agencies to changes (path dependency) (b) because of the fear of losing international comparability, and (c) due to alleged logistical/financial constraints (which affect any survey anyway). This means that, realistically, perhaps not all methodological alternatives proposed in this paper can be embedded in official systems but some can. In that case the question would be to identify the most important alternative options, something that is likely to depend on the national context.

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APPENDIX A1. EXAMPLE OF EMPLOYMENT MATRIX

Note to the enumerator: Provide a complete list of all activities engaged in by The Respondent and ask questions for each of these activities
Matrix E1. Describe ALL of the activities / occupations on which you have worked DURING THE PAST 12 MONTHS
[**Note to enumerators:** It is expected that each Respondent will have undertaken SEVERAL activities]

Type of Occupation / Work	**1(a) Number of months**	**1b) Usually, how many days per month?**	**1(c) Usually, how many hours per day?**	**1(d) How long does it/did it usually take for you to travel to your place of work in this occupation?**	**1(e) Did anybody help/work for you in this activity for a payment in cash or in kind Yes No**
1a. Farmer (on your own or on your family farm)				. … .hours __ minutes	1 2
1b. Agricultural labourer (on large farm as permanent or seasonal worker)				. … .hours __ minutes	1 2
1c. Agricultural labourer (on any other type of farm as casual worker)				. … .hours __ minutes	1 2
1d. Fishing (using your own or family equipment)				. … .hours __ minutes	1 2
1e. Fishing (for a wage or part of the catch)				. … .hours __ minutes	1 2
2a. Collecting, begging, recycling, foraging				. … .hours __ minutes	1 2
2b Wood/charcoal/ collector and seller				. … .hours __ minutes	1 2
3a. Sales / wholesale trade / shop-keeper (warehouse)				. … .hours __ minutes	1 2
3b. Sales / retail trade (street vendor)				. … .hours __ minutes	1 2
4a. Transportation (bicycle, motorcycle –boda boda-, fares collector, porter, wheel barrow pusher)				. … .hours __ minutes	1 2
4b. Transportation (lorry driver, bus driver or chauffeur)				. … .hours __ minutes	1 2
5. Construction labourer / brick making / sand collecting/ quarrying/ stone breaking				. … .hours __ minutes	1 2
6. Carpenter/Mason				. … .hours	1 2

				_ _ minutes	
Type of Occupation / Work	**(a) Number of months**	**(b) Usually, how many days per month?**	**(c) Usually, how many hours per day?**	**(d) How long does it/did it usually take for you to travel to your place of work in this occupation?**	**(e) Did anybody help/work for you in this activity for a payment in cash or in kind** Yes No
7. Cleaner (in a company, hotel, etc.)				. ….hours _ _ minutes	1 2
8. Domestic servant (in a private house)				. ….hours _ _ minutes	1 2
9. Restaurant / bar (server) / food stall worker (inc. hotel) / local drinking hall				. ….hours _ _ minutes	1 2
10. Security guard, including vehicle (car, motorcycle etc.) guard				. ….hours _ _ minutes	1 2
11. Factory worker (including processing for tea, coffee, etc.)				. ….hours _ _ minutes	1 2
12a. Professional / technical (teacher, electrician, mechanic, plumber etc.)				. ….hours _ _ minutes	1 2
12b. Managerial / administrative / team supervisor				. ….hours _ _ minutes	1 2
13. Clerical / secretarial				. ….hours _ _ minutes	1 2
14. Food / drink preparation or processing				. ….hours _ _ minutes	1 2
15. Craftsmanship (incl. tailoring, crafting, cobbling, basket production, pottery)				. ….hours _ _ minutes	1 2
16. Personal services (laundry, barbers, photography)				. ….hours _ _ minutes	1 2
17. Other, describe: ………………………………………………………… ………………………………………………………… ……………………………………				. ….hours _ _ minutes	1 2

Matrix E2. Describe the characteristics of the Respondent's employment/work/activity carried out (each column)		
Type of occupation / work	**2(a) Type of employment**	**2(b) Location of workplace: Where do you/did you usually work in this activity?**
1a. Farmer (on your own or on your family farm)	|__|	|__|
1b. Agricultural labourer (on plantation/large farm permanent or seasonal	|__|	|__|
1c. Agricultural labourer (on any other type of farm as casual worker)	|__|	|__|
1d. Fishing (using your own or family equipment)	|__|	|__|
1e. Fishing (for a wage or part of the catch)	|__|	|__|
2a. Collecting, begging, recycling, foraging	|__|	|__|
2b. Wood/charcoal/ collector and seller	|__|	|__|
3a. Sales / wholesale trade / shop-keeper (warehouse)	|__|	|__|
3b. Sales / retail trade (street vendor)	|__|	|__|
4a. Transportation (bicycle, motorcycle boda boda, fares collector, porter,	|__|	|__|
4b. Transportation (lorry driver, bus driver or civil service driver)	|__|	|__|
5. Construction labourer / brick making / sand collecting/ quarrying/ stone	|__|	|__|
6. Carpenter or Mason	|__|	|__|
7. Cleaner (in a company, hotel, etc.)	|__|	|__|
8. Domestic servant (in a private house)	|__|	|__|
9. Restaurant / bar (server) / food stall worker (inc. hotel) / local drinking	|__|	|__|
10. Security guard	|__|	|__|
11. Factory worker (including processing for tea, coffee, etc.)	|__|	|__|
… cont	|__|	|__|
14. Food / drink preparation or processing	|__|	|__|
15. Craftsmanship (incl. tailoring, crafting, cobbling, basket production,	|__|	|__|
16. Personal services (laundry, barbers, photography)	|__|	|__|
17. Other,	|__|	|__|
CODES: 2(a) 1. Private salaried (monthly); 2. Private wage (daily, weekly, piece rate, task rate); 3 State salaried (monthly); 4. State wage (daily, weekly) 5. Own account; 6. Commission; 7. Cooperative salaried; 96. Don't know		**CODES: 2(b)** 1. Home (of respondent); 2. House (of employer); 3. Factory; 4. Shop, hotel, bar; 5. Office; 6. Street, fixed location; 7.Street, no fixed location/moving around; 8. Field/bush; 9. Other……… ..

APPENDIX A2. Computer assisted personal interviews (CAPI)

Since the innovation of tablet computing this practice is increasingly becoming the norm in social science research, due to a number of inherent advantages. These include:

a. Cost: Usually, after only a relatively small number of interviews (depending on setup, about 100-200 interviews per tablet computer) the cost of the initial investment will be amortised. The main reason for this is that CAPIs induce significant savings of recurrent costs because of procedures like the printing and shipment of questionnaires, data backup (physical copying), and in particular manual data entry are no longer required. Especially the latter point regularly constitutes a considerable saving of financial and human resources.

b. Availability of data: Electronically generated data is immediately available for data analysis and cross-checks by researchers and survey designers, with no need for separate data entry. Given modern forms of telecommunication, collected data can be analysed both by field officers as well as researchers based in different places, on the same day that it was collected, assuming interviewers and supervisor can access internet.

c. Data consistency and quality: due to the possibility to programme a wide range of internal consistency checks, skip & fill rules, data validation tools, as well as in-built questionnaire navigation and guidance, CAPIs routinely generate data that is much more consistent and of higher quality compared to that collected on paper. Interviewers are prevented from committed to the majority of common mistakes (such as typos, illogical answers, or asking wrong questions), because the electronic questionnaire will highlight/disallow inconsistent answers and generally guide interviews as required in any specific case, i.e. only displaying questions that are applicable to a particular respondent based on previous answers. As a result, the need for data cleaning is greatly reduced (implying another significant cost saving). Moreover, electronic equipment also facilitate the use of media during the conduction of interviews. This is important as a source of key notes to add to questionnaires, for example on measurement units when these are not conventional or consistent, so interviewer can take pictures to illustrate the case.

These advantages make a compelling case for the use of CAPIs, especially in circumstances where questionnaires are highly standardised and repeated in large numbers. Familiarisation with the computer devices aside, arguably there will be a reduced need for interviewer training, because the scope for errors is vastly reduced. Field experience by the FTEPR study also suggests, that conventionally expressed challenges related to rural fieldwork are usually of little concern:

a. Battery life of modern devices is usually sufficient to last for at least 8 hours, i.e. at least one full or two half working days. In most circumstances, external batteries (including car batteries) or generators can be used to charge devices in cases of power outages.

b. Most modern devices are GPS enabled, which create a large potential for further facilitation of the sampling and data collection process. (as discussed above)

c. Rugged cases are available for most devices, making them highly resistant against most adverse situations in the field (including dust, rain, falling, etc.)

d. The often-feared alienating effect of computing devices has not been observed by the FTEPR team, which has used this technology in highly remote areas in Uganda and Ethiopia without respondents reacting negatively to the use of computers instead of paper questionnaires. To the contrary, more often than not, respondents showed an increased curiosity and interest to participate and cooperate.

The main challenge associated with CAPIs are concerned with the time spent on programming and setup, maintaining the devices in the field, as well as the initial cost of investment. To effectively make use of the potential of CAPIs, it is essential that sufficient time and resources are reserved to allow the careful programming (and testing) of the electronic questionnaire. Specific experience is required to successfully develop a functioning electronic questionnaire, including the necessary validation rules, underlying navigation and ski- & fill logic, etc. Depending on the length of the questionnaire, an experienced programmer can be expected to spend between one and three weeks (full-time) to finalise such a tool. Furthermore, as with all technological equipment, maintenance in the field is an important aspect of this approach. For this reason, it is crucial that at least one member of the survey team (usually the field supervisor) is well-versed in the use and maintenance of the devices, in case any error or fault should occur. In addition, the initial cost of investment is of course considerable, especially if survey entails a large number of enumerators. This may be an important consideration, especially if the financial savings derived from no need for data entry and no printing of questionnaires are not substantial as some World Bank specialists have pointed out (Kilic 2012).

Another possible challenge is battery and charging devices in situations where there are frequent and extended power cuts. In such scenarios an alternative plan with paper questionnaires or having a back-up power generator would be advisable to prevent any delays or even interruption of fieldwork due to logistical constraints.

Finally, there will be additional training needs since not all selected enumerators will have expertise in the use of CAPIs for purposes of questionnaire-based interview. However, in our experience, the training involved is relatively straightforward and most enumerators nowadays are used to working with tablets and smartphones.

In sum, the various pros and cons of using CAPIs as part of the survey have to be weighed up against each other. The main recommendation is that, provided that qualified team members can be relied on, the advantages of using electronic questionnaires greatly outnumber the downsides.

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A05

Measuring and monitoring decent work in rural areas in support of sustainable development

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ABSTRACT

Making progress towards sustainable development and poverty reduction will require a concerted effort to promote decent work in rural areas, particularly among developing countries. It will require analysis of targeted indicators on decent work in rural and urban areas that can be used to advance national development agendas. But what do we know about rural workers and their participation in the labour market or, more broadly, about decent work in rural areas as compared to urban areas? The internationally agreed decent work measurement framework and recently adopted standards by the International Conference of Labour Statisticians (ICLS) on measuring paid and unpaid forms of work are the starting point for the measurement and monitoring of decent work.

However, currently there are different criteria applied by countries to define rural areas. The paper presents the case that the lack of a harmonized international statistical definition of rural and urban areas combined with a major data gap for even a basic set of decent work indicators in many countries limits the possibility of providing meaningful analysis on decent work in rural areas at the national, regional or global levels and presents recommendations on the way forward to address the challenges.

Keywords: Decent work, labour market, labour statistics, International Conference of Labour Statisticians (ICLS), rural areas, rural workers

PAPER

1. Introduction

Achieving sustainable development is the key challenge of our time. Countries have adopted a set of ambitious goals and specific targets that seek to end poverty, protect our planet and ensure prosperity for all by 2030. The largest concentration of the world's poor, about 800 million poor women, children and men, live in rural areas, many of whom work as subsistence farmers, herders, fishers, and artisans (Rural Poverty Portal, IFAD). Making real progress towards the Sustainable Development Goals (SDGs) will require a concerted effort to promote decent work in rural areas, particularly among developing countries. While rural poverty is a complex issue, achieving full and productive employment and decent work in rural areas is recognized as a principle means of tackling it.

Launched in 1999, the concept of decent work is understood as a need of people in all societies regardless of level of development. It is defined as opportunities for women and men to obtain decent and productive work, in conditions of freedom, equity, security and human dignity. The Decent Work Agenda has received widespread international endorsement. During the 2005 United Nations World Summit, Heads of State and Government expressed their strong support for a fair globalization and for making the goals of full and productive employment and decent work for all, including for women and young people, a central objective of their policies and national development strategies.

The International Labour Organization's (ILO) Declaration on Social Justice for a Fair Globalization adopted in 2008 by ILO Member States represents a road map for the promotion of a fair globalization based on decent work, and is intended as a tool to accelerate progress in the implementation of the Decent Work Agenda at the country level (ILO 2008). It acknowledges the universality of the Decent Work Agenda in which all ILO Members will pursue policies based on the four strategic objectives – international labour standards and fundamental principles and rights at work, employment creation, social protection, and social dialogue and tripartism. These objectives are seen as inseparable, interrelated and mutually supportive.

The Declaration calls upon the ILO to assist Member States in their efforts towards its implementation and states that "ILO Members may consider the establishment of appropriate indicators or statistics, if necessary with the assistance of the ILO, to monitor and evaluate the progress made." To facilitate such technical assistance, in 2008 the ILO convened a tripartite meeting of experts to establish a measurement framework to monitor progress towards decent work.

In 2008, the Framework on the Measurement of Decent Work (FMDW) was presented to the International Conference of Labour Statisticians (ICLS) and to the ILO Governing Body both of which have encouraged an ILO work programme to further develop and test the framework. The FMDW has since been successfully piloted in different countries and nearly 20 decent work country profiles have been developed on the basis of the framework. The newly adopted SDG targets and indicators that relate to employment and decent work, particularly under Goal 8 "Promote inclusive and sustainable economic growth, employment and decent work" offer a fresh opportunity to redouble efforts towards monitoring decent work, including in rural areas, in order to address extreme poverty of many developing countries.

2. The Framework on Measuring Decent Work (FMDW)

The FMDW is intended to assist countries to assess progress towards decent work and to offer comparable information for analysis and policy development. It offers the possibility of disaggregating most statistical indicators by rural and urban area to analyse differences by geographic area and includes a specific indicator to measure the discrimination of rural workers. It is a model of international relevance that allows the adaptation to national circumstances and priorities and that has the potential to evolve dynamically over time. The framework can be applied to all countries, although it is recognized that adequate technical support is required for countries with limited statistical capacity.

The FMDW covers ten dimensions or substantive elements as follows: (1) employment opportunities; (2) adequate earnings and productive work; (3) decent working time; (4) combining work, family and personal life; (5) work that should be abolished; (6) stability and security of work; (7) equal opportunity and treatment in employment; (8) safe work environment; (9) social security; and (10) social dialogue, employers' and workers' representation. These substantive elements are closely linked to the four strategic objectives of the Decent Work Agenda noted above and represent the structural dimensions of the framework under which both statistical and legal framework indicators on decent work are organized. There is an additional substantive element related to the economic and social context for decent work whose indicators are not intended to measure decent work per se but rather serve to provide data users information that relates to the characteristics of the economy and population. The substantive elements and corresponding statistical and legal framework indicators are presented in the Annex.

The statistical indicators were identified by looking through the eyes of people, that is, from the perspective of how decent work is perceived by individual people. They are quantitative indicators that can be derived from official national data sources. The legal framework indicators are qualitative in nature and are primarily based on legal, policy or programme texts and other related information. While statistical indicators make up the vast majority of the indicators in the FMDW, the legal framework indicators are equally important. The two sets of indicators are mutually reinforcing and thus both considered essential for monitoring progress towards decent work in a given national economy.

There is a layered approach to the statistical indicators as follows. Main indicators represent a parsimonious core set of indicators to monitor progress towards decent work. Additional indicators are to be used where appropriate, and where data are available. Future indicators are currently not feasible, but are to be included as data become more widely available. Gender equality is a cross-cutting element in the Decent Work Agenda, thus it is recommended that the indicators be disaggregated by sex whenever possible.

Many of the decent work statistical indicators are best calculated using estimates derived from a labour force survey (LFS). The primary objective of a LFS is to obtain reliable estimates about the labour force of a given population based on a sample of households. This instrument permits the estimation of the number of persons employed as well as the size of the working age population and can be designed to provide both stock and flow estimates. It generally covers all workers, including all self-employed persons and often allows disaggregation of data by demographic variables such as sex, age group and in some cases, ethnic group. Moreover, it often allows breakdowns by status in employment, occupation group and economic activity group. Other sources are used to complement the estimates from labour force surveys such as other topic-specific household surveys (like child labour surveys) and other household surveys, employment-related establishment surveys, and administrative records.

The measurement scope of the FMDW extends to all persons in a given country who are or potentially could be engaged in productive work in the broadest sense. It includes both persons in the labour force and persons outside the labour force. Its scope goes beyond the working age population since child labour is included. Moreover, because one of the main pillars is the objective of social protection for all, including workers and non-workers, children and adults, the population scope on this topic covers the entire population in a given country. It covers all usual residents and therefore covers migrant workers and non-migrants and workers of all ethnic and indigenous origins.

3. Concept definitions: What is meant by work, employment, rural, and rural workers?

The ICLS and concept definitions of work and employment

Since 1923, the ILO has been responsible for organizing the International Conference of Labour

Statisticians (ICLS). The ICLS is held every 5 years and seeks to promote the development and use of statistical concepts, definitions, and methods. ICLS standards are the world reference for producing statistical information on employment and unemployment and a wide range of other decent work-related subjects. In 2013, the 19th ICLS adopted a new international statistical standard, the "Resolution concerning statistics of work, employment and labour underutilization" (referred to hereafter as the Resolution) (ILO, 2013). The Resolution adopted in 2013 establishes a new framework on work statistics, defining the concept of work as comprising "any activity performed by persons of any sex and age to produce goods or to provide services for use by others or for own use".

Work is defined irrespective of its formal or informal character or of the legality of the activity. It excludes activities that do not involve producing goods or services (e.g. begging and stealing), self-care (e.g. personal grooming and hygiene) and activities that cannot be performed by another person on one's own behalf (e.g. sleeping, learning and activities for own recreation). According to the Resolution, the concept of work covers all activities within the general production boundary as defined in the System of National Accounts 2008 (SNA 2008). According to the Resolution, work can be performed in any type of economic unit as distinguished by the SNA 2008, namely: (i) market units (i.e. corporations, quasi-corporations and household unincorporated market enterprises, the latter encompassing, as a subset, informal sector units); (ii) non-market units (i.e. government and non-profit institutions serving households); and (iii) households that produce goods or services for own final use.

The Resolution identifies five mutually exclusive forms of work, distinguishing them on the basis of the intended destination of the production (for own final use; or for use by others, i.e. other economic units) and the nature of the transaction (i.e. monetary or non-monetary transactions, and transfers). These include:

a) **own-use production work** comprising production of goods and services for own final use (an unpaid form of work) - (note that own-use production of goods includes as a subset category, subsistence food production);

b) **employment work** comprising work performed for others in exchange for pay or profit;

c) u**npaid trainee work** comprising work performed for others without pay to acquire workplace experience or skills;

d) **volunteer work** comprising non-compulsory work performed for others without pay;

e) **other work activities** (including such activities as e.g. unpaid community service and unpaid work by prisoners, when ordered by a court or similar authority, and unpaid military or alternative civilian service).

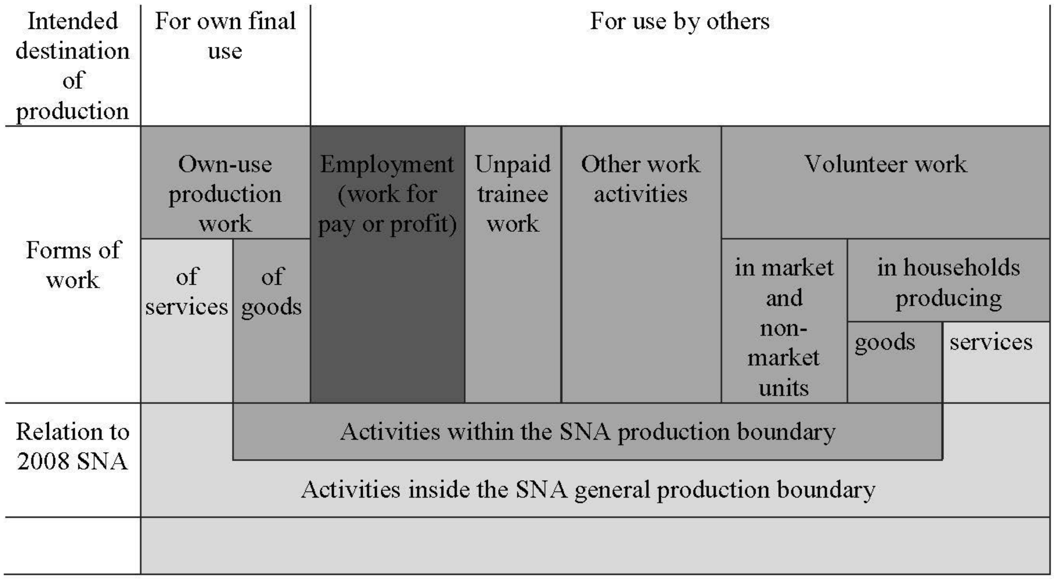
Own-use production of goods, employment, unpaid trainee work, a part of volunteer work and "other work activities" are within the SNA 2008 production boundary, while own-use production of services and the remaining part of volunteer work are beyond the SNA production boundary but inside the SNA general production boundary. In the previous ICLS standards on measuring employment and unemployment adopted in 1982, employment corresponded to persons engaged in activities within the SNA production boundary, and thus for example included subsistence farming activities. Figure 1 below presents the conceptual framework for work statistics.

The current definition of employment (work for pay or profit) is thus much narrower than it was under the previous standards and excludes own-use production of goods (including subsistence workers) and other unpaid forms of work. This change is expected to have a notable impact on various headline indicators in the future as countries begin to implement the standards in their household surveys (including LFS). Thus for example, countries which have in the past included persons engaged in subsistence food production activities in employment may well see increases in the unemployment rates, particularly in rural areas. Until now, rural unemployment rates have been consistently lower than urban unemployment rates in many developing countries, but this situation will likely reverse with the implementation of the 19th ICLS Resolution. It is thus important that countries produce parallel series (using the old and new standards) for at least 12 months and carry out an appropriate communications strategy with data users to inform them of the changes in methodology and any changes in the time series.

Definition of rural and urban areas

The definition of rural and urban areas as used in labour statistics or other statistical domains is a complex issue, since there are no existing international statistical guidelines that would allow coherent, harmonized reporting. Currently, a broad array of different criteria is applied in national definitions of rural/urban areas reflecting a myriad of geographic and socio-economic realities in countries across the globe. This situation presents serious challenges when attempting to make cross-country comparisons of labour statistics by rural/urban area or even regional or global estimates of different indicators, for example, labour force participation rates, gender pay gaps, youth unemployment rates,

Figure 1 – Conceptual framework for work statistics

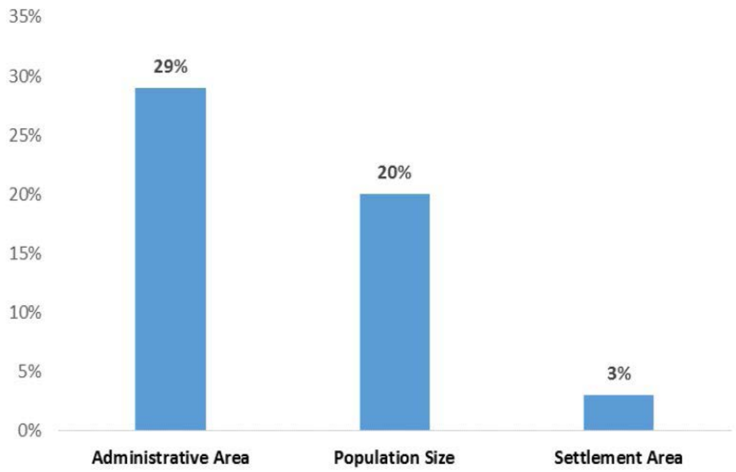


Source: ILO, 2013

or child labour rates, to name just a few.

The ILO has developed an inventory of country-level statistical definitions of rural and urban areas for 214 countries/territories which confirms that the definitions are highly heterogeneous (Robles, Kashef and Castillo, 2016). Countries often define urban areas and provide no specific definition of rural areas. The fact that rural areas in many countries are defined de facto by urban areas is telling, since it signals that urban areas are the main target, and rural areas, a residual category. A majority of countries (52%) base their definitions on a single criterion, most often administrative area, population size or type of settlement area (Figure 2). It is interesting to note that predominance of agricultural activities is not commonly used as a single criterion.

Figure 2 – Percentage of countries applying a single criterion to define rural/urban areas by the main criterion



Source: ILO, 2016. Values are given as a percent of 214 countries, 52 percent of which applied a single criterion

Forty-eight percent of countries use multiple criteria to define rural/urban areas, that is, they combine criteria such as administrative area, population size and/or density, predominance of agricultural/ non-agricultural activities, and availability of infrastructure services and amenities, among others to distinguish between rural and urban areas. Where multiple criteria were found to define rural/ urban areas, the vast majority (60 percent) of countries use administrative area and other criteria, mainly population size and/or density. Predominance of agriculture/non-agriculture activities together with other criteria are used in 15 percent of the countries, mainly in Europe, Central Asia and Africa. Availability of infrastructure services and amenities along with other criteria are applied in 12 percent of the countries.

Some key similarities and differences in the rural/urban definitions across regions should be mentioned. In Latin America, Asia and Europe, administrative area is the most common criterion, followed by population size. Both Latin America and Asia apply predominance of agriculture/non-agriculture activities as a third most commonly used criterion. In Africa, population size is the most commonly applied criterion, followed by administrative area, predominance of agricultural/non-agricultural activities, and availability of infrastructure services and amenities.

The highly heterogeneous criteria used to define rural/urban areas in different countries and regions around the world is an issue that needs to be addressed. In order to have meaningful cross-country comparisons of different statistical indicators disaggregated by rural/urban areas, the international statistical community should establish an internationally recognized definition of rural and urban. A recently published FAO working paper proposes a conceptual framework and territorial definitions to support better coherence and comparisons of rural statistics (Offutt, 2016).

Definition of worker and rural worker

While the ICLS recently adopted a statistical definition of the concept of work, it didn't explicitly define "worker". However, since according to the 19th ICLS Resolution work refers to the productive activities carried out within the SNA general production boundary, a worker by extension can be understood as any person that is engaged in one or more of the five forms of work defined in the Resolution during a given reference period. A rural worker can then be defined for statistical purposes as a worker engaged in any job or work activity that is located in a rural area during a given reference period. This issue requires special attention in survey measurement, since often the geographic location of the household or housing unit in a household survey is assumed to be the same as the geographic location of the person's job(s) or work activity(ies). However, individual workers may be living in one geographic area and working in another. This is depicted in Figure 3 below, where cells 2 and 3 reveal situations where a worker's household is located in one geographic area but the job or work activity is in another.

Figure 3 – Worker's household location versus job or work activity location

	Urban household	Rural household
Urban-based job or work activity	Urban household and urban-based job or work activity 1	Rural household and urban-based job or work activity 2
Rural-based job or work activity	Urban household and rural-based job or work activity 3	Rural household and rural-based job or work activity 4

Source: ILO

In order to best identify the geographic location of the job/work activity, specific questions should be introduced in the questionnaire that allow identification of the geographic location according to the national definition of rural and urban areas. Such a question(s) should be appropriately tested prior to full-scale implementation in a household survey. The ILO is currently field testing a question on this in model LFS questionnaires that are part of a pilot LFS programme intended to support countries to implement the 19th ICLS Resolution on work statistics.

4. What do available data reveal about decent work and the labour market situation of rural workers?

When reviewing data currently available in international labour statistics repositories such as ILOSTAT, it is evident that substantial data gaps exist for even several main decent work indicators. When seeking decent work indicators disaggregated by rural/urban areas or additional disaggregations, for example, by rural/urban areas and by sex or age, data are even scarcer. The most commonly available indicators disaggregated by rural/urban areas for a large set of countries are basic labour market indicators related to employment, unemployment and labour force. Table 1 below presents the very limited country coverage of decent work indicators disaggregated by rural/urban areas available in ILOSTAT. This table reveals that the only substantive elements of the FMDW for which statistics are readily available are (1) Employment opportunities (denoted EMPL) with six variables/indicators, and (2) Social security (SECU) with seven indicators. Thus, for eight of the ten substantive elements, there are too few countries producing the corresponding statistical indicators to allow their inclusion in the database. Whilst there are also some indicators available under the substantive element of Economic and social context for decent work (CONT), these do not allow the direct monitoring of decent work.

The ILO Department of Statistics has recently begun to analyse the few available labour market indicators disaggregated by rural/urban areas. It should be noted that the available statistics reflect definitions on employment, unemployment and labour force that correspond to international standards adopted by the 13th ICLS in 1982. The scarce availability of quality labour statistics, the lack of implementation of the 19th ICLS Resolution on work statistics, and the lack of a commonly applied international definition of rural/urban areas makes analysing the labour market situation in different countries an enormous challenge. The lack of harmonization in concept definitions and methods limits the possibility of constructing regional or global estimates, or even averages for a small set of countries.

Table 1: Country coverage of decent work indicators by rural/urban areas and further disaggregations by sex and age (in number of countries)

TOPIC	Indicator	RUR/URB	RUR/URB + SEX	RUR/URB + AGE (Youths and Adults)	RUR/URB + SEX + AGE (Youths and Adults)
CONT	Estimates and projections of the total population	195	195	195	195
CONT	Working-age population	116	110	35	34
CONT	Poverty gap at national poverty line	67			
CONT	Poverty gap at rural poverty line	67			
CONT	Poverty headcount ratio at national	98			
CONT	Rural poverty headcount ratio at rural poverty line	97			
EMPL	Labour force	113	110	38	36
EMPL	Labour force participation rate	93	88	31	31
EMPL	Employment	122	117	36	35
EMPL	Employment-to-population ratio	99	92	31	31
EMPL	Unemployment	113	108	35	34
EMPL	Unemployment rate	112	102	32	32
SECU	Active contributors to an old age contributory scheme as % of employment	21	21		
SECU	Share of population above statutory pensionable age receiving a contributory old age pension	20	20	NA	NA
SECU	Legal health coverage	159			
SECU	Out-of-pocket expenditure	118			
SECU	Coverage gap due to financial resources deficit	147			
SECU	Coverage gap due to health professional staff deficit	161			
SECU	Maternal mortality ratio per 10 000 live births by geographical coverage	142			

Source: ILOSTAT. Note: Countries are counted if they present at least one data point for the indicator from 1980 until 2015

The analysis below seeks to present the changes during the period 2012-13 in just three available labour market indicators—labour force participation rate, employment to population ratio, and unemployment rate—in a few selected countries to show the key differences between urban and rural areas using existing concept definitions. It exemplifies the challenges to analysing the indicators as available today disaggregated by rural/urban areas, where cross-country comparisons are not possible.

Labour market situation in selected countries, 2012-13

During 2012-13, global growth was slow in the wake of the 2008 global financial crisis. According to the IMF, during 2013 advanced economies began to expand again but needed to continue restructuring the weakened financial sector and promote job growth (IMF, 2013).

Emerging market economies faced the challenges of slowing growth and a more difficult global financial situation.

Table 2 below presents labour market data for seven countries for which the trends and rural/urban differences are noteworthy during the period. The set of indicators cannot be compared across countries, since there are serious data comparability issues involving measurement of the labour market concepts and definitions of rural and urban areas.

As noted previously when describing the currently applied (13th ICLS, 1982) standards on the measurement of employment and unemployment, due to the current broad measurement of employment, all but one country present lower unemployment rates in rural areas as compared with urban areas in both years. The exception is Sri Lanka that reported a slightly higher rural unemployment rate in 2012 as compared with the urban rate, but this situation reversed in 2013.

With the forthcoming implementation of the 19th ICLS Resolution on work statistics, many countries will show the reverse situation, that is, rural unemployment rates are expected to be higher than urban unemployment rates. Moreover, with the implementation of the Resolution, countries will have a broader set of labour underutilization indicators to choose from to complement the unemployment rate, allowing for a more refined analysis and more targeted policy interventions in both urban and rural areas.

Table 2: Key labour market information for selected countries (percentages)

Countries	Labour force participation RUR/URB + AGE (Youths and Adults)				Employment-to-population ratio				Employment-to-population ratio			
	Rural		Urban		Rural		Urban		Rural		Urban	
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Armenia	73.3	72.5	57.1	58.3	69.4	68.2	42.5	44.6	5.3	6.0	25.5	23.4
Dominican Republic	62.8	53.4	66.1	57.5	54.3	45.8	56.0	48.6	13.6	14.2	15.3	15.4
Egypt	50.0	49.9	46.8	46.7	45.0	44.6	39.2	39.0	9.9	10.7	16.3	16.5
Indonesia	70.5	67.4	65.3	66.1	67.2	64.0	60.3	61.3	4.7	5.1	7.7	7.3
Iran, Islamic Republic of	40.0	39.7	36.5	36.9	36.2	36.7	30.9	31.4	8.2	7.0	13.8	11.8
Serbia	48.0	50.1	45.7	47.3	38.3	40.9	33.4	35.6	20.1	18.4	26.9	24.9
Sri Lanka	48.0	55.3	43.7	49.0	46.1	52.9	42.1	46.4	4.0	4.2	3.7	5.3

Source: ILOSTAT

Another point to note from the data in Table 2 is that a particular labour market indicator for a rural area will sometimes move in the opposite direction when compared with the indicator for an urban area, reflecting specific labour market demand and supply conditions in the different geographic areas. This is exhibited in the cases of Armenia and Indonesia, where the rural unemployment rates increased during the period (reflecting a decline in rural labour demand that exceeded the decline in rural labour supply) while the urban unemployment rates declined (reflecting an increase in urban labour demand that exceeded the increase in the labour supply).

Finally, some of the indicators in Table 2 present very large differences between rural and urban areas. In Armenia for example, there is a 20.2 and 17.4 percentage point gap between the rural and urban unemployment rates in 2012 and 2013, respectively. Serbia, Iran and Egypt present somewhat smaller but still notable differences between urban and rural unemployment rates in both years. Iran and Serbia report low values of employment-to-population ratios, while Serbia, Dominican Republic and Egypt report high values of unemployment rates. Disaggregations by sex, age, ethnicity and other factors are highly important for understanding some of these values in rural areas, but such data are not always available.

5. Conclusions

Policymakers increasingly require more refined analysis based on targeted decent work indicators and greater levels of disaggregation by sex, age, ethnicity and other variables in addition to geographic area, and this demand is expected to grow considerably in the coming years due to the launch of the Sustainable Development Goal (SDG) indicators. Yet, despite the existence of robust conceptual frameworks and international recommendations related to the measurement of decent work and work statistics, there remain many obstacles that prevent the production of timely, high quality statistics on decent work and productive employment disaggregated by rural and urban areas. The international statistical community should act quickly and create opportunities to meet the challenges, including considering new strategies and partnerships. There are a number of interrelated measures and steps that should be considered in this process, that include the following:

1. Countries need to build capacity as regards the latest statistical standards on work statistics and other ICLS standards, in order to implement the standards in their labour statistics system and produce high quality statistics. This should be accomplished through technical assistance.

2. ILO Guidance and toolkits that support the implementation of the international standards need to be developed and shared with countries.

3. An international statistical definition on rural/urban areas should be developed in collaboration with national statistical offices and international agencies. Countries should be encouraged to continue to use national definitions as appropriate, but would use the international definition for international reporting and cross-country comparisons.

4. A statistical conceptual framework on rural workers should be developed that is consistent with the latest ICLS standards and considers decent work indicators specifically for rural workers that go beyond the existing set of decent work indicators.

5. Capacity-building activities (training) should be strengthened around the topic of rural labour statistics and analysis, including topics of gender mainstreaming in rural labour statistics, youth and ethnicity in rural labour statistics, and other selected topics pertinent to rural development and poverty reduction.

6. Partnerships among donors and various international agencies with a mandate on rural labour statistics should be strengthened in order to support countries on rural labour statistics production and analysis.

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ANNEX I

Table A. Measurement of decent work based on guidance received at the Tripartite Meeting of Experts on the Measurement of Decent Work (September 2008)

Substantive element of the Decent Work Agenda	**Statistical Indicators**	**Legal Framework Indicators**
Numbers in parentheses in the first column below refer to ILO strategic objectives: 1. Standards and fundamental principles and rights at work; 2. Employment; 3. Social protection; 4. Social dialogue.	Selection of relevant statistical indicators that allow monitoring progress made with regard to the substantive elements. M – Main decent work indicators A – Additional decent work indicators F – Candidate for future inclusion / developmental work to be done by the Office C – Economic and social context for decent work (S) indicates that an indicator should be reported separately for men and women in addition to the total.	L – Descriptive indicators providing information on rights at work and the legal framework for decent work. Description of relevant national legislation, policies and institutions in relation to the substantive elements of the Decent Work Agenda; where relevant, information on the qualifying conditions, the benefit level and its financing; evidence of implementation effectiveness (as recorded by ILO supervisory bodies); estimates of coverage of workers in law and in practice; information on the ratification of relevant ILO Conventions.
Employment opportunities (1 + 2)	M – Employment-to-population ratio (S)* M – Unemployment rate (S) M – Youth not in employment, education, or training, 15-24 years (S)* M – Informal employment rate (S)* A – Labour force participation rate (1) [to be used especially where statistics on Employment-to-population ratio and/or Unemployment rate (total) are not available] A – Youth unemployment rate,15-24 years (S) A – Unemployment by level of educational attainment (S)* A – Employment by status in employment (S) A – Proportion of own-account workers and contributing family workers in total employment (S)* [to be used especially where statistics on informal employment are not available] A – Share of wage employment in non-agricultural employment (S) F – Labour underutilization (S) Memo item: Time-related underemployment rate (S) grouped as A under "Decent Working time"	L – Government commitment to full employment L – Unemployment insurance

Adequate earnings and productive work (1 + 3)	M – Working poverty rate (S)* M – Employees with low pay rate (below 2/3 of median hourly earnings) (S)* A – Average hourly earnings by occupation group (S)* A – Average real wages (S) A – Minimum wage as a percentage of median wage A – Manufacturing wage index A – Employees with recent job training (past year / past 4 weeks) (S)	L – Statutory minimum wage*
Decent Working Time (1 + 3)*	M – Employment in Excessive Working Time (more than 48 hours per week) (S)* A – Employment by weekly hours worked (hours in standardized hour bands) (S)* A – Average annual working time per employed person (S)* A – Time-related underemployment rate (S) F – Paid annual leave (developmental work to be done by the Office; additional indicator)	L – Maximum hours of work L – Paid annual leave
Combining work, family and personal life (1 + 3)	F – Asocial / unusual hours (developmental work to be done by the Office) F – Maternity protection (developmental work to be done by the Office; main indicator)	L – Maternity leave (including weeks of leave, and rate of benefits) L – Parental leave*
Work that should be abolished (1 + 3)	M – Child labour rate [as defined by ICLS resolution] (S)* A – Hazardous child labour rate (S)* A – Rate of worst forms of child labour (WFCL) other than hazardous work (S)** A – Forced labour rate (S)** A- Forced labour rate among returned migrants (S) **	L – Child labour (including public policies to combat it) L – Forced labour (including public policies to combat it)
Stability and security of work (1, 2 + 3)	M - Precarious employment rate ** A - Job tenure** A - Subsistence worker rate** A – Real earnings of casual workers** (S) Memo item: Informal employment is grouped under employment opportunities.	L – Termination of employment* (incl. notice of termination in weeks) Memo item: 'Unemployment insurance' is grouped under employment opportunities; needs to be interpreted in conjunction for 'flexicurity'.
Equal opportunity and treatment in employment (1, 2 + 3)	M – Occupational segregation by sex M – Female share of employment in senior and middle management* A – Gender wage gap A – Share of women in wage employment in the non-agricultural sector A – Indicator for Fundamental Principles and Rights at Work (Elimination of discrimination in respect of employment and occupation) to be developed by the Office. A – Measure for discrimination by race / ethnicity / of indigenous people / of (recent) migrant workers / of rural workers where relevant	L – Equal opportunity and treatment* L – Equal remuneration of men and women for work of equal value*

	and available at the national level to be developed by the Office. F – Measure of dispersion for sectoral / occupational distribution of (recent) migrant workers F – Measure for employment of persons with disabilities. Memo item: Indicators under other substantive elements marked (S) indicator should be reported separately for men and women in addition to the total.	
Safe work environment (1 + 3)	M – Occupational injury frequency rate, fatal* A – Occupational injury frequency rate, nonfatal* A – Time lost due to occupational injuries A – Labour inspection (inspectors per 10,000 employed persons)	L – Employment injury benefits* L – Occupational safety and health (OSH) labour inspection
Social security (1 + 3)	M – Share of population above the statutory pensionable age (or aged 65 or above) benefiting from an old-age pension (S) * M – Public social security expenditure (percentage of GDP) A – Healthcare expenditure not financed out of pocket by private households A– Share of economically active population contributing to a pension scheme (S) * F – Share of population covered by (basic) health care provision (S) (to be developed by the Office; additional indicator) F – Public expenditure on needs based cash income support (% of GDP) F – Beneficiaries of cash income support (% of the poor) F – Sick leave (developmental work to be done by the Office; additional indicator) [Interpretation in conjunction with legal framework and labour market statistics.]	L – Old-age social security or pension benefits (public/private)* L – Incapacity for work due to sickness / sick leave L – Incapacity for work due to invalidity Memo item: 'Unemployment insurance' is grouped under employment opportunities.
Social dialogue, workers' and employers' representation (1 + 4)	M – Trade union density rate (S) * M – Employers' organization density rate (ED) (S)* M – Collective bargaining coverage rate (S) M/F – Indicator for Fundamental principles and rights at work (Freedom of association and collective bargaining) to be developed by the Office; main indicator A – Days not worked due to strikes and lockouts*	L – Freedom of association and the right to organize L – Collective bargaining right L – Tripartite consultations
Economic and social context for decent work	C – Children not in school (percentage by age) (S) C – Estimated percentage of working-age population who are HIV-positive C – Labour productivity (GDP per employed person, level and growth rate)	L – Labour administration** Developmental work to be done by the Office to reflect environment for Sustainable enterprises, incl. indicators for (i) education, training and lifelong learning, (ii)

	C – Income inequality (90:10 ratio) C – Inflation rate (Consumer Price Index, CPI) C – Employment by branch of economic activity C – Education of adult population (adult literacy rate, adult secondary-school graduation rate) (S) C – Labour share of Gross Value Added (GVA)* C (additional) – Real GDP per capita (level and growth rate)* C (additional) – Female share of employment by economic activity (ISIC tabulation category)* C (additional) – Wage / earnings inequality (90:10 ratio)* C (additional) – Poverty measures **	entrepreneurial culture, (iii) enabling legal and regulatory framework, (iv) fair competition, and (v) rule of law and secure property rights. Developmental work to be done by the Office to reflect other institutional arrangements, such as scope of labour law and scope of labour ministry and other relevant ministries.

Source: ILO compilation on the basis of the Discussion paper for the Tripartite Meeting of Experts on the Measurement of Decent Work (Geneva, 8 -10 September 2008).

*Wording modified by ILO in the pilot phase; **Indicator added by ILO in the pilot phase (2009-2013).

Table B. Sustainable Development Goal (SDG) Indicators related to Monitoring Decent Work

SDG Goal	Indicator number	Indicator name
Goal 1. End poverty in all its forms everywhere	1.1.1	Proportion of the population below the international poverty line
	1.a.2	Proportion of total government spending on essential services
	1.3.1	Coverage of social protection floors
Goal 5. Achieve gender equality and empower all women and girls	5.5.2	Proportion of men and women in managerial positions
Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	8.2.1	Annual growth of real GDP per employed position
	8.3.1	Proportion of Informal employment in non-agriculture employment
	8.5.1	Average hourly earnings of female and male employees
	8.5.2	Unemployment rate
	8.6.1	Proportion of youth not in education, employment or training
	8.7.1	Proportion and number of children engaged in child labour
	8.8.1	Frequency rates of fatal and non-fatal occupational injuries
	8.8.2	Increase in compliance of labour rights
	8.b.1	Total government spending in social protection and employment porgammes as a proportion of national budgets and GDP
Goal 10. Reduce inequality within and among countries	10.4.1	Labour share of GDP
	10.7.1	Recruitment costs borne by employee as a proportion of yearly income
Goal 16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels	16.10.1	Number of verified cases of killing, kidnapping, enforced disappearance, arbitrary detention and torture of journalists, associated media personnel, trade unionists and human rights advocates in the previous 12 months

Note: Other SDG indicators not listed above may also be also relevant for monitoring progress towards decent work. The above list includes only those for which the ILO is closely involved or a direct custodian. While the language formulation in the above indicators may differ slightly from that used in the decent work indicators, nearly all of the listed SDG indicators are also decent work indicators. Note also that while SDG indicator 8.3.1 related to informal employment excludes agriculture, the corresponding decent work indicator (EMPL-4) does not exclude agriculture.

A05

A framework for measuring rural women's empowerment within the context of decent work: focus on economic and social advancement[1]

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ABSTRACT

The objective of the paper is twofold: (i) to provide an assessment of existing measures of rural women's economic and social empowerment within the decent work framework, and (ii) to propose the first part of a new measurement framework to better capture the nexus between women's empowerment and decent work within rural areas in developing countries where agricultural is an important part of the economy. This partial measurement framework proposes an indicator set on time use as a way to measure an aspect of rural women's empowerment, complementing the conventional approaches to measuring employment and decent work in the rural economy.

Keywords: Gender and sex-disaggregated indicators, rural, agriculture, Decent Work, women's empowerment

PAPER

1. Introduction

Gender-sensitive labour indicators disaggregated by rural/urban areas are crucial to better understanding how roles, rights, and opportunities shape men and women's access to decent work in rural areas in developing countries. They can assist in identifying disparities in rural men and women's participation in decent work, as well as in pinpointing differences in men and women's constraints in participation in decent work. Over the last decade, the development of international standards and guidelines has resulted in a greater number of gender-sensitive and sex-disaggregated statistics. However, despite the progress made, a gender-sensitive statistical measurement tool to explore the nexus between women's greater empowerment and decent work within the rural areas in a developing country context where many rural households are engaged in agricultural production has not yet been fully developed. The objective of the paper is twofold: (i) to provide an assessment of existing measures within the decent work framework of women's economic and social empowerment in developing countries particularly with a focus on rural areas, and (ii) to propose the first part of a new measurement framework to better capture the nexus between women's empowerment and decent work within this context. The full measurement framework aims to incorporate a set of core indicators to monitor rural women's empowerment, complementing the conventional approaches to measuring employment and decent work in the rural,agricultural context.Because of space, this paper presents only the first part of the full measurement framework, and within this partial framework it specifically focuses on a set of indicators measuring work time. The paper is structured as follows: Section 2 links the concept of women' empowerment with the concept of decent work and discusses the gender dimensions of work within the rural areas in a developing country context where many rural households are engaged in agricultural production. Section 3 assesses the decent work indicators and how well they capture women's social-economic empowerment (or constraints to empowerment) with work within this context and provides the first part of set of core indicators to monitor rural women's empowerment. Section 4 discusses data collection for the set of indicators measuring work time. Section 5 concludes.

Setting the stage: defining empowerment in terms of work and understanding the gendered dimensions of work within the rural areas in a developing country context where many rural households are engaged in agricultural production

The term empowerment encompasses a broad range of concepts, which generally comprises of, at least in part, the idea of having an environment or the conditions for which an individual can achieve his or her goals and having the ability to make decisions over one's life (Malhotra, Schuler and Carol 2002). Within the context of decent work–where the concept of work, according to the Resolution on work, employment, and labour underutilization adopted by the 19th International Conference of Labour Statisticians (ICLS) in 2013, is defined as any activity performed by persons of any sex or age to produce

[1] Contribution to the ICAS VII: Rough draft on gender and rural women's empowerment in relation to DW/rural employment.

goods or provide services for use by others or for own use —empowerment means that there are equal work opportunities for women and men in conditions of freedom, equity, security, and dignity (ILO 1999). This concept of decent work, as developed by the ILO and endorsed as a global goal, goes beyond a simple analysis of labour market outcomes such as unemployment reduction and employment creation. According to the Declaration on Social Justice for a Fair Globalization adopted in 2008 by ILO Member States, it incorporates four mutually intra-dependent strategic pillars: (I) employment creation and enterprise development, (II) social protection, (III) standards and rights at work, and (IV) governance and social dialogue (ILO 1999)[2]. Following a Tripartite Meeting of Experts in 2008 with the aim to provide guidance on how to measure decent work, a Decent Work Measurement Framework was established and structured along 10 core substantive elements of decent work. Such substantive elements --ranging from čemployment opportunitiesč to čadequate earnings and productive workč and čsocial dialogue, workers' and employers' representationč-- were attached to one or more of the four strategic pillars of the Agenda. Seventy-one statistical indicators and twenty-one legal framework indicators are currently contained in the Decent Work Measurement Framework as a way to measure progress within these substantive elements.The selected decent work indicators serve as a tool for a) assisting constituents to assess progress towards decent work and b) to offer comparable information for analysis and policy development. Building from this framework, the Food and Agriculture Organization (FAO 2016) developed a conceptual framework which incorporates rural women's empowerment in terms of work directly as well as all aspects outside of work but that affect work in a gendered way (e.g. health facilities and infrastructure, education, gender training, etc.) The FAO 2016 framework—which overlaps in parts but also extends beyond Decent Work agenda—has three empowering components as a way to conceptualise women's empowerment within the framework of decent work. These are 1) Social and Economic Advancement; 2) Power and Agency; and 3) Dignity and Value. The Social and Economic Advancement component focuses specifically on individual's engagement in work within and outside employment with a focus on rural and agricultural work. It also focuses on education and the skills development needed to access gainful employment activities within this context. It aims to measure men and women's work time, returns to wage work and differences in employment and skills development. The Power and Agency component focuses on access, control over, and influence of community and individual resources as well as engagement in social and economic decisions related in agriculture production and other productive activities in the household. It also focuses on control over and input into the use of income earned from the household's productive activities. It aims to measure ownership of physical and financial resources important in this context, decision-making over the use of productive assets and income earned form productive activities, and leadership in the community. The Dignity and Value pillar underlines the quality of life and work perceived by the individual and as measured by his or her surrounding environment. It aims to measure the freedom to choose and satisfaction with work, conditions of employment, forced labour, and child labour.

While the FAO 2016 paper provides a comprehensive framework for conceptualizing rural women's empowerment in decent work, this paper provides a core set of indicators within this first pillar (social and economic empowerment) focusing specifically on measures of men and women's engagement in work. The setting is on developing countries where agriculture is an important part of the countries' economies, there is a large rural population, poverty remains largely rural, and many rural households engage in agricultural production. For the purpose of this paper we define agriculture as the production of crop and animal products, as well as hunting, trapping, fisheries and aquaculture, forestry and related activities. Rurality is defined in contrast to urban areas, referring to areas outside of urban agglomeration. These areas may lack sufficient infrastructures that connect rural to urban areas and thus may be cut off from more developed urban markets. The population density in rural areas is lower than urban areas, but what exactly constitutes rurality as defined by national statistical offices varies across country (United Nations 2014)[3]. Within this context, members of small-holder households in agriculture often engage in multiple livelihood activities as a way to try to minimise their vulnerability to variability and cyclicality of income throughout the year due to seasonality and uncertainty in agriculture production. These activities may include self-employment activities in agriculture, earnings or in kind from temporary or casual wage labour, petty trading, street vending, or rent from leasing land.Income diversification is recognized as an important survival strategy for poor households particularly in rural Africa, and many studies of households in developing countries have found that income diversification is positively associated with greater welfare in rural households, particularly when the diversification is in activities outside of agriculture (see for instance, Ersado 2006; Block and Webb 2001Davis, et al. 2010).

In addition to income earning activities, own-use production, including subsistence farming, is

[2] The Decent Work Agenda (1999) is a policy framework endorsed by ILO Member States for conceptualising how to achieve decent work at the national level, which has received endorsement at the highest political and international levels. The 2008 Declaration on Social Justice for a Fair Globalisation indicates that member States should consider the ―establishment of appropriate indicators or statistics, if necessary with the assistance of the ILO, to monitor and evaluate progress made...[towards decent work]‖(ILO 2008 Paragraph II.B.ii).

[3] The United Nation (UN) statistical division has proposed a minimum set of criteria for international comparability. Rural areas are generally classified in accordance with "the size of locality or, if this is not possible, the smallest administrative division of the country." In other words, rural areas comprise a less dense population even if country specific characteristics usually make these areas different from country to another (United Nations 2008).

particularly important to the well-being and survival of poorer rural households, where own-use production is the production of household goods and services for the household's consumption or family living in other households[4]. It includes unpaid caregiving services and household maintenance such as cleaning, laundry, agricultural production for consumption, food preparation, gathering food, and providing for children or elderly. When dealing with shocks or income shortfalls, households may substitute market goods and services with goods and services provided by household members. Since incomes tend to fluctuate, there can be a large amount of fluidity between the consumption of goods and services produced for home consumption and goods and services purchased in the market. In poor rural households engaged in agriculture, it is often the combination of income from employment work activities and own-use production work in collaboration with other household members that sustains the household. The same activity in own use production (e.g. harvesting maize, or food preparation, etc.) can be considered a form of employment if the work is paid or the goods are intended for sale. There are a gendered aspects to these work activities. Evidence from the literature suggests that women perform a large majority of the household's own-use production work; although it varies by context (see, among others, Antonopoulos 2009, Bardasi and Wodon 2006, Budlender 2008; Ilahi 2000). Additionally, contributing family work is a widespread form of employment among women, particularly among the extremely and moderately working poor (ILO 2014). Data from the ILO global employment trend (2014), for instance, suggests that 59 percent of the female labour force in South Asia, 35 percent in Southeast Asia and the Pacific, 35 percent in Sub-Saharan African, and seven percent in Latin America are contributing family workers in the household's business. While contributing family workers are included in the definition of employment (with the ICLS 19th Resolution), remuneration of the work is paid to another household or family member. Indirect remuneration is subject to individual with control of the revenue. Women's greater engagement in work for which they are not directly paid (such as own-use production work and contributing family labour) compared to men results, in some contexts, in women working a greater number of hours than men, and a greater likelihood of facing time poverty, where time poverty is defined as not having adequate time for rest and relaxation. Bardasi and Wodon (2005), for instance, find that women work more hours than men on average in Guinea for 2002-2003 and that time poverty rates are much greater in rural areas than in urban areas. Women's greater engagement in own-use production work and contribution family labour than men also affects how and to what degree women can engage in employment activities for which they are paid directly. Women, for example, may be more likely to combine own-use production and other non-remunerated activities with remunerated work, taking on multiple work tasks at the same time. Floro (1995) argues that overlapping activities are particularly applicable to women in poorer households that do not have the access to resources that would allow them to purchase market substitutes. Additionally, studies suggest that the concentration of women from low-income households in informal paid work is in part related to the greater ability to combine unpaid household work and paid work (Mitra 2005; Chen et al. 2005; Kucera and Roncolato 2008; Roncolato and Radchenko forthcoming). This is because the informal nature of many self-employment jobs, such as street vending or trading, often allows greater flexibility in terms of time dedicated to other activities.

Assessment of current Decent Work indicators for measuring rural women's Social and Economic empowerment in work and proposal for a conceptual framework for measuring rural women's empowerment within decent work

The concept of Decent Work is a means to identify countries' major priorities in terms of labour market outcome achievements as well as a better understanding of productive work overall of both men and women. Recognizing that men and women may not have the same opportunity and treatment in work, and the women may face different constraints around family and engagement in work, many of the Decent Work indicators are sex disaggregated and there are a number of gender relevant indicators including occupation segregation, wage gap, maternity protection, and work time arrangements. While these indicators are important, many are not as easily applicable in a context described above where many individuals may engage in multiple income-earning activities, self-employment activities are the norm, and own-use production work is vital to sustaining the household compared to contexts where individuals are mostly engaged in one or two primary jobs in the formal market. The gender wage gap indicator (EQUA-3), for example, is calculated based on average hourly earnings from employers, which is less applicable in this context where work with earnings from employers is only a small percent of

[4] Specifically, if it is unpaid, the 19th ICLS Resolution considers own-use production work as
a. Producing and/or processing for storage agricultural, fishing, hunting and gathering products that are not intended for sale or profit ;
b. Collecting and/or processing for storage mining and forestry products, including firewood and other fuels;
c. Fetching water from natural and other sources;
d. Manufacturing household goods (such as furniture, textiles, clothing, footwear, pottery or other durables, including boats and canoes);
e. Building, or effecting major repairs to, one's own dwelling, farm buildings, etc.
f. Household accounting and management, purchasing and/or transporting goods;
g. Preparing and/or serving meals, household waste disposal and recycling;
h. Cleaning, decorating and maintaining one's own dwelling or premises, durables and other goods, and gardening;
i. Childcare and instruction, transporting and caring for elderly, dependent or other household members and domestic animals or pets, etc.

Table 1: Proposed work indicators for measuring rural women's empowerment within the context of decent work under the economic and social empowerment component of the FAO (2016) conceptual framework

	Area	Indicators	Already in the DW framework
1.1	Employment and labour force participation	• Men's employment-to population ratio, Women's employment-to population ratio • Men's labour force participation rate; Women's labour force participation rate	Yes (EMP-1 and EMP-5)
1.2	Informal employment, including the agricultural sector	• Proportion of men informally employed; Proportion of women informally employed	Yes (EMP-4)
1.3	Own account workers and contributing family workers	• Proportion of employed men who are own-account workers; Proportion of employed women who are own- account workers • Proportion of employed men who are contributing family workers; Proportion of employed women who are contribution family workers	Yes (EMP-9)
1.4	Work contribution	• Average total number of hours per day men dedicate to remunerated and non-remunerated work in agriculture Average total number of hours per day women dedicate to remunerated and non-remunerated work in agriculture • Average total number of hours per day men dedicate to all remunerated and non-remunerated work; Average total number of hours per day women dedicate to all remunerated and non-remunerated work	No

the work done by men and women. Profits from and time worked in self-employment activities, which often overlap with other activities and are difficult to separate from own-use production, makes the data difficult to capture in this context. Similarly, measures of maternity protection and work time arrangements within employment are less applicable in a setting where much of employment work is informal. Occupational segregation (EQUA-1) measures men and women's difference in occupations in their main job. While important, the occupational categories are broad (ISCO sub-major groups) and less informative than the EMP indicators when disaggregated by sex. Indeed, when compared to the employment-to-population ratio (EMP-1), the other labour force indicators disaggregated by sex: informal employment rate (EMP-4), employment status in employment (EMP-8), and proportion of contributing family labours in total employment (a part of EMP-9) allow for a greater understanding of men and women's differences in employment work as well as engagement in employment that does not provide direct exchange for the work within this context. Previously these indicators included individuals engaged in own-use production of goods (but not services) as a main job in the definition of employment. This changed with the 19th International Conference of Labour Statisticians (ICLS Resolution I, 2013), which distinguishes between work for pay or profit,or employment, and unpaid forms ofwork across five forms of work:1) own-use production work, 2) employment, 3) unpaid trainee work, 4) other work activities, 5) volunteer work. The new concept includes only formal and informal wage employment, self-employment activities, and contributing family labour in the definition of employment. The exclusion of own-use production makes the employment indicators more comparable across countries. Within this context, however, to capture the full extent of men and women's work, the Decent Work framework also needs to include measures of own-use production work and time worked in employment and non-employment work activities. Based on current definitions, the Decent Work time use indicators only focus on time associated with employment activities, not all work activities. The Subsistence Worker Rate (STAB-3), which is the proportion of employed persons who are subsistence workers—where subsistence workers are subsistence farmers, fisheries, hunters, and gathers—needs to be modified to be in line with the new definitions. Even with a modification, a proportion indicator only captures who engages in the work and not the extent to which individuals engage in the type of work.

Additionally, it does not capture all forms of own-use production work.

Under the Social and Economic Advancement component of the FAO 2016 framework,Table 1 presents our proposed set of core indicators that we believe may better capture a decent work framework for the measurement of rural women's socio-economic empowerment in developing countries where small household agriculture in an important part of the economy. The set of indicators is based on both the FAO conceptual framework as well as the ILO decent work Agenda and Decent Work indicators already part of the framework. The indicators proposed are at the country-level. Since rurality differs by country, it is difficult to compare across countries if the focus is only on rural areas. However, we recommend countries also disaggregate by rural/urban areas.

Indicators 1.1, 1.2 and 1.3 are already part of the Decent Work Measurement framework. The employment indicators (under 1.2 and 1.3) provide information on the type of the employment and whether the type of jobs men and women engage in lack basic social or legal protections or employment benefits. Greater empowerment is proxied though fewer women (and men) in informal type work of those employed. The criteria adopted to construct the proportion of employed rural population working under informal labour arrangements follow the resolution adopted by the 17th International Conference of Labour Statisticians. According to the ILO (2012), informal employment is a job-based concept capturing the extent to which employed persons lack basic social protections in a given economy[5]. These indicators are often limited to individuals' main jobs. The 17th International Conference of Labour Statisticians recommendations suggest to countries to compile statistics on multiple jobholders, but countries often do not have the resources to incorporate this into Labour Force Survey questionnaires.

The final indicator set (under 1.4) captures women and men's time spent in all work in agricultural activities and total work time spent in all activities (agriculture and non-agriculture). The indicator set in not currently included in the current Decent Work indicators. Similar to the indicators proposed in the Global Strategy for Improving Agricultural and Rural Statistics "Guidelines for collecting data for sex-disaggregated and gender-specific indicators in national agricultural surveys" (FAO forthcoming) we propose including (1) the average time spent in all agricultural activities by men and women and (2) the average time spent in all work activities in general by men and women. Specifically these are $\left\{\frac{\sum_i T_{Ai}}{X_T}, \frac{\sum_j T_{Aj}}{Y_T}\right\}$ and $\left\{\frac{\sum_i T_{wi}}{X_T}, \frac{\sum_j T_{wj}}{Y_T}\right\}$, where X_T is the total number of adult women in the time use sample, Y_T is the total number of adult men in the time use sample, and T_A is the time spent by the ith female or jth male in work in agricultural production, and T_w is the time spent by the ith female or jth male in all work. We aggregate own-use production and employment in agricultural work and all work, because in this context often the boundaries between own-use production work and employment work are not distinct. For example, it can be difficult to distinguish activities where the crops are primarily for sale versus activities where the crops are for home consumption, since so often these are dual-purpose, particularly in smallholder agriculture. Even aggregated, the indicator set captures the extent of rural women's work as compared to men in this context in a way all the other Decent Work indicators focused only on employment work do not.

Recommendations for data collection of the new indicator set measuring work time

To capture time use data, many labour force surveys as well as agricultural surveys tend to use stylised time methods where time in a specific activity is estimated over a week or month. Data collected in this way are best used when activities take place on a regular basis and when general trends, rather than the actual time spent, are sought (Juster, Ono and Stafford 2003). The preferred approach for collecting time use data is through experimental sampling method for time use data collection, where an individual records their own activities at random times throughout a specified time period. This approach tends to be less prone to systematic measurement error than recall methods, but more burdensome to the respondents and more costly to implement than stylized approaches. As a middle ground—following the Global Strategy Guideline—we propose using a 24-hour recall module that can be included as part of labour force surveys. Unlike other stylised methods where the time period is much longer, the 24-hour recall method reduces methodological biases and allows for the detail needed

[5] From a statistical standpoint, the employment in the informal sectors can be computed according to the characteristics of the enterprises owned by the own-account worker and employers. According to the ICLS, the informal nature of their jobs follows directly from the characteristics of the enterprise, which they own. Three main criteria are employed in defining the jobs performed in the informal agricultural sectors: 1) produced goods are meant for sale or barter; 2) the size of the farm in terms of employment falls below a certain threshold–determined according to national circumstances— 3) farms are not registered under specific forms of national legislation. The informal employment is captured by summing up the total number of informal jobs performed under informal arrangements and not regulated labour relationships. This is the case of contributing family workers who, by definition, inherently hold informal jobs. Accordingly, the ILO statistical definition of ―informal employment— (ILO, 2003) classifies jobs held by contributing family workers as a priori informal, irrespective of the formal or of informal nature of the sector in which they work. The classification does not apply to employees, since the informal nature of the performed job mainly reflects the absence of national labour legislation, social protection or employment benefits that apply to their jobs. In practice individuals within the rural population may engage in multiple forms of employment, the labour force statistics collected, however, are usually based only on individual's primarily and sometimes secondary occupations.

to capture differences in time spent in different work activities (Kan and Pudney 2008). An example module in the appendix merges the time use modules in the American Time Use Survey (ATUS) and the Women's Empowerment in Agriculture (WEAI and pro-WEAI) Surveys. To collect information on the selected respondent's activities, the enumerator asks the respondentfor activities from 4 a.m. the previous day until 3:59 a.m. the day of the interview using pre-codes to record activities. Using the data from this module, the mean population estimates can be inferred by collecting time use data from one randomly selected respondent per household in a subsample of households (and weighted as needed based on the probability of an individual within his or her household) (Frazis and Stewart 2012). A drawback to the 24-hour approach, however, is that we are often interested in time use over a longer period of time than a single day. If data is collecting for many households over a period of time (such as a particular season), inferences will be made on men and women's average time use over that full season. To be comparable across years the module will need to implemented at the same time period every year. Ideally, the module would be implemented quarterly (or at least twice a year) as a way to capture seasonality. Future drafts will include examples of set of time use indicators using data from districts in Uganda.

2. Conclusion

This paper proposes the first part of set of core work indicators with the socio-economic component of the FAO 2016 women's empowerment framework to monitor rural women'sempowerment in the context of decent work within rural areas in developing countries where agricultural is an important part of the economy. This paper is the first of three papers. The other two will cover the Power and Agency and Dignity and Value components of the FAO 2016 women's empowerment framework.

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Appendix

TIME USE MODULE

TIME USE MODULE

PLEASE RECORD A LOG OF THE ACTIVITIES FOR THE INDIVIDUAL IN THE LAST COMPLETE 24 HOURS (STARTING YESTERDAY MORNING AT 4 AM, FINISHING 3:59 AM OF THE CURRENT DAY). THE TIME INTERVALS ARE MARKED IN 15 MIN INTERVALS. MARK ONE ACTIVITY FOR EACH TIME PERIOD BY ENTERING THE CORRESPONDING ACTIVITY CODE IN THE BOX.

	TIME_id	TIME_code	TIME_children		TIME_id	TIME_code	TIME_children
	TIME	Activity (use codes)	Did you care for children 12 years or younger while performing this activity? Yes 1 No 2		Time	Activity (use codes)	Did you care for children 12 years or younger while performing this activity? Yes 1 No 2
	4 am				4 pm		
	4:30				4:30		
	5				5		
Night	5:30				5:30		
	6				6		
	6:30				6:30		
	7				7		
	7:30				7:30		
	8				8		
	8:30				8:30		
	9				9		
	9:30				9:30		
	10				10		
	10:30				10:30		
	11				11		
	11:30				11:30		
	12 pm				12 am		
	12:30				12:30		
	1				1		
	1:30				1:30		
	2				2		
	2:30				2:30		
	3				3		
Day	3:30			Night	3:30		

TIME USE CODES

WENT TO SLEEP FOR THE NIGHT	0
SLEEPING, RESTING, RELAXING	1
EATING OR DRINKING	2
PERSONAL CARE / PERSONAL HYGIENE - E.G. DRESSING, GROOMING, WASHING SELF	3
UNPAID DOMESTIC AND CAREGIVING SERVICES FOR HOUSEHOLD AND FAMILY MEMBERS	
CAREGIVING SERVICES FOR HOUSEHOLD AND FAMILY MEMBERS	4
FOOD AND MEALS MANAGEMENT AND PREPARATION	5
CLEANING AND UPKEEP OF DWELLING AND SURROUNDINGS	6
COLLECTING WATER FOR HOUSEHOLD USE	7
COLLECTING FIREWOOD AND OTHER NATURAL FUELS FOR HOUSEHOLD USE	8
SHOPPING OR BUYING FOOD, CLOTHES, OR OTHER	9
CONSTRUCTION OR REPAIR OF THE HOUSEHOLD PREMISES	10
WEAVING, SEWING, TEXTILE CARE FOR HOUSEHOLD USE	11
OTHER UNPAID DOMESTIC AND CAREGIVING SERVICES FOR HOUSEHOLD AND FAMILY MEMBERS	12
UNPAID VOLUNTEER, TRAINEE AND OTHER UNPAID WORK FOR AN ENTERPRISE, GROUP OR ORGANIZATION	13
UNPAID HELP A NEIGHBOUR, FRIEND, OR OTHER INDIVIDUAL WHO IS NOT FAMILY	14
EXCHANGE AGRICULTURAL WORK FOR ANOTHER HOUSEHOLD	15
WAGE OR SALARY WORK IN AGRICULTURE, AQUACULTURE OR LIVESTOCK PRODUCTION NOT IN AGRICULTURE, AQUACULTURE OR LIVESTOCK PRODUCTION	 15 16
SELF-EMPLOYMENT OR OWN BUSINESS WORK IN AGRICULTURE, AQUACULTURE OR LIVESTOCK PRODUCTION NOT IN AGRICULTURE, AQUACULTURE OR LIVESTOCK PRODUCTION	 16 17
HELPING A FAMILY MEMBER WITH THEIR WAGE OR SALARY WORK IN AGRICULTURE, AQUACULTURE OR LIVESTOCK PRODUCTION NOT IN AGRICULTURE, AQUACULTURE OR LIVESTOCK PRODUCTION	 18 19
WORK FOR FAMILY OR THE HOUSEHOLD BUSINESS IN AGRICULTURE, AQUACULTURE OR LIVESTOCK PRODUCTION NOT IN AGRICULTURE, AQUACULTURE OR LIVESTOCK PRODUCTION	 20 21
AGRICULTURE, AQUACULTURE OR LIVESTOCK PRODUCTION ON THE HOLDING PRIMARILY FOR OWN-USE	22
TRAINING IN AGRICULTURE, AQUACULTURE OR LIVESTOCK PRODUCTION NOT IN AGRICULTURE, AQUACULTURE OR LIVESTOCK PRODUCTION	 23 24
ORGANIZATIONAL MEETING IN AGRICULTURE, AQUACULTURE OR LIVESTOCK PRODUCTION NOT IN AGRICULTURE, AQUACULTURE OR LIVESTOCK PRODUCTION	 25 26
SCHOOL OR HOMEWORK	27
SOCIALIZING AND RELIGIOUS PRACTICE INCLUDING PRAYER OR MEDIATION OR OTHER SPIRITUAL ACTIVITY	28
CULTURE, LEISURE, MASS-MEDIA AND SPORTS PRACTICES, INCLUDES WATCHING TV, LISTENING TO RADIO, READING, EXERCISING, HOBBIES, MASS MEDIA USE	29
COMMUTING OR TRAVELING TO AND FROM WORK OR SCHOOL	30
COMMUTING OR TRAVELING (NOT TO AND FROM WORK OR SCHOOL)	31
OTHER	32

THEMATIC SET

A06

MEASURING THE SOCIAL AND ECONOMIC IMPACT OF CONFLICTS AND POLITICAL INSTABILITY ON AGRICULTURE

Session Organizer
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ABSTRACT

Violent conflict has significant effects on the welfare, resilience and behaviour of individuals, households and communities. These impacts deserve close study at the micro-level, both as a new field of academic inquiry and as an aid to development and poverty reduction policy. Policy practitioners have increasingly realized the importance of understanding, compensating for, and overcoming the constraints caused by violent conflict.

Subsistence agriculture is one of the key livelihood strategies of extremely poor people affected by violent conflict, including those forced to flee. In rural areas, conflict often puts an end to formal economic activities (e.g., export-oriented agriculture), destroys productive assets (e.g., livestock), and restricts access to formal markets and traders. In response, resilient households resort to various informal, small-scale, labour-intensive activities including subsistence agriculture. This can prove particularly valuable for refugees in protracted humanitarian emergencies, given the restrictions on their movement and their inability to access to much land. For example, planting very small vegetables gardens is one of the most labour intensive and least land intensive forms of agriculture, which can even be undertaken even inside a refugee camp.

However, relatively little is known about how households struggling to survive protracted violence and displacement get by economically, what shapes their (agricultural) livelihoods and what determines their food security. This is true both of socio-economic determinants and of the natural science of smallholder agriculture in conflict and fragile settings.

Standard agricultural surveys in conflict-affected countries only sporadically feature questions related to the causes and consequences of violence, leaving treatments ad-hoc and incomparable across different settings. This makes it hard to build a systematic and comparable understanding of how violence has affected different people, communities and population groups, and constitutes a key gap in agricultural policies in conflict-affected settings. To gather better data on the impacts of conflict and instability, well-designed surveys need to acknowledge the prior existence of violent conflict in formal questionnaires and survey designs. A recent publication by the World Bank helps to address this need (Brück, T. et al, 2013. „Measuring Conflict Exposure in Micro-Level Surveys". LSMS-ISA Sourcebook, World Bank, Washington, D.C.) as do the many papers published by the Households in Conflict Network (www.hicn.org).

Building on these insights, this session will review recent efforts to measure violence, conflict, instability and fragility at the micro-level in the agricultural sector in low, middle and high income countries. Particular preference will be given to papers developing and testing new methodologies for data collection on conflict dynamics or individual behaviour and welfare outcomes in rural settings and to papers using such data analytically to understand the performance of agriculture and rural development in times of violent conflict.

LIST OF PAPERS

Agriculture census in Georgia and statistics

K. Nadiradze | Association for Farmers Rights Defense, AFRD | Tbilisi | Georgia
N. Phirosmanashvili | Association for Farmers Rights Defense, AFRD | Tbilisi | Georgia
M. Goginashvili | Association for Farmers Rights Defense, AFRD | Tbilisi | Georgia
DOI: 10.1481/icasVII.2016.a06

THEMATIC SET

A06

Gender perspective to effects of violent communal conflicts on selected rural communities in Edo and Ondo states, Nigeria

M. J. Koyenikan | University of Benin | Benin City | Nigeria
G. N. Vincent-Osaghae | University of Benin | Benin City | Nigeria
S. I. Ohiomoba | Federal Ministry of Agriculture | Abuja | Nigeria
G. O. Alufohai | University of Benin | Benin City | Nigeria
V. O. Okotie | Federal Ministry of Agriculture | Abuja | Nigeria
DOI: 10.1481/icasVII.2016.a06b

Assessment of conflicts activities on livelihood of fishing and fish farming households in Nigeria

B. Fregene | University of Ibadan | Ibadan | Nigeria
J. Idogun | University of Ibadan | Ibadan | Nigeria
M. Bello | University of Maiduguri | Maiduguri | Nigeria
DOI: 10.1481/icasVII.2016.a06c

The impact of civil war on crop production in Somalia

O. Jeilani | Consultant | Mogadishu | Somalia
DOI: 10.1481/icasVII.2016.a06d

Agriculture census in Georgia and statistics

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DOI: 10.1481/icasVII.2016.a06

ABSTRACT

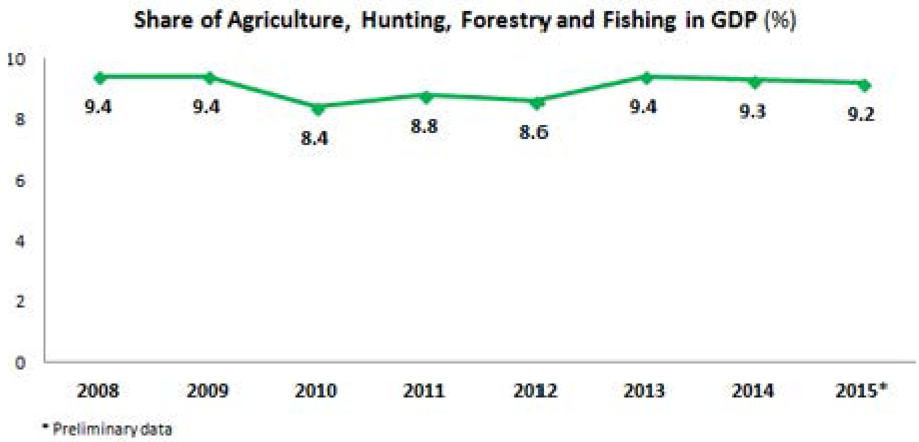
According to the recent census results in Georgia, as of October 1, 2014, there are 642.2 thousand holdings in the country: of which 640.0 thousand households and 2.2 thousand legal entities. 30.9% of holders are women. Among the regions, the largest number of holdings is observed in Imereti (19.6%), Kakheti (15.1%) and Samegrelo-Zemo Svaneti (13.3%). The diagram below illustrates regional distribution of holding numbers.

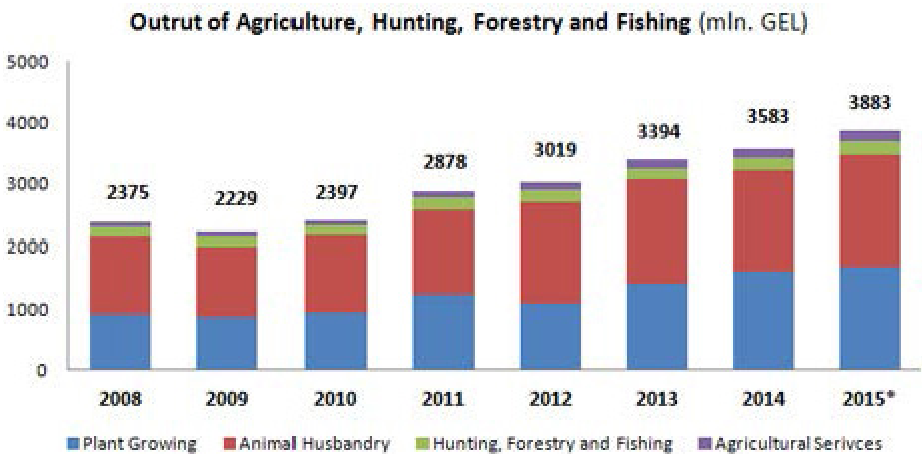
Keywords: Keyword 1, Keyword 2, Keyword 3 (character 12 pt, double-justified)

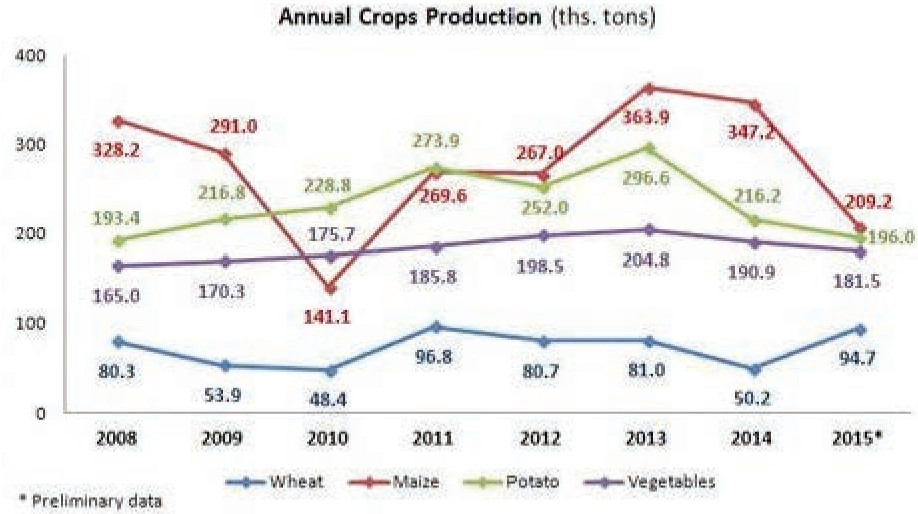
PAPER

1. Agricultural Census Data in Georgia

Major portion of holdings are operating small-sized land. In particular, more than three fourth of holdings (77.1%) are operating agricultural land of size less than 1 ha and their total area constitute 21.5% of whole operated agricultural land. 40.1% of agricultural land operated by holdings are located in Kakheti, 15.5% - in Kvemo Kartli, and 9.7% - in Samtskhe-Javakheti. The census has covered all agricultural holdings in the country (on the territory controlled by the Government of Georgia) and it was done according to the methodology developed by the Food and Agriculture Organization.





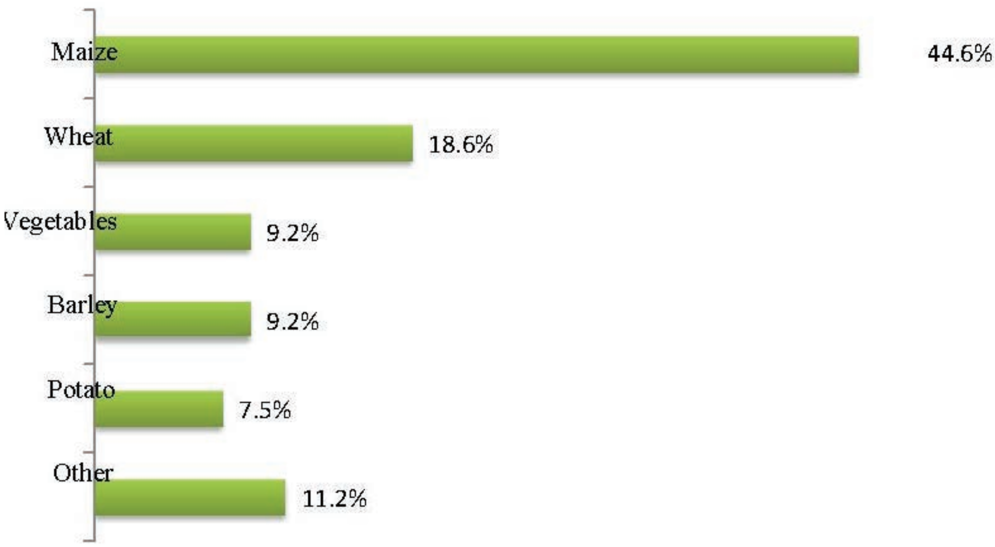


2. Food Security as challenge for Georgian Farmers

Georgian food producers, farmers and Agricultural Cooperatives should be in response of a growing number of outbreaks associated with consumption of fresh fruits and vegetables. All our efforts are on a development of the a science-based regulatory frameworks to address the production of all fruits and vegetables in organic manner according existing guidance documents and regulations; and, consistent with a mission to promote uniform food safety laws, rules and regulations.

Opportunities in Food microbiology research are the gateway to sustaining and improving agriculture and food production in Georgia, quality, and safety. Multidisciplinary research must be undertaken to capitalize on advances in different disciplines, such as genomics, nanotechnology, and computational biology. Research into the interactions of animal and plant hosts with pathogens and beneficial microbes is essential to preventing disease and encouraging mutuality interactions. On a more holistic scale, interactions occurring among organisms within a microbial community require study so that a healthy balance between the highly managed ecosystems of industrial agriculture and the unmanaged ecosystems of the Food Security can be achieved.

Figure 1 - Structure of Land under Temporary Crops by Particular Crops (as of October 1, 2014)



As of October 1, 2014, there is 377.4 thousand ha of arable land operated by holdings, of which 85.5% is operated by households and 14.5% - by legal entities. An average area of arable land operated by holdings is 0.7 ha. 86.9% of holdings are operating arable land of size less than 1 ha. 70.3% (265.4 thousand ha) of arable land area is covered by temporary crops1. This indicator is 77.2% (249.2 thousand ha) for households and 29.5% (16.2 thousand ha) - for legal entities. 49.4 thousand holdings are operating the land under temporary crops of size 1 ha and more, 3.5 thousand holdings - 5 ha and more, and 1.6 thousand holdings - 10 ha and more. 44.6% of land under temporary crops is covered by maize, 18.6% - by wheat, 9.2% - by vegetables, and 9.2% - by barley. The diagram below shows the structure of land under temporary crops by particular crops.

Table 1: Livestock and Poultry Numbers and Average Values (as of October 1, 2014)

Indicator	Unit of measurement	Holdings of all categories	Households	Legal entities
Livestock and poultry numbers				
Cattle	Thousand heads	1,005.4	997.0	8.5
Sheep and goat	Thousand heads	989.3	962.0	27.3
Pig	Thousand heads	213.1	195.3	17.8
Poultry	Thousand heads	8,216.0	5,441.3	2,774.7
Number of holdings with livestock/poultry				
Cattle	Thousands	271.9	271.7	0.1
Sheep and goat	Thousands	23.7	23.7	0.0
Pig	Thousands	93.9	93.9	0.0
Poultry	Thousands	364.9	364.8	0.1
Average number per holding[2]				
Cattle	Heads	3.7	3.7	60.4
Sheep and goat	Heads	41.7	40.6	700.7
Pig	Heads	2.3	2.1	424.1
Poultry	Heads	22.5	14.9	32,264.0

Tables: The highest number of cattle is observed in Samegrelo-Zemo Svaneti (195.2 thousand heads), Imereti (168.8 thousand heads) and Kvemo Kartli (140.7 thousand heads). 14.1 thousand holdings have 10 and more cattle, while 0.5 thousand holdings have 50 and more. The diagram below shows regional distribution of cattle numbers.

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http://enpard.ge/en/

A06

Gender perspective to effects of violent communal conflicts on selected rural communities in Edo and Ondo States, Nigeria

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ABSTRACT

Rural dwellers cherish social relationships and are passionately engaged in such interactions even as they carry out agricultural practices on which they depend for livelihood. The situation can readily be jeopardized by conflicts. Violent communal conflict (VCC) is usually unpredictable, could retard development, perpetuate poverty and household food nutrition and health, insecurities, and widen gender inequalities. Individuals and groups, including gender categories are usually affected differently irrespective of the causes of VCC. Empirical data on causes and effects of VCC on gender categories will be valuable to inform individual, community and policy decisions.

This study assessed gender perspective to effects of violent communal conflicts on selected rural communities in Edo and Ondo States of Nigeria. Specifically it by gender; described the socio-economic characteristics of the respondents; ascertained gender roles in key household activities; identified causes and severity of VCCs experienced; and examined the effects of VCC on social and livelihood activities; ascertained the coping/survival strategies used; and identified perceptive solutions to conflict.

A two-stage sampling procedure was adopted; firstly the purposive selection of three communities that experienced VCC within 2010-2014 in each State and secondly, the random selection of sixty (60) households / respondents per community to give a total of 360 respondents. Data were collected using structured questionnaire while focus group discussion (FGD) and key informants were used to triangulate information. Data analysis was by descriptive and inferential statistics.

The study revealed that male youth constituted 20. 7%, adult males (40.6%), female youth (10.4%) and adult females (28.2%) that majority of the respondents were males (61.4%), married (68.6%), and with a mean age of45.8years. About 24.5% had no formal education,71.5%were indigenes and family size was5-9 persons. About 67.7% held two leadership positions, with 63.1% engaged in agricultural enterprises in a mean farm size of 2.09ha. It was found that VCCs were mostly caused by power/ leadership tussle (65.7%). Gender roles slightly changed with increase in activities of females. Gender categories differed significantly with respect to effect of VCC on social relations (F=9.743; p=0.000) and livelihood (F=13.705; p=0.000). Wilcoxon signed-rank test shows that the difference before and after conflict is statistically significant for bread winning (z= -9.603), ownership of land (z= -9.368), use of land (z= -7.673) and use of credit (z= -7.802).

The VCC adversely affected gender categories differently but more severe on the females. Bread winning and agricultural indicators such as credit access, land ownership and use were negatively affected after VCC. Appropriate policy support for compensation, peace-building and conflict prevention are recommended.

Keywords: Communal conflicts, socio-economic variables, gender categories

PAPER

1. Introduction

1.1 Background to the Study

Communal connotes shared social interaction which entails interpersonal contact, reciprocal response and an inner adjustment of behavior to the actions of others (Ekong, 2010). Conflict is a form of social interaction in which the actors seek to obtain scarce reward by eliminating or weakening other contenders, (Ekong, 2010). It degenerates into violent situations when excessive physical force and weapons are used. Yesufu, (2005) observed that in rural Nigeria, conflicts may arise where there is difference of opinion, exploitation, and challenge to security between groups. In conflicts, security and livelihood activities are disrupted and high level of poverty, food and nutrition insecurities and communal living and individuals could be affected.

Gender is an acquired identity that is learned, changes over time, and varies widely within and across cultures. It is relational and refers not simply to women or men but to the relationship between them, (USAID, 2007). It is could be seen as development issue since it limits potentials and opportunities. These also dictate their access to and control of resources. Gender inequalities arise from deep-rooted and durable social norms. According to Kabeer, (2012), barriers range from social norms that constrain women's choices and actions, to discriminatory legal and regulatory frameworks tend to restrict opportunities to engage economic and social engagements. In cases where changes in roles have been experienced over the years, corresponding access and control of resources could not be guaranteed (Kabeer, 2010).

Bolarinwa, Abdulsalam-Saghir and Oyekunle (2013) in Nigeria, found adverse impact of conflicts on farmers' livelihood (crops, domesticated and wild life animals), lost productive land. In another study, Bolarinwa, et al.,(2013) found that communal conflict management styles, employed by farmers often lead to destruction of life and properties in core conflict areas. Yesufu, (2005) observed that the frequency of religious and communal clashes, riots, conflicts and violence since 1980, has reached endemic proportions. He suggested the need for self-appraisal, correcting the inherited primordial, religious and cultural, and colonial structures. Nwonu, et al., (2013) found that both the Boko Haram crisis and the Niger Delta crisis have adverse impact on the country's international image and tourism development, consequently on youths' unemployment rate.

1.2 Statement of Problem

Conflicts are antagonistic social interactions and have been of frequent occurrence globally and particularly Nigeria in recent times. It is necessary to provide evidence and understanding of indicators involved in communal conflicts at micro level (Bruck and Justino, 2013) to improve academic research on the issues to better inform policy and interventions. Edo and Ondo States recorded various VCCs which disrupted communal life particularly because of the rural sector's dependence on agriculture and other primary occupations. Conflict could affect the gender groups differently due to varying roles, opportunities, resources, empowerment/capabilities and barriers the society ascribes to the positions occupied by individuals.

1.3 Objectives of the Study

This study assessed gender perspective to effects of violent communal conflicts on selected rural communities in Edo and Ondo States, Nigeria. Specifically it by gender;

1. described the socio-economic characteristics of the respondents;

2. identified causes and severity of VCCs experienced;

3. ascertained gender roles in key household activities before and after VCC;

4. examined the effects of VCC social and livelihood activities;

2. METHODOLOGY

2.1 Study Area

This study was conducted in Edo and Ondo States located at the south western agro-ecological zone of Nigeria. Edo State has an area of 6,873 square miles, 6° 30oN 6°E as its coordinates and an estimated population of over 3,497,502. Ondo State is made up of 18 local government areas. The state lies between longitude 4o 30o N and 6 o East of the Greenwich meridian, 50 450and 80 150 North of the Equator. It has a land area of 14788.723 square kilometers (km2) and a population of 3,441,024 comprising of 1,761,263 males and 1,679,761 females (National Population Commission, 2006).

Edo and Ondo States are made up of 18 Local Government Areas each. They have tropical climate characterized by two distinct conditions of wet and dry seasons. The people are mostly subsistence farmers, public servants, traders and artisans. Major crops produced are rubber, oil palm, cocoa, yam, cassava, maize, rice and plantain. There is also significant animal husbandry, fisheries and forestry activities.

2.2 Sampling Technique

A two-stage sampling process was adopted involving firstly purposive selection of three communities in Edo and Ondo States which experienced VCC in the last five years. They are;

Edo-Egbaen, Okhoromi, Eghirhe communities, Western Post news July 18, 2014; December 31, 2014(http://westernpostnigeria.com/boundarydisputeclaims-livesinedo)

Second stage was the random selection of 60 households per community to give a total of 360 respondents. FGD was used in Edo State but key informants were involved in Ondo communities due to lingering court action in Arigidi communities. Vanguard News August 21, 2011 (www.vanguardngr.com/2011/02/ondo-sets-up-commission-of-in...)

The pre-test was carried out in Okhoromi community which is not included in the study. Test-retest method showed reliability with r=0.893.

Fine tuned instrument content.

2.3 Data collection

Data were collected using structured questionnaire. Focus group discussion (FGD) involving four (4) focal groups (adult male, adult female, male and female youths) was used in Edo communities while key informants were used to complement the questionnaire in Ondo communities due to lingering hostilities. However, questionnaire from 13 respondents were incorrectly filled and so were excluded in the final data analyses.

2.5 Data Analysis

Data analysis involved the use of descriptive statistics and inferential statistics such as using SPSS.

2.6 Measurement of Variables

Gender roles/division of labour in households: level of involvement was measured using a 3point likert type scale of: Highly involved (3), Little involved (2) and Not involved (1). A mean score ⚹2 =involved.

Income from livelihood activities-Average annual income (N)/household.

Severity of VCC indicator items-Actual occurrence/quantity of relevant items were obtained and categorized into 3pt scale while others were measured on a 3-point likert type scale of very serious=3, serious=2 and not serious=1 for 23items minimum=23, maximum=69

Perceived Effect on social and livelihood indicators- was measure on a 3-point scale for 15 items of social indicators to give scores; minimum=15 and maximum=45. Livelihood indicator items were 20 to give scores; minimum=20 and maximum=60.

Extent of usage of coping/survival strategies was measured on a 3point scale: regularly/highly used=3, occasionally/moderately used=2, not used=1;

Perceptive measures for VCC resolution- was measured on a 3point scale: regularly/highly used=3, occasionally/moderately used=2, not used=1

3. RESULTS AND DISCUSSION

3.1 Socio-economic characteristics of respondents by gender

Table 1 shows the socio-economic characteristics of the respondents. Male youths constituted 20. 7%, Adult males (40.6%), female youth (10.4%) and adult females (28.2%) that majority of the respondents were males (61.4%), married (68.6%), mean age was 45.8years with more over 50 years (51.6%), 24.5% had no formal education and reasonable proportion had tertiary education (35.5%), majority were indigenes (71.5%), family size of 5-9 persons (67.7%) held two leadership positions, engaged in agricultural enterprises (63.1%) and mean farm size of 2.99ha.

Findings show that males were more in rural communities. High proportion of educated respondents could imply that unemployed youths were resident. The findings also show that more of older male and female an indication that adults populate the communities. Female represented households had less education, farm size but engaged more in agriculture related enterprises.

3.2 Causes of Violent Communal Conflict

Table 2 shows that major cause of conflict was power/leadership tussle (89.6%) followed by land dispute (53.6%). The finding on power is in line with global trend whereby countries have been plunged into crises due to struggle for leadership. Land/boundary disputes affect major source of livelihood for most rural dwellers. Herdsmen versus crop farmers conflicts are not widespread.

3.3 Severity of conflicts

Table 3 shows minimum and maximum responses to the severity items. On the average, five persons died, 120 injured, 123 were displaced, and 28 lost their means of livelihood among other indicators. These are indications of adverse effect on the people.

Table 2: Causes of violent communal conflict

*Causes of VCC	Frequency	Percentage
Land	186	53.6
Political	64	18.4
Community power/Leadership	311	89.6
Herdsmen versus crop farmers	23	6.6
I can't say	4	1.2

*Multiple responses

Table 3: Severity of conflicts

Indicators	No.	Minimum	Maximum	Sum	Mean
Dead persons	28	2	12	151	5.39
Injured persons	27	5	100	559	120.70
People displaced	21	6	100	497	123.67
People rendered unemployed or lost means of livelihood	21	6	40	604	28.76
Students who dropped out of school	6	6	50	186	31.00
People rendered incapacitated	5	4	14	42	8.40
Houses burnt	26	6	50	319	12.27
Vehicles damaged burnt	23	6	33	277	12.04
Farms destroyed	9	1	20	54	6.00
Looting	17	1	40	161	9.47
Abduction	3	10	10	30	10.00
Other properties damaged	16	8	30	194	12.13
Agricultural produce lost	3	20	20	60	20.00
Land forfeited	17	10	25	257	15.12
Sexual abuse	4	10	15	45	11.25
Relocation	21	10	136	726	34.57
Temporary flee	22	1	132	1273	57.84
Gun shots injury	21	21	120	1671	79.57
Machetes and other weapon injury	23	1	50	488	21.22
Use of indigenous knowledge for warfare	22	1	40	612	27.82
Intervention of law enforcement agencies	18	1	25	402	22.33
Committee/tribunal	2	1	1	2	1.00
NEMA's intervention with relief materials	0				
Visit of government functionaries	3	1	5	7	2.33
Valid N (listwise)	0				

3.4 Gender Roles before and after

Roles of males before and after

Fig 1 shows male gender roles in key household activities before and after VCC. The results show that some activities which were considered exclusively women's were undertaken by men before and after VCC experience though at lower extent than female. These include fetching water, sweeping, cooking, and washing clothes. This is an indication of modern values infiltrating the communities. The performance of some of the roles changed/increased after VCC experience.

Roles of females before and after VCC

Fig 2 shows female gender roles in key household activities before and after VCC. The results show that some activities which were considered exclusively men's were undertaken by women before and after

Figure 1 - Roles of male before and after

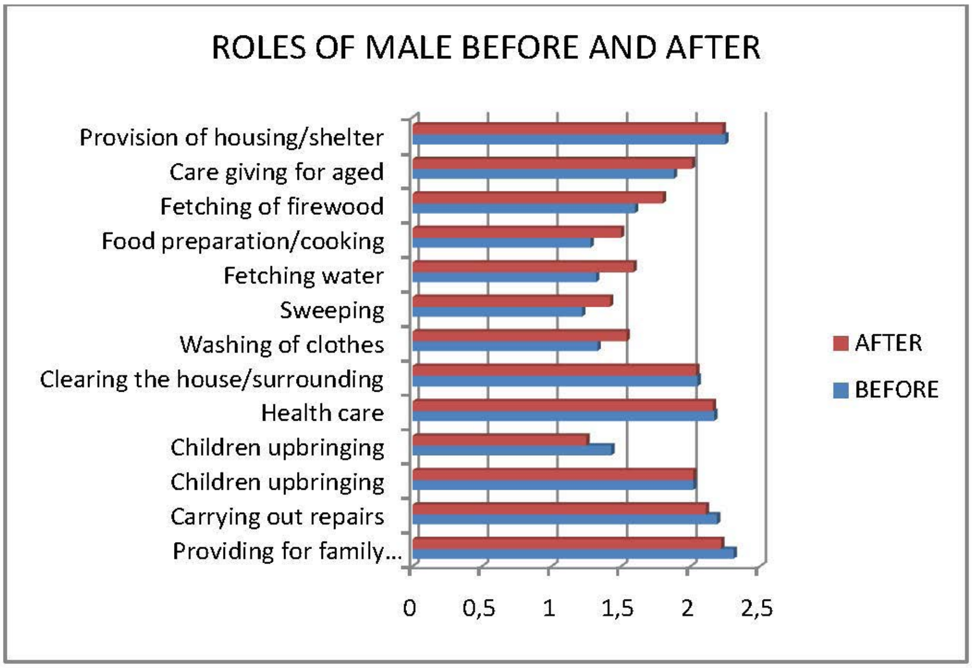
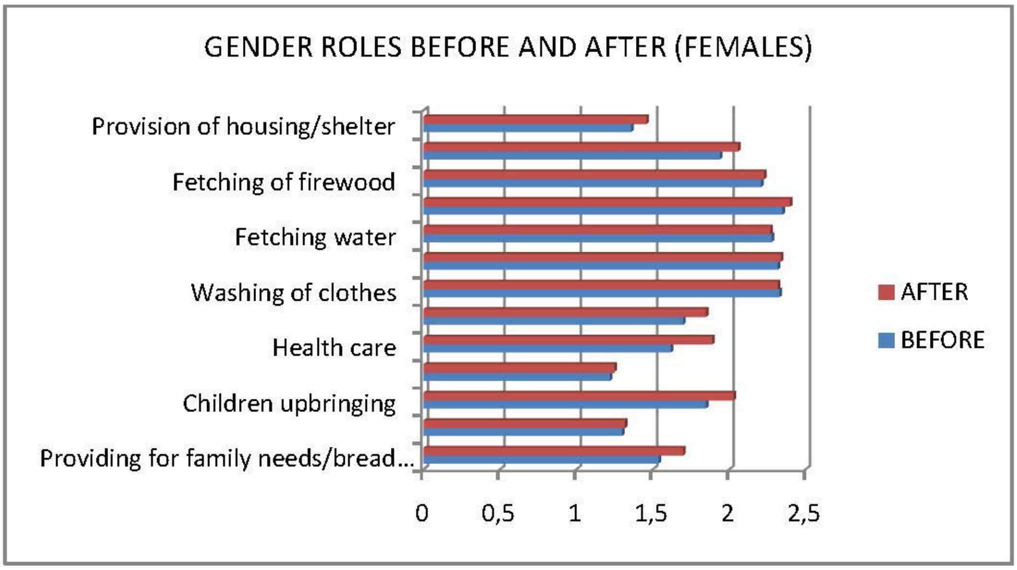


Figure 2 - Roles of female before and after



VCC experience. Theses include provision of shelter and bread winning. Women's performance of roles was high for all the roles before and after VCC experience. Higher performance after VCC was revealed for almost all and no decline in performance of any. This is an indication that females carried additional burdens after VCC. It could be that their spouses died or were maimed or relocated. The performance of some of the roles changed/increased after VCC experience.

3.5 Effects of Violent Conflicts

3.5.1 Perceived effects of VCC on social activities by gender

Table 5a shows that respondents' social lives were affected in several ways as the result of VCC. The effects of items 1-3 were common to the gender categories: poor participation in community activities (X =2.21-2.51) highest for female youth, disruption of peace (2.56), social insecurity (X =2.50). In addition to these female youth perceived effect on disruption of worship (X =2.22), loss of human dignity/ confidence (X =2.89), suspicion (X =2.03) especially for female youth.

Some positive social effects were perceived by the females; clearer definition of issues in contention (X =2.42), group cohesion and solidarity (X =2.31), alertness to members interests (X=). The findings confirm the vulnerability of females which agrees with Kanono (2015) which found that women were

Table 5a: Perceived effects of VCC on social activities by gender

Social activity items	Male Youth		Male Adult		Female Youth		Female Adult	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Poor participation in community activities	2.21*	.768	2.29*	.798	2.53*	.810	2.46*	.676
Disruption of peace	2.08*	.666	2.33*	.751	2.56*	.735	2.47*	.661
Social insecurity/fear	2.01*	.682	2.03*	.643	2.50*	.737	2.30*	.661
Disruption of worship	1.46	.670	1.57	.647	2.22*	.898	1.74	.631
Marriage barrier	1.28	.587	1.28	.525	2.25*	.967	1.45	.628
Accommodation barrier	1.42	.622	1.52	.628	2.31*	.889	1.66	.657
Hostility outside the communities	1.32	.577	1.49	.628	2.17*	.878	1.84	.699
Loss of human dignity/confidence	1.51	.605	1.51	.543	2.89*	.785	1.92	.821
Mental problem	1.22	.562	1.28	.539	1.47	.810	1.29	.537
Inferiority complex	1.50	.712	1.55	.626	1.97	.696	1.87	.698
Suspicion	1.65	.632	1.71	.671	2.03*	.654	2.17*	.825
Clearer definition of issues in contention	1.75	.868	1.85	.801	2.42*	.770	2.02*	.760
Amicable resolution of issues	1.57	.668	1.70	.734	2.19*	.822	1.85	.737
Group cohesion and solidarity	1.58	.622	1.73	.736	2.31*	.624	1.93	.722
Alertness to members' interest to prevent future conflicts	1.68	.601	1.88	.824	2.14*	.723	2.26*	.803

*≥2.00=serious effect/seriously affected

vulnerable. The low indication of effects of social items by males could be that males might not want to exhibit weakness.

3.5.2 Perceived effects of VCC on livelihood activities by gender

Table 5b shows that respondents' livelihood were affected in several ways as the result of VCC.

Table 5b: Perceived effects of VCC on livelihood activities by gende

Livelihood indicator items	Male Youth		Male Adult		Female Youth		Female Adult	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Malnutrition	1.39	.545	1.40	.654	1.67	.478	1.78	.740
Reduction in life expectancy	1.38	.516	1.38	.516	2.69*	.467	2.68*	.667
Low productivity in livelihood activities	1.44	.528	2.71*	.702	1.81	.525	2.18*	.791
Poverty	2.40*	.573	2.31*	.729	2.64*	.467	2.72*	.753
Increased dependency	1.44	.625	1.67	.704	1.92	.500	1.87	.636
Reduction in feeding regime	1.56	.625	1.62	.604	2.07*	.478	1.85	.664
Wasting	1.65	.675	1.70	.715	2.65*	.478	1.95	.791
Irregular school system	2.69*	.642	2.65*	1.001	1.81	.624	1.48	.596
Relocation	1.64	.657	1.72	.730	2.00*	.586	2.24*	.774
Displacement from land	1.76	.796	1.65	.738	2.11*	.575	2.08*	.728
Rural urban migration	2.94	.748	1.82	.740	2.31*	.525	2.28*	.835
Dysfunctional social amenities	1.72	.655	1.62	.702	2.14*	.593	2.13*	.782
Poor nutrition	1.47	.649	1.58	.645	2.03*	.446	1.92	.769
Unemployment and restiveness	2.67*	.732	2.83*	.686	1.89	.465	2.11*	.675
Environmental hazards	1.61	.662	1.62	.651	1.72	.513	1.84	.725
Food insecurity	1.50	.531	2.67*	.724	2.75*	.500	2.87*	631
Inability to educate children	1.51	.628	1.65	.643	1.72	.454	1.54	.654
Poor living standard	2.67*	.605	2.79*	.754	2.81*	.467	2.16*	.512
ill health	2.61	.662	1.57	.589	1.86	.543	1.71	.515
Low production	1.75*	.622	2.73*	.696	1.97	.560	2.14*	.618

*≥2.00=serious effect/seriously affected.

The females indicated more effects on livelihood activities than males. This is also an indication vulnerability of females than males. Males were affected mostly in areas.

3.6 Difference between gender categories with respect to the effects of VCC (ANOVA)

From Table 6a, there were significant differences between gender categories with respect to effect of social and livelihood activities with F=9.743; p=0.000 and F=13.705; p=0.000 respectively. The Post Hoc test shows that the perceived effects for male youth and male adult were similar, but different from the effect on female youth and female adult which were also similar.

3.7 Difference between selected socio-economic variables of respondents before and after VCC

Table 7 shows that or the first variable, providing for family needs, the result shows the effect after the event. It shows that 119 people had their situation turned negative as a result of the clash hence could perform less of this duty of providing for their family needs. Only one respondent had situation turned positive while 227

Table 6a: Difference between gender categories with respect to the effects of VCC

		Sum of Squares	df	Mean Square	F	Sig.
	Between Groups	577.421	3	192.474	9.743	.000
Social activities	Within Groups	6775.841	343	19.755		
	Total	7353.262	346			
	Between Groups	2490.073	3	830.024	13.705	.000
Livelihood activities	Within Groups	20772.993	343	60.563		
	Total	23263.066	346			

Table 6b: Post Hoc Tests

Gender	**Perceived effects on social activities**	**Perceived effects on livelihood activities**
Male youth	23.69[a]	28.20[a]
Male adult	24.22[a]	31.33[a]
Female youth	29.49[b]	38.36[b]
Female adult	30.06[b]	38.39[b]

Means for groups in homogeneous subsets are displayed.

respondents' situation was not changed after the incident. However, Wilcoxon signed-rank test shows that the difference after the conflict is statistically significant, z= -9.603b, p← 0.0005. The same goes for all other

Table 7: Wilcoxon Signed Ranks Test

	Providing for family/bread winning	Ownership of land - Ownership of land	Use of land - Use of land	Use of credit/money - Use of credit/money
Z	-9.603[b]	-9.368[b]	-7.673[b]	-7.802[b]
Asymp. Sig. (2-tailed)	.000	.000	.000	.000

Ranks

		N	Mean Rank	Sum of Ranks
Providing for family needs/bread winning - Providing for family needs/bread winning	Negative Ranks	119[a]	60.29	7174.00
	Positive Ranks	1[b]	86.00	86.00
	Ties	227[c]		
	Total	347		
Ownership of land - Ownership of land	Negative Ranks	117[m]	66.04	7726.50
	Positive Ranks	9[n]	30.50	274.50
	Ties	221[o]		
	Total	347		
Use of land - Use of land	Negative Ranks	90[p]	56.75	5107.50
	Positive Ranks	15[q]	30.50	457.50
	Ties	242[r]		
	Total	347		
Use of labour - Use of labour	Negative Ranks	85[s]	55.20	4692.00
	Positive Ranks	17[t]	33.00	561.00
	Ties	245[u]		
	Total	347		
Use of credit/money - Use of credit/money	Negative Ranks	100[y]	66.04	6603.50
	Positive Ranks	21[z]	37.02	777.50
	Ties	226[aa]		
	Total	347		

variables: ownership of land, use of land, use of labour and use of credit. The findings are indications that those engaged in agriculture related enterprises were adversely affected by VCC.

4. CONCLUSIONS

Violent communal conflicts affected social relations and livelihood activities of the respondents. The effects were different from one gender category to another. Agriculture related variables were adversely affected by VCC. The female youth and adult felt the brunt more.

5. RECOMMENDATIONS

1. Community outreaches should be mounted and available communication channels used to appeal to members and enlighten on ills of violent conflicts.

2. Appropriate policy support for compensation, peace-building and participatory conflict prevention and resolution are recommended.

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A06

Assessment of conflicts activities on livelihood of fishing and fish farming households in Nigeria

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ABSTRACT

There has been an appreciable decrease in fish catch from inland waters due to conflicts from environmental pollution, religious and tribal clashes; as well as at the household level based on differences in gender roles. Lack of enforcement of fisheries laws and data collection have also resulted in failure to coordinate and restrain the many users, thereby affecting livelihood of fisher folks and food security. However, evidence of conflict on their livelihood and on fish catch and production has not been documented. The study was therefore aimed to identify various forms of conflict, perception of fisher folks and impact on the fishing and fish farming households in Nigeria; and factors influencing conflict. Multistage stratified sampling method was used to select households involved in fishing and fish farming from two States each in the North East (NE) and South South (SS) political zones of Nigeria. Fishing and fish farmers were proportionally and randomly sampled from lists obtained from Agriculture Development Program and Ministry of Agriculture and Natural Resources in each state based on known conflict Local Governemt Areas. Both primary and secondary data were used for the study. Qualitative primary data were collected through In-Depth Interviews with heads of Fisheries Department and leaders of livelihood groups along the capture fisheries and aquaculture value chains. Structured questionnaires were administered to a sample size of 96 and 44 for fisher folks and fish farmers respectively in NE, while 93 and 117 were sampled among fisher folks and fish farmers respectively in SS; being a total of 350 households. Descriptive statistics and logit model were used for the analysis. Various forms of conflicts, effects on fisher folks" livelihood and food security in fishing communities were documented. Types of perception, vulnerabilities, and methods of adaptation to the various forms of conflict were documented. Implication of conflict and migration on the household and fisheries activities as major sources of livelihood were discussed. Types of conflict and productivity of fish differed with political zones. In conclusion, conflict activities had adverse effects on livelihoods and food security of fishing and fish farming households.

Keywords: Perception, Vulnerabilities, Adaptation, Food security

PAPER

1. Introduction

Fisheries resources are a major source of food especially as animal protein for humans and provide employment and economic benefits. According to Food and Agriculture Organisation (2016), in 2013, fish accounted for about 20 percent of animal protein intake in developing countries; Nigeria inclusive. Fisheries can therefore play a role in eradicating extreme poverty and hunger especially in the South-South where most households within the region depends on fishing and fish marketing (Kingdom and Alfred-Ockiya, 2009). Based on the immense role fisheries play to the food security and development of a country such as Nigeria, it is imperative to know that it is being affected by the complex, multi-lingual, multi-cultural diversities of the people. In recent years, these have triggered different forms of conflicts ranging from ethno-religious conflicts to cultural conflicts to political conflicts and to conflict in resource use (Danfulani, 2009). Conflicts take place in fisheries when groups or individuals seek the same resource using different methods or try to utilize the same space for their activities with either party seeking dominance (FAO, 2003). Therefore, conflicts over access and control of fisheries and aquatic resources are a global phenomenon. However, they have particular importance in Nigeria where a significant portion of the population depends on capture fisheries for food and livelihoods. Conflict has led to violence, but avoiding and shunning conflict is also problematic. This is because unresolved problems may flare up again, often with renewed vigour (Salayo et al., 2006). This has been the case in the North East (NE) and South-South (SS) Agro-ecological Zone (AEZ) of Nigeria where unresolved conflict activities have been noted to be a major factor affecting production of fish.

1.1 Problem Statement

Fish catch from inland waters have decreased over the years due to conflicts from environmental pollution, religious and tribal clashes. There has also been inadequate enforcement of fisheries laws and data collection which failed to coordinate and restrain the many users, thereby affecting livelihood of fisher folks and food security. Livelihoods are now threatened as a result of the depletion of aquatic lives, deforestation of farm lands and loss of biodiversity resulting from overexploitation of existing resources and the resultant pollution (Egbe, 2012). Though there is no specific statistics as to how much conflict has dwindled fish production in the agro-ecological zones but according to Davies (2008) the livelihood of fisher folks which was once solely dependent on fisheries resources, accounting for more than 85% annual income, is now combined with other occupation such as arable farming and trading among several others. These livelihoods play complimentary and supplementary role in stabilizing the economy of fishing communities (Fregene, 2005).

1.2 Justification for Study

The presence of many inland water bodies in the NE and SS provide sources of livelihood from fishing and fish farming. Moreover, FAO (2008) reports that the fisheries sector is valuable and important for employment, livelihood support, poverty reduction, food security as well as foreign exchange earnings. The sector employs men in the main fishing activity/pond construction, while women are involved with the on-shore postharvest activities such as processing, storage and trading. Due to various conflict activities in the region, the fisheries sector has become vulnerable and the livelihoods of most fishers are threatened. However, evidence of conflict on their livelihood and on fish catch and production has not been documented.

1.3 Objectives and Hypothesis of Study

The study was therefore aimed to identify various forms of conflict, perception of fisher folks and impact on the fishing and fish farming households in Nigeria; vulnerabilities, adaptation and factors influencing conflict.

$\mathbf{H_{01}}$= None of the demographic and socio-economic factors have any significant relationship on enhancing conflict activities.

2.0 Methodology

2.1 Sampling Procedure

Multistage sampling method was used to select two geopolitical zones in which conflict activities were more prominent among fish folks and fish farmers. In the NE, Borno and Taraba States were selected, while Delta and Edo States in SS zones. Households involved in fishing and fish farming were proportionally and randomly sampled from lists obtained from Agriculture Development Program and Ministry of Agriculture and Natural Resources in each state based on known conflict affected Local Governemt Areas (LGAs). Structured questionnaires were administered to a sample size of 96 and 44 for fisher folks and fish farmers respectively in NE, while 93 and 117 were sampled among fisher folks and fish farmers respectively in SS; being a total of 350 households. Both primary and secondary data were used for the study. Qualitative primary data were collected through In-Depth Interviews with heads of Fisheries Department and leaders of livelihood groups along the capture fisheries and aquaculture value chains.

2.2 Data Analysis

Descriptive statistics was used was to describe household characteristics. Logit model will be used to analyze factors enhancing conflicts.

3.0 Results and Discussion

3.1 Socio-economic Characteristics

Presented in Table 1 are forms and perceptions of conflicts in NE and SS AEZs of Nigeria. In the NE AEZ, the predominant form of conflict is religious (57.1%), while 25.7% indicated no activity of conflict. The dominant forms of conflict in the SS AEZ range from politics (19.0%) to oil pollution (13.3%) and land ownership (5.7%) which are collectively 'resource control' form of conflict; but 41.4% observed none. The perception of conflict indicated as very severe was 83.6%) in NE, but in the SS AEZ main perception of conflict were severe 40.0% and very severe (18.6%). This is in line with the findings of El-Bushra et al (2013) who reported that land disputes such as competition over access to oil-bearing land and to compensation for environmental impact of oil and gas including political manipulation of elections are the major cause of conflict in the south-south AEZ. Arong and Egbere (2013) also reported that oil spills have destroyed the aquatic ecosystem leading to decline of fisheries resource.

The major form of livelihood in the NE was fishing (68.6%) while 31.4% were engaged in fish farming as an alternative (Table 2). In the SS AEZ the major form of livelihood was fish farming (55.7%) and fishing (44.3%). It was observed that people were leaving fishing due to polluted waters resulting in little or no yield. Historically, fishing and agriculture have been the two main occupations in the region. However,

Table 1: Forms and Perceptions of Conflicts in North Eastern and South Southern AEZs of Nigeria

	North Eastern AEZ						**South Southern AEZ**					
	Borno State		Taraba State		Total		Edo State		Delta State		Total	
	n	%	n	%	n	%	n	%	n	%	n	%
Forms of Conflict												
None	21	15.0	15	10.7	36	25.7	37	17.6	50	23.8	87	41.4
Religious	41	29.3	39	27.9	80	57.1						
Land ownership	4	2.8	0	0	4	2.8	17	8.1	7	3.3	24	11.4
Tribal	0	0	0	0	0	0	3	1.4	9	4.3	12	5.7
Oil pollution	0	0	0	0	0	0	0	0	28	13.3	28	13.3
Politics	20	14.3	0	0	20	14.3	14	6.7	28	12.4	40	19.0
River portion	0	0	0	0	0	0	16	7.6	3	1.4	19	9.0
Perception of Conflict												
None	0	0	0	0	0	0	3	1.4	0	0	3	1.4
Not severe	0	0	3	2.9	3	2.9	34	16.2	50	23.8	84	40.0
Severe	0	0	9	6.4	9	6.4	37	17.6	47	22.4	84	40.0
Very severe	86	61.4	31	22.1	117	83.6	13	6.2	26	12.4	39	18.6

after Nigeriaǧs independence in 1960, conflicts between local communities, oil companies, and the federal government started to emerge. As a result of this, communities have come into conflict with oil companies and with the security forces over a range of issues including payments, land acquisition, and environmental damage (Niger Delta Development Commission, 2005). Fishermen were also engaged in fish related activities such as fish processing, fish transportation etc. (Akinrotimi et al., 2007).

The major vulnerability in the NE AEZ was division and crisis caused by the Islamic sect (60%) and the inaccessibility to credit facilities (34.3%). In the SS, the major vulnerabilities was due to inaccessibility to natural resources (42.4%) as a result of either pollution or over-exploitation and the corrupt practices of leaders who seek to amass the wealth and resources for themselves without giving thought to the sustainability of livelihood (41.0%). The major coping strategy in NE AEZ was migration (75%) whereas in the SS AEZ was livelihood diversification. The implication of conflicts on livelihoods of households in the study area was that people were displaced from their homes and forced to undertake other livelihood activities not peculiar to them. As a result this has invariably caused fish production to dwindle in the study area. In view of this, the United Nations Development Project (2007) argues that men and women in the Niger Delta (South-South) feel politically disenfranchised and disadvantaged when compared to the other geopolitical zones of Nigeria. They are frustrated that they cannot legitimately benefit from the oil resources. Therefore, there is a clash of interest among individual, companies and the host communities. For instance, being designated as a "host community" to an oil facility comes with benefits, but historically this practice has exacerbated grievance and fighting among communities and has also led to disputes over "oil" boundaries. Insecurity and volatility in the region have disrupted livelihoods, damaged the ecosystem and created a challenging environment for social and economic development (Environmental Impact Assessment, 2003).

3.2 Test of Hypothesis

Results of the binary logistic regression (Table 3) showed that number of tribes (p←0.05), the type of livelihood and the major cause of conflict (p←0.01) were significant factors enhancing conflict in the NE. In the SS, education (p←0.05) and the major cause of conflict (p←0.01) contributed significantly to conflict activities. This is similar to the findings of Kamilu et al., (2012) who found that the conflict situation in Taraba state cut across level of religion, exposure education, occupation and personal characteristics. In terms of natural resource conflict, El-Bushra et al 2013 reported that in Nigeria, conflict between indigenous and incoming fishermen over sustainable fishing methods in the NE, while in the SS, land disputes such as competition over access to oil-bearing land and to compensation for environmental impact of oil and gas The Hosmer and Lemeshow test revealed that the logit model regression had an overall goodness of fit. The Cox and Snell R^2 and Ngelkerke R^2 for the northeast showed that the model explained 42% and 62% respectively of the variation in the dependent variable whereas in the south-south 33% and 41% respectively are explained in the variation of the dependent variable.

4.0 Conclusion

Conflict activities vulnerabilities and coping strategies differed among the North East and South-South Agro-

Table 2: Livelihoods, Vulnerabilities and Coping Strategies

	North Eastern AEZ						South Southern AEZ					
	Bornu State		Taraba State		Total		Edo State		Delta State		Total	
	n	%	n	%	n	%	n	%	n	%	n	%
Livelihood												
Fishing	58	41.4	38	27.1	96	68.6	66	31.4	27	12.9	93	44.3
Fish farming	28	20.0	16	11.4	44	31.4	21	10.0	96	45.7	117	55.7
Vulnerabilities												
Division by Islamic sect	69	80.2	15	27.8	84	60.0	0	0.0	0	0.0	0	0.0
Inaccessibility to water/land	0	0.0	8	14.8	8	5.7	43	49.4	46	37.4	89	42.4
Bad leadership	0	0.0	0	0.0	0	0.0	8	9.2	27	22.0	86	41.0
Inaccessibility to credit	17	19.8	31	57.4	48	34.3	36	41.4	50	40.7	35	16.7
Coping strategies												
None	19	13.6	16	11.4	35	25.0	37	17.6	50	23.8	87	41.4
Migration	67	47.9	38	27.1	105	75.0	13	6.2	11	5.2	24	11.4
Diversify							20	9.5	28	13.3	48	22.9
Loans/claims							0	0	15	7.1	15	7.1
Solidarity							17	8.1	19	9.0	36	17.1

Table 3: Results of Binary Logistic Regression for North Eastern and South Southern AEZs of Nigeria

	North Eastern AEZ			South Southern AEZ		
	Parameter estimate	S. E.	Significance	Parameter estimate	S. E.	Significance
Education	-0.035	0.046	0.448	0.087	0.043	*0.045
Household size	-0.056	0.047	0.233	0.010	0.021	0.641
Number of tribes	-0. 356	0. 171	*0.038	0.103	0.117	0.378
Type of fisheries	2.199	0.641	**0.001	-0.051	0.422	0.903
Major cause of conflict	4.730	1.162	**0.000	3.528	0.570	**0.000
Constant	0.484	0.791	0.541	-1.819	0.789	0.021
Hosmer and Lemeshow test			**0.002			*0.020
Likelihood ratio (model X^2)	24.298			18.236		
d.f.	8			8		
Cox and Snell R^2	0.416			0.325		
Ngelkerke R^2	0.616			0.438		
N	140			210		

*=p<0.05
**=p<0.01

ecological Zones of Nigeria. Major causes of conflict include religious, politics and oil pollution. Impact of conflict effects on livelihoods and food security of fishing and fish farming households include inaccessibility to credit and water/land.

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A06

The impact of civil war on crop production in Somalia

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PAPER

1. Introduction on Somali Agriculture

Somalia has got potential agricultural resources that can feed its people (10.8m) and even produce surplus for export. It consists of agricultural land (44mha), forestry land (6.7mha), surface water (179.8km^3/annum) and potential underground water unidentified, livestock population (→36m heads), sea and inland fishery resources (3333km long coast) and forestry sectors. Gross Agricultural Products, GAP, contributed in average 62% to the national GDP for the period of 1977-1987. 25% of the GAP is of plant origin whilst 75% comes from the livestock sector. Agriculture commodities represent the only exports for Somali economy. Nearly 70% of the people live in rural areas, being agriculture their main source of livelihood. This statistics clearly indicates how important the agricultural sector is to the national economy. According to the data from the Ministry of Agriculture in 1989, prior to the outbreak of the civil conflict, the tilled area distributed as 564,600ha of rain-fed and 113,000ha of irrigated land; and around 360,300ha was under fallow. Crop production in Somalia is dependent mainly on the rain-fed system while the irrigated area reached at its best 200,000ha. Thus, adoption of water harvesting techniques in rain-fed agriculture, efficient use of the available water for irrigation, delivery of proper agricultural services and availability of farm labor constitute the major determinant factors for the success of crop production.

Upon the outbreak of civil conflicts in the capital and its surroundings in late 1990, wild destruction and looting of public properties including factories, premises, vehicles, machineries, utilities and the like has happened. Looting of heavy and light arms, weapon and ammunition from the military camps is considered the major reason for the continuous civil conflicts. It encouraged the criminals to rob mercilessly the public and private belongings. As a result, the delivery of all social services including education, health and security suspended. The unemployment rate reached its peak due to release of tens of thousands of public employees. During this period, the contribution of the private sector to the national economy was negligible. Consequently, the living condition of the people was badly affected. The impacts of the conflict on the different agricultural sectors will be discussed in the following sections.

2. Methodology

There is no official statistics on the related issues available; but, as secondary data, we reviewed contents of the websites of FAO, IDP, WB, and UNHCR; and fortunately we received the last technical report from the Ministry of Agriculture in 1989. In addition, we organized a discussion with a selected focus group of 13 farmers who have practiced farming before and after the outbreak of the civil conflict. During the meeting, we have discussed all possible conflict factors impacted on crop production; and the results are shown below.

3. Impacts of the conflict on crop production activities

Displacement and migration trend

One of the worst consequences of the civil conflict is the fearful dilemma it created in the people. When killings, robbery, and thievery rates increased, as a coping mechanism, millions of people resorted to flee from their homes to relatively peaceful places in the country; and the number of displaced people reached 1.1m people in 2013 with a distribution pattern of 893,000 in South and Central Somalia, 129,000 in Puntland and 84,000 in Somaliland. Based on the size of support they expect from the relief agencies or their relatives and friends, some people have migrated to abroad. They have been mainly located in the neighboring countries like Kenya, Ethiopia, Djibouti and Yemen; while the others are scattered all over the world. According to World Bank report, the number of Somali refugees also reached 1.1 million people in 2013. The absence of the IDPs and the migrants from their families can not only be regarded as a loss since they have significantly supported their families back, few received high degrees, gained experience and/or earned money from self-employment or employment from other institutions. But, out of that number, 2.2m of IDP and migrants, they compose of a workforce of 1.2m people (56% of 2.2m, ILO model). Being agriculture the major source of employment for the Somali people, in their presence in the country, sizable proportion of that number could have joined to the ongoing agricultural activities in the country.

Increased use of drugs (Qat)

Qat (Catha edulis) is a drug plant grown in Kenya, Ethiopia and Yemen. It was medically proved that it is harmful to human health. This drug is believed to have been introduced to Somalia from the neighboring countries, the producers, for decades back. The annual imports of this poisonous plant cost hundreds millions of dollars. In the past, the government banned Qat twice but failed due to the evasive tactics used by the black marketers. In response, the government imposed heavy taxes on the imports to minimize the quantity and the number of chewers. Now Qat is very cheap, available and widely consumed. Nearly all of the chewers are men; and under the influence of the drug, they always have problems with themselves, their families and environments. Due to income constraints, chewers sometimes beg and skimp on their family needs. During the civil conflicts, Qat chewing reached to the farming areas; and since the addicts hardly abstain from consuming, they resorted to sell their assets, farms, animals. Their productivity and their health status declined. Farmers believe that the absence of effective government is the main factor behind the widespread of Qat chewing habits. There is a widely accepted perception that Qat is incentive for on-going fighting.

Untimely food aid distributions

Prior to the outbreak of the civil conflict, there has been large number of refugee population. They were supported by the government with the support from UN agencies such as WFP. Food commodities were distributed properly to the needy people. In addition, sometimes when seasons fail and the expected harvests fall short, the deficit was filled from commercial imports and food aid. In the economic language when the supply of a product increases, the prices decline. So, the government, by protecting the local producers, set food distribution timing strategy; and taxes were imposed on the cheap imports for price adjusting. Marginal profit was allowed for the farmers' encouragement. But currently agriculture is not the priority area of the government; and farmers are at loss in bumper seasons due to purposeful coincidence of food aid distribution at harvesting time. It is worth-mentioning that the farmers gain profits during poor seasons because there is no food aid distributed and the food prices soar. This does not mean that farmers are happy with the hunger of their people, but the relief agencies concerned are dormant during his period and there is no effective government institutions that can communicate effectively with the concerned partners to purchase the surplus of the harvests in some regions for the benefit of the others. In case the local supply could not meet the gap, food aid imports should be sought from abroad. This could have encouraged and motivated the local producers.

Loss of banana export markets

Somalia is known to produce good quality banana which has been exported to Europe and Gulf markets for nearly a century. It is the only crop exported to abroad; and it constituted 20% of the GAP. Banana production which is a very lucrative industry is considered as one of the most labor intensive agricultural projects. Prior to the outbreak of the civil war, there was a strong banana business run by Somalifruit Company which was shared by Italian Businessman (51%) and Somalia (49%). The company managed about 7000 hectares, thousands of skilled and non-skilled labor force, large network of transportation vehicles, refrigerated marine fleet, substantial agriculture supporting services, banana processing facilities, packaging factory among others. Suspension of such project has caused the release of thousands of technicians and farm labor. Nearly the entire banana industry collapsed. As a result, the unemployment rate of the farming communities rose. Reopening of this business has been tried in 1994, but aggressive competition between farmers of Somalfruit and Sombana (Dole Food Companies) has ended up to the closure of this business. In light of FAO data 2013, the area of the banana shrank from 6000ha to 1900 ha which is equivalent to 216% whilst there was light yield improvement of 15.8% which moved from 17.7t/ha to reach 20.5t/ha for the average years of 1986/90 to 2010/2013 respectively. The area shrinkage can be attributed to lack of export markets, high wages from farm labor shortages, high transportation cost from rough roads, road blocks and the like.

Lack of agriculture supporting services

Crop production practices and civil war incidences are only confined in the southern regions of Somalia. The farming communities are peaceful and unarmed; but competition of the resources by the rival groups is considered the main reason for the concentration of the incidences in these zones. In Somalia, small farmers produce nearly all types of the crops, except the fruit crops which are grown by the commercial farmers. Their production system is traditional with less improved seeds, no use of fertilizers, chemicals and other inputs. During the government period, farmers paid reduced fees for land preparation services to ONAT, the government agency. Currently all of the machinery services are offered by the private sector for profit basis. Prior to the outbreak of the civil conflict, government institutions offered extension services to all farmers. For instance, they were told when to irrigate their farms to avoid water salinity, trained animal power were sometimes freely distributed, competitions for crop productivity were organized annually, for the sake of farmers, market price was controlled properly for the protection of the farmers. Due to the developments on the ground, all of the said services are currently lacking.

Weak judiciary system

On the other hand, in the past, when animals grazed farms accidently or purposefully, the crop farmers received legal support from the police forces against the owners of the herd; and they got compensations commensurate with the damages incurred; but currently irresponsible herders with guns attack farms; and there is no reliable security forces to seek support. These incidences often happen when some neighboring farms harvested and the remaining others postpone harvesting till the crops dry very well for economic reasons. Thus, the latter groups are often attacked by livestock herders; and consequently clashes often erupt. It is worth mentioning that in the past, farmers grew tillering sorghum varieties in the first season, Gu'; and at harvest they did not razed the plants at soil level, but left 10-20cm above the soil in an effort to ratoon in the next rains, the second season. New earlier crop with less input facilities have been harvested next. But, in light of the recurrent clashes with the livestock herders, that agronomic package cannot be adopted.

Lack of quality control institutions

The world is full of unethical people who always run after their interests. They do not care of the crimes they commit. This kind of people is found anywhere in the world including Somalia. Those people can only be managed by strong government institutions. We, in Somalia, during the chaos period, have suffered a lot from this kind of mischievous acts. Those criminals imported poor quality/expired food commodities, fake medicines, poor agrochemicals and fertilizers, machineries, electronics and the like; and large number of people suffered from their evil acts. Lack of such institutions has lead to emergence of such gangs. These harmful products are quite cheap, and the poor has no choice since his purchasing power is very limited. On the other hand, the local production is uncompetitive with the price of the alternative cheap/low quality food imported from abroad. Thus, the local producer and the citizens as a whole are at loss without the government protection.

4. Conclusion

Despite the fact that getting solutions to the problems mentioned by the farmers come under the government responsibilities, but since we have been out of the scene for more than quarter of a century and the challenges are too complex, getting back to the normal track will not be easy. At this end, we call for the global partners to feel sympathy for the suffering Somali people and extend them the maximum technical and financial support they can to restore peace; otherwise, nothing can be achieved.

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THEMATIC SET

B07

MEASURING PRODUCTIVITY IN AGRICOLTURE, FISHERY, AND FORESTRY

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ABSTRACT

Despite the key role of the agricultural sector in the economy of many countries, serious weaknesses persist in the measurement of agricultural outcomes and in our understanding of the factors hampering agricultural growth, particulary among smallholders. While governments and donors alike target agriculture for large-scale investments with ambitious goals of raising agricultural productivity multi-fold, large gaps remain in the way we measure returns to key activities like agriculture, particularly among smallholders. Similarly, even greater challenges emerge in the measurement of returns from activities such as fishery and forestry which are central to the livelihood of a large share of poor people. The much heralded Data Revolution and the ensuing use of advanced technologies and new data sources promises to be an opportunity to fill some of the existing knowledge gaps through the development and testing of novel and more cost-effective ways to measure productivity in agriculture, fishery and forestry. Particularly, the use of satellite imagery, remote sensing, mobile phones and various types of sensors are already routinely used in many countries but often their applicability to developing countries contexts – characterized by complex smallholder farming systems and low capacity – has yet to be fully proven. For this session, we invite submissions of theoretical and empirical research proposing innovative uses of technologies and new methods for the cost-effective measurement of productivity of smallholders in developing countries involved in crop and livestock production, fishery and forestry. Especially, we encourage submissions of original applications that contribute to solving particularly thorny issues that continue to challenge agricultural statisticians such as, but not confined to, the measurement of productivity of root and continuous crops, production under intercropping and returns to livestock rearing. We would also welcome innovative examples of integration of new data sources like Big Data with more traditional instruments like surveys and census data to improve on the way we measure productivity among smallholders.

LIST OF PAPERS

Performance of goats and sheep under communal grazing in Botswana using various growth measures

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DOI: 10.1481/icasVII.2016.b07

An alternative methodology for estimation of cotton yield using double sampling approach

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THEMATIC SET

B07

Effect of data aggreegation on inefficiency estimates

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Methodological experiment on measuring Cassava production, productivity, and variety identification in Malawi

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B07

Performance of goats and sheep under communal grazing in Botswana using various growth measures

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ABSTRACT

We conducted a survey to evaluate the growth of goats and sheep under communal grazing, and to determine the relationship between weight, heart girth, shoulder height, and body condition score in Kweneng, Central and Kgalagadi districts, Botswana. The same animals were measured on two separate occasions, approximately one month apart, to allow growth rates to be recorded. Significant differences in growth rates between the three case study districts were found for both goats and sheep. Amongst the goats measured, gains in height and weight were significantly greater in the Kweneng district, while gains in heart girth measurement were greatest in the Central district. In the case of sheep, weight gain was significantly higher in the Central and Kgalagadi districts, increases in girth measurement were significantly higher in the Central district, and shoulder height gain was significantly greater in the Kweneng district. Statistical tests were used to determine the relationships between animal weight and the other measures taken for goats and sheep. Heart girth in both goats and sheep was shown to be a significant predictor of weight across all three districts. Likewise, shoulder height proved to be a statistically significant predictor of animal weight for both goats and sheep, across each district. The data therefore suggest that heart girth and shoulder height have potential to act as proxy measurements of weight in both goats and sheep, potentially providing smallholder farmers with a cost-effective way of estimating small-stock productivity.

Keywords Tswana goats, Tswana sheep, growth performance, heart girth.

PAPER

1. Introduction

Small-stock such as goats and sheep play a vital role in the livelihood of smallholder farmers in rural Botswana. The goat population in Botswana was estimated to be 1.6 million in 2013, and the sheep population at just under 300,000 (Statistics Botswana, 2015). Just about all goat and sheep production in Botswana takes place in the traditional smallholder sector, with commercial livestock production focusing mainly on cattle (Burgess 2006). The indigenous Tswana breed accounts for the majority of goats and sheep owned by farmers. Goats and sheep are raised mainly for domestic consumption of meat, milk, hides, for income generation, and for other social activities like payment of dowry (Aganga & Aganga 2015).

Small-stock in Botswana are mostly commonly managed in communal grazing areas, where fencing is not permitted (Nsoso et al. 1999). Most local farmers allow their goats, sheep and cattle to browse on tree forages in the rangelands. They may also periodically cut tree branches or harvest tree pods, to use as feed supplements (Aganga & Autlwetse 2000).

However, most smallholder farmers in Botswana invest relatively little in supplementary feeding, labour, and disease and parasite control for their goats and sheep. Although in the case of supplementary feed this may be partly due to irregularity of fodder production arising from variable weather conditions (Burgess 2006), the result of this lack of investment is to hinder the productivity of small-stock. Lack of availability of accurate scales makes it difficult for smallholder goat and sheep producers to gauge the productivity of their animals (ESGPIP 2009). In this study, we therefore sought to evaluate the growth performance of goats and sheep under a communal grazing system, and to determine the relationship between weight, heart girth, shoulder height, and body condition score, by repeated measurement of these characteristics in a sample of animals. A key objective of the study was to determine the extent to which heart girth, shoulder height and body condition score may be used as proxy measures of goats and sheep weight.

2. Materials and Methods

2.1 Study Area

The study was conducted from September through to November 2015 in Kweneng and Kgalagadi districts in the south and south-west of Botswana, and Central district in eastern Botswana. The climate in the Kweneng district is classified as semi-arid, and is influenced by the local steppe. Average annual temperature is 19.6°C, and average annual rainfall is 455 mm (Climate-Data.Org 2016). In the Central district the climate is semi-arid. Average annual temperature is 20.4°C, and average annual rainfall is 452 mm (Climate-Data.Org 2016). The Kgalagadi district is classified as having a desert climate.

2.2 Description of goats and sheep

The Tswana goats are a large horned, multicoloured, medium size breed, with lopping ears, a short course hair structure, and are predominantly bearded and horned (Katongole et al. 1996, Podisi, 1999). Tswana sheep have a well developed fat tail, hairy coat, and are usually white or black and white in colour (Nsoso et al. 1999).

2.3 Small-stock management and data collection

Goats and sheep measured during the project, across all farms and in all three districts, were ear tagged for repetitive collection of data during the study period. All goats and sheep in sampled farms aged "one year and below" were selected for the study. Farmers usually released the goats and sheep between 1000hrs and 1100hrs to forage in communal grazing areas. The small-stock were returned to the „kraals" (fenced enclosures) in the evening. In each farm, initial measurements (weight, girth and shoulder height) were taken before the goats or sheep were released for grazing. A second series of measurements were taken approximately four weeks after initial measurement, to allow a determination of growth rate to be made.

2.4 Statistical analysis

In order to determine the growth rates of livestock for each animal the first measurement of each of these characteristics was subtracted from the second measurement, resulting in three figures for change in weight, heart girth measurement and shoulder height measurement respectively. In order to determine the relationship of different measures of sheep and goat size, analysis of variance (ANOVA) of fixed effects was carried out using the General Linear Model (GLM) procedures of the Statistical Analysis System software package (SAS, 2010). The fixed effects considered were animal type (sheep or goat) and district (Kweneng, Central or Kgalagadi). Initial animal weight was used as a covariate variable. The response variable analysed were weight, heart girth measurement, shoulder height measurement, and body condition score[1]. Simple regression analysis was used to determine the relationship of weight, heart girth, shoulder height, and body condition score. A linear trendline was fitted to each scatterplot. All tests were considered significant at a $P<0.05$ level.

3. Results and Discussion

Data analysed for both goats and sheep showed that district and sex interactions with the variables were not significant, although growth rates measured amongst female goats and sheep alike were smaller than amongst male goats and sheep. Likewise, there was a poor relationship between weight and body condition score, as a potential proxy estimate of animal weight. Consequently, these results are not reported.

Feed availability for grazing animals play a significant role in determining growth performance. Grazing animals like cattle, goats and sheep will usually selectively graze in communal areas when released. Therefore, if forage quantity is limited then selection of the best forages or plant parts by the animal is limited (Zalesky 1997). In an accompanying study of sample communal pastures in the three case study districts (Kgosikoma, unpublished data), Kgalagadi district had the highest grass biomass, at 154kg/ha for good species and 187.50kg/ha for intermediate species. The Kweneng district had the least grass biomass, at 1.48kg/ha for good grass species, and 7.26kg/ha for intermediate grass species. Grass palatability was also most likely to be estimated as intermediate or poor in this district. The population of small shrubs (<0.5m to <1m in height) was highest in Kweneng at 1700 plants/ha and lowest at Kgalagadi with 150 plants/ha. Larger shrubs (>1m to <2m in height) were present in more dense populations in the Central and Kweneng districts, at 700 plants/ha.

[1] Body condition score (BCS) is used as an assessment of the fat reserves of livestock, and involves a physical assessment of fat coverage around the lumbar vertebrae, breastbone, and rib cage (eXtension.org 2009; New South Wales, Department of Agriculture, Agrifact A2.23). A scale of 1 to 4 was used for this research. BCS scores of 1.0 to 2.0 indicate a management or animal health problem. BCS scores of 2.5 to 4.0 indicate a healthy animal in most cases (eXtension.org 2009).

3.1 Growth rates of goats and sheep

The monthly weight gain of goats in the Kweneng district was significantly greater than the other districts (2.19kg; Table 1). The monthly weight gains for goats in the Kgalagadi and Central districts were not significantly different, at 1.97kg and 2.01kg respectively (Table 1). In previous controlled experiments carried out in Botswana (Aganga et al. 1998, Aganga et al. 2000, Aganga et al. 2001) the monthly weight gain of Tswana goats ranged from 0.9kg to 2.4kg, based on a diet of Buffalo grass supplemented with browse species. In these experiments, goats whose diets were supplemented with either lucerne or lablab gained 2.1kg monthly. These results were comparable to the results of our study. In rangelands, goats tend to prefer woody species over grass species. Mphinyane et al. (2015) reported that the diet of goats comprised 72% „browse" consumption in summer, with this proportion increasing to 82% in spring. The higher growth performance of goats in the Kweneng district suggests that a browse-dominant diet appears to be rich in minerals and protein (Le Houerou, 1980, Aganga et al. 2000), and is generally a more significant source of minerals and protein during dry seasons and drought periods (Dambe et al. 2015). According to Devendra (1980) goats are opportunistic foragers, and can maintain a high quality diet under different ecological zones. This was reflected at the Kgalagadi district where the plant population per hectare was the lowest of the three case study districts (↓ 300 plants/ha). Despite this, the goats managed to survive from ample grass that was denser in this district in communal grazing areas than in the other two case study districts surveyed for the study.

Table 1 - Monthly growth parameters of goats browsing natural pastures in communal areas across three districts of Botswana

	Kweneng[1]	Kgalagadi[2]	Central[3]	P-value
Height gain (cm)	3.21±0.21	1.98±0.16	1.89±0.20	*0.0001*
Girth gain (cm)	3.31±0.23	1.99±0.18	6.01±0.21	*0.0001*
Weight gain (kg)	2.19±0.08	1.97±0.06	2.01±0.08	*0.019*

[1] Number of observations in Kweneng; 372. [2] Number of observations in Kgalagadi; 620. [3] Number of observations in Central; 439. ± refers to standard error of the mean (S.E.M).

Height gain was significantly greater amongst goats in the Kweneng district than in the other two districts (3.21cm; Table 1). Browse utilization is dependent on accessibility for foraging animals. Livestock can only fully utilise browse material from plant heights that are within their reach (Le Houerou 1980). Hence, goats in the Kweneng district may have displayed better weight gain because they were able to access browse material from the greater diversity and quantity of shrubs that were within reach, compared to the other two districts where shrub density was not as great. The monthly weight gain of sheep was significantly higher in the Mahalapye and Kgalagadi districts (Table 2; 2.75kg and 2.91kg respectively; Table 2). In Kgalagadi, this may be attributable to the high grass biomass of 341kg/ha for good and intermediate species combined. In Mahalapye, sheep may have benefited from a combination of seedlings (<0.5m) which had a population count of 1200/ha, and grass biomass of 30kg/ha for good and intermediate species combined. Sheep in the Kweneng district gained the least weight, perhaps because most of the shrubs in the area were not within their reach. In this regard the sheep may only have benefited from fallen tree leaves as they drop naturally from trees, and by that stage the feed value of the leaves may have reduced (Dambe et al. 2015).

Table 2 - Monthly growth parameters of sheep browsing natural pastures in communal areas across three districts of Botswana

	Kweneng[1]	Kgalagadi[2]	Central[3]	*P-value*
Height gain (cm)	2.97±0.2	1.65±0.49	1.53±0.37	*0.033*
Girth gain (cm)	-0.15±0.62	0.82±0.25	5.52±0.43	*0.0001*
Weight gain (kg)	1.53±0.29	2.75±0.12	2.91±0.22	*0.0002*

[1] Number of observations in Kweneng; 63. [2] Number of observations in Kgalagadi; 378. [3] Number of observations in Central; 109. ± refers to standard error of the mean (S.E.M).

Similarly, since cattle and sheep are primarily grazers, both livestock species are more likely to be negatively impacted by drought or extended dry periods, because herbaceous plants are more sensitive to periodic moisture stress than wood plants (Mphinyane et al. 2015). Unlike goats in the Kweneng district, sheep gained relatively less weight, since their inability to forage from a bipedal stance from higher plants (as goats do) meant they did not have access to much of the woody plant material on communal grazing lands in this district. Nonetheless, height gain was significantly greater (3.21cm; Table 1) amongst sheep in the Kweneng district than the other two districts, showing that there was not necessarily a correlation between the extent of height gain and weight gain across the three districts.

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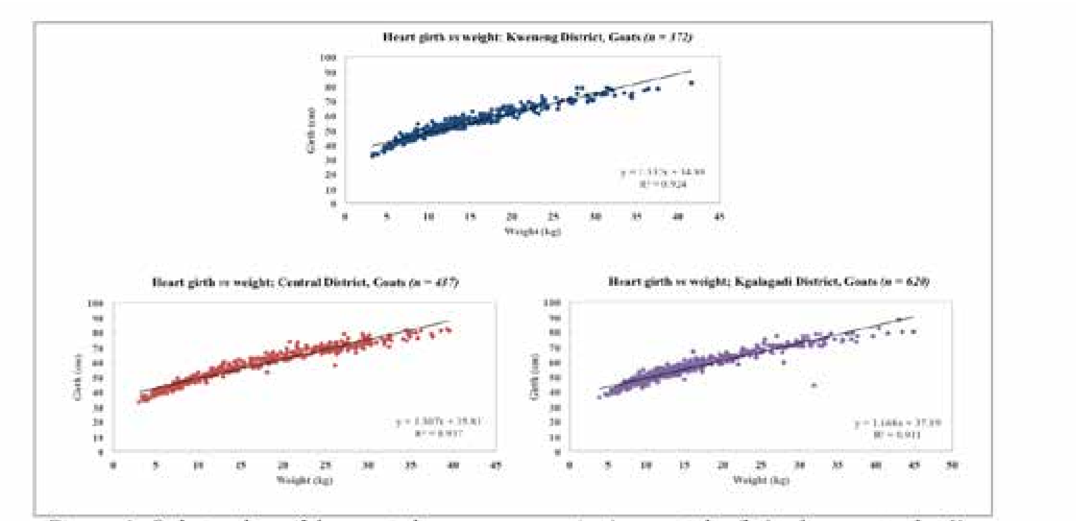
3.2 Relationships of growth measures

3.2.1 Relationship of heart girth measurement to weight

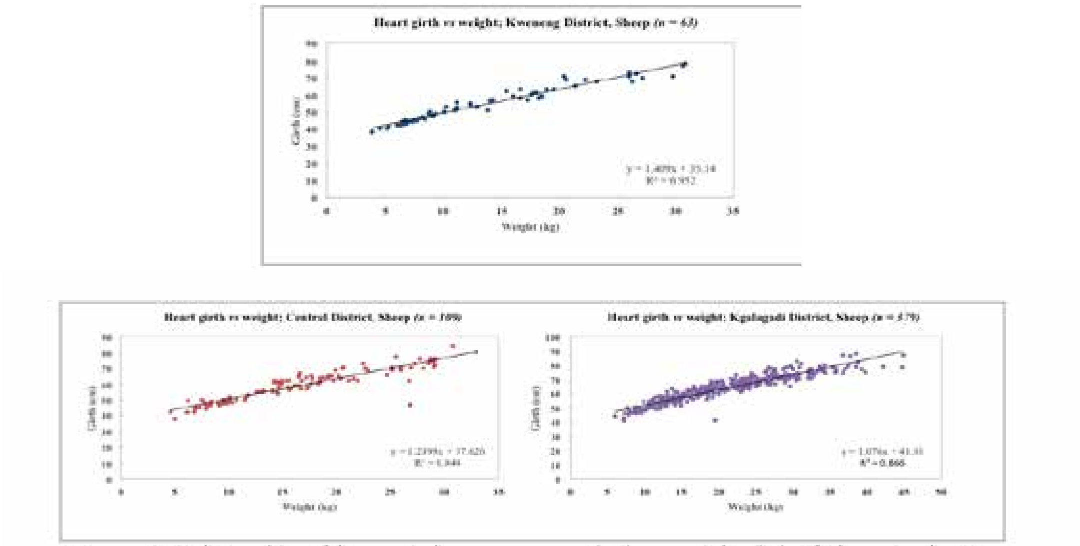
Data on body condition score showed no statistically significant relationships with weight in both goats and sheep, and consequently the results are not presented. Heart girth measurement in goats appears to be a statistically significant predictor of weight in the Kweneng, Central and Kgalagadi districts (R2=0.92, R2=0.95 and R2=0.91 respectively; Figure 1). As this Figure shows, heart girth measurement accounted for a large amount of the variability associated with animal weight across the sample of goats measured.

Figure 1 - Relationship of heart girth measurement (cm) to weight (kg) of goats in the Kweneng, Central and Kgalagadi districts, Botswana



As was the case with goats, heart girth measurement in sheep was highly correlated to weight in Kweneng, Central and Kgalagadi districts (R2=0.95, R2=0.85 and R2=0.87 respectively; Figure 2). Once again, heart girth measurement accounted for a large amount of the variability associated with animal weight across the sample population.

Figure 2 - Relationship of heart girth measurement (cm) to weight (kg) of sheep in the Kweneng, Central and Kgalagadi districts, Botswana



3.2.2 Relationship of shoulder height measurement to weight

As was the case with heart girth measurement, the shoulder height of goats in the sample showed a strong correlation with weight in Kweneng, Central and Kgalagadi districts (R2=0.82, R2=0.87 and R2=0.72 respectively; Figure 3).
In sheep, shoulder height also proved to be a strong predictor of weight in Kweneng, Central and Kgalagadi districts (R2=0.76, R2=0.79 and R2=0.62 respectively; Figure 4.).

Figure 3 - Relationship of shoulder height measurement (cm) to weight (kg) of goats in the Kweneng, Central and Kgalagadi districts, Botswana

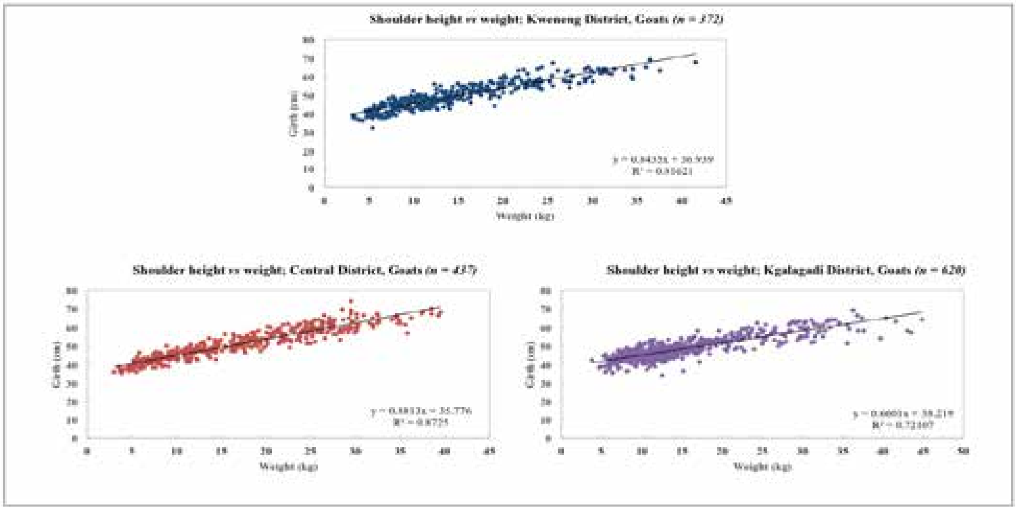
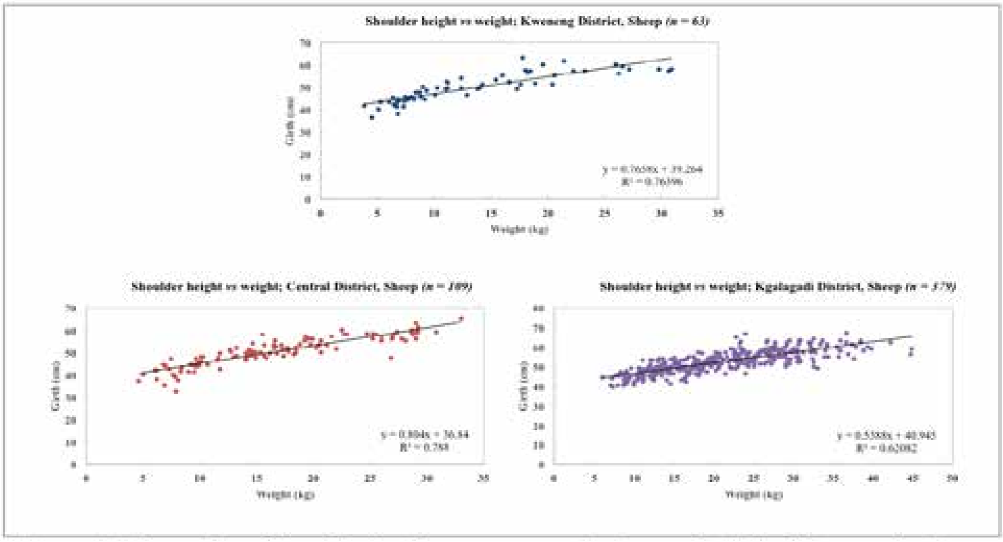


Figure 4 - . Relationship of shoulder height measurement (cm) to weight (kg) of sheep in the Kweneng, Central and Kgalagadi districts, Botswana



4. Conclusions

The results suggest that goats performed well in the Kweneng district, as a result of a high population density of browse species (particularly small shrubs). Previous research has suggested that small shrubs are the preferred source of feed for goats in Botswana during the dry season (Omphile et al. 2004). Sheep tended to perform well in Kgalagadi and Central districts, due to the relatively high grass biomass observed in these districts. Both heart girth measurement and shoulder height measurement appeared to be consistent and statistically robust predictors of weight in all the three districts in this study. As has been suggested in previous studies conducted elsewhere (e.g. ESGPIP 2009, Cam et al. 2010, Musa et al. 2012), heart girth appeared to be a better proxy measure of weight than shoulder height, however both can be used in a complementary fashion to estimate the weight of goats and sheep under communal grazing.

Future research in determining the potential for linear measurements to act as proxy measures for small-stock weight may involve expanding data collection to fully-grown animals, or those over 12 months of age, providing a sample of animals of known age could be identified. Likewise, data on breed may be collected for each animal measured to allow potential differences in weight, heart girth and shoulder height measurements by breed to be identifed.

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An alternative methodology for estimation of cotton yield using double sampling approach

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ABSTRACT

Cotton, a multiple picking crop, is grown in nine states in India. The existing procedure of estimation of average yield of cotton is based on crop cutting experiment approach, which utilizes data on all pickings, is cumbersome and cost prohibitive. The double sampling approach can be gainfully employed in this case by collecting data on picking which has highest correlation with the total picking yield on a larger sample and the total picking yield data on a smaller sample. Accordingly, a stratified two-stage two phase sampling design has been proposed for selection of representative sample and an appropriate estimation procedure, based on double sampling regression estimator, has been developed for estimation of average yield of cotton at district level. Utilizing the data of survey conducted in the Aurangabad and Amravati district of Maharashtra State and Adilabad and Guntur district of Andhra Pradesh wherein third picking data is collected on a larger sample and total picking yield data on a smaller sample,expression for optimum number of villages for larger and smaller sample have been obtained by minimizing cost subject to fixed percentage standard error of the estimates. The results show that the average yield of cotton can be estimated with at most 5% standard error, if 137 preliminary sample villages are selected for third picking and 48 sub-sample villages are selected for the remaining pickings from each selected district while the corresponding sample size for an estimator which make use of entire picking data is 51 villages. Recommendations have been made with regard to which picking data can be used as auxiliary variable, in the double sampling regression estimator, for 9 cotton growing states in India.

PAPER

Cotton is an important fibre yielding crop of global importance. It is also known as the "White Gold" or the "King of Fibres". It is grown, world over, in tropical and subtropical regions of more than 80 countries. It is an internationally sensitive commodity. Occupying an area of around 35.72 million ha, cotton is cultivated mainly in U.S.A. (11%), China (15%) and India (34%). Current estimates of world production are about 27.25 million tonnes annually, accounting for around 2.5% of the world's arable land. China is the world's largest producer of cotton, but most of this is used domestically. India occupies highest area under cotton (12.18mha) and is the second largest country, after China, as far as production is concerned (35.20 mt). In India, the States of Gujarat (34.09%) Maharashtra (20.45 %), and Andhra Pradesh (13.92%) are the leading cotton producing states having a predominantly tropical wet and dry climate.

The yield estimation of cotton in India is carried out using crop cutting experiment technique. A limitation of the crop cutting experiment technique is that it requires observation on yield data of all the pickings of sampled fields. In case, data of one or two pickings of some of the selected fields are not available, not only precision of the yield estimate will suffer but estimate of average yield will be biased. Moreover, it is very difficult to capture data for all the pickings (up to 8 pickings in some states) creating practical difficulties in implementation of the procedure. Practical feasibility of crop cutting experiment technique for multiple picking crops like cotton is a matter of concern in India. Another important consideration is cost aspect of crop yield estimation survey. The cost on conduct of crop cutting experiment involving multiple picking crops increases manifold when data are to be collected on all the pickings. Therefore, there is a need to develop an alternative technique which is easier to implement as well as capable of providing unbiased estimates of average yield of cotton with desired precision.

2. Existing procedure for estimation of average yield of Cotton

The existing estimation procedure followed, under the General Crop Estimation Surveys (GCES), for estimation of average yield of Cotton is as under:

At the stratum level, the average yield of the crop is obtained as a simple arithmetic mean of plot yields (net) within a stratum.

Let

Y_{hij}= The plot yield (net) in gms/plot of the jth plot in the ith village in the hth stratum

n_{hi}= Number of experiments conducted in the ith village of hthstratum

m_h= Number of villages in which experiments are conducted in the hthstratum

n_h= Number of experiments conducted in the hthstratum

L = Number of strata in a district

a_h= The area (net) under the crop in the hthstratum

d = The driage ratio

f = The conversion factor for converting the green yield per plot into the yield of dry marketable produce per hectare

The average green yield for the h^{th} stratum is obtained as

$$\bar{y}_h = \frac{1}{n_h}\sum_{i=1}^{m_h}\sum_{j=1}^{n_{hi}} y_{hij}$$

and the district level average yield of the dry marketable produce per hectare is given by

$$\hat{\bar{Y}} = d.f.\frac{\sum_{h=1}^{L} a_h \bar{y}_h}{\sum_{h=1}^{L} a_h}$$

The sampling variance of $\hat{\bar{Y}}$ is obtained as

$$\hat{V}(\hat{\bar{Y}}) = \frac{d^2.f^2\left[W\sum_{h=1}^{L}\frac{a_h^2}{n_h} + (B-W)\sum_{h=1}^{L}\frac{a_h^2\sum_{i=1}^{m_h} n_{hi}^2}{\lambda_h n_h^2}\right]}{\left[\sum_{h=1}^{L} a_h\right]^2}$$

where

$$\lambda_h = \frac{n_h^2 - \sum_{i=1}^{m_h} n_{hi}^2}{n_h - (m_h - 1)},$$

$$B = \frac{\sum_{i=1}^{m_h}\frac{\left(\sum_{j=1}^{n_{hi}} y_{hij}\right)^2}{n_{hi}} - \frac{\left(\sum_{i=1}^{m_h}\sum_{j=1}^{n_{hi}} y_{hij}\right)^2}{n_h}}{\sum_{h=1}^{L}(m_h - 1)},$$

the mean square between villages and

$$W = \frac{\sum_{h=1}^{L}\left[\sum_{i=1}^{m_h}\sum_{j=1}^{n_{hi}} y_{hij}^2 - \sum_{i=1}^{m_h}\frac{\left(\sum_{j=1}^{n_{hi}} y_{hij}\right)^2}{n_{hi}}\right]}{\sum_{h=1}^{L}(n_h - m_h)},$$

the mean square within villages

The percentage standard error of $\hat{\hat{Y}}$ is given by

$$\%S.E.(\hat{\hat{Y}}) = \frac{\sqrt{\hat{V}(\hat{\hat{Y}})}}{(\hat{\hat{Y}})} \times 100$$

3. Sampling design used for selection of sample

Stratified multistage random sampling design is generally adopted for carrying out General Crop Estimation Survey (GCES) with taluks/revenue inspector circles as strata, revenue villages within a stratum as a first stage unit of sampling, survey number/field within each selected village as a sampling unit at the second stage and experimental plot of a specified shape and size as the ultimate unit of sampling.

Sampling design for GCES

Strata – Taluk

↓

First stage sampling unit – Revenue Village

↓

Second stage sampling unit – Survey Number/Field

Ultimate unit of sampling – Experimental Plot

(Specified shape and size)

Total numbers of experiments at district level are finalized as per following norms: (i) 130 to 150 experiments are planned at district level (65 to 75 villages having two experiments per village) if area under experimental crop in a district is above 80,000 hectares.

(ii) 100 to 120 experiments are planned at district level (50 to 60 villages having 2 experiments per village) if area under experimental crop in a district is between 20,000 to 80,000 hectares.

(iii) 40 to 80 experiments are planned at district level (20 to 40 villages having two experiments per village) if area under experimental crop in a district is below 20,000 hectares.

The number of villages allotted to a district is distributed among the strata, within a district, roughly in proportion to the area under the crop in stratum. Generally, Crop insurance scheme is implemented at taluk/circle level in India. To determine compensation to be paid to the farmer in the event of crop loss, average yields are calculated on 18/12 crop cutting experiments at taluk/circle level respectively. The number of villages is increased up to 9/6, if the distributed villages to the strata within a district are less than 9/6 at taluk/circle level respectively. Hence, due to implementation of crop insurance scheme, number of crop-cutting experiments planned at district level increased up to 700.

In each taluk/circle, in Maharashtra, a number of villages are selected every year for crop cutting experiments as per above norms at the time of district level-training programs conducted every year in Kharif, Rabi and Summer season. The list containing the names of the selected villages are made available by State Statistical Authority, Department of Agriculture, Maharashtra State, Pune to the concerned officers.

In each selected village, two fields growing the particular crop are selected according to the random sampling method. For the above purpose, two survey numbers are first selected out of all survey numbers for experimental crop in the village according to the said method.

In each selected survey number, where there are more than one field sown with the crop, one such field nearest to the South-West corner of the selected survey number should be selected. In each field thus selected, one plot of specified size is to be located at random.

4. Proposed procedure of estimation of crop yield of cotton

A detailed examination of the data pertaining to five districts of Andhra Pradesh (A.P.) and five districts of Maharashtra showed that the yield of cotton at different pickings were highly correlated with the total yield. Hence, it may not be statistically efficient to collect data in respect of all the pickings from the same sample of fields since the additional information gained would be only marginal. Therefore, it would be desirable to examine the possibility of using other sampling design such as double sampling which may not only be more efficient but also operationally more convenient resulting in more reliable data for estimation of crop yield of multiple picking crop like cotton.

Table 3.1 - Picking-wise correlation with total yield in Maharashtra for the year 2006-07

District	Pick-1	Pick-2	Pick-3	Pick-4	Pick-5	Pick-6	Pick-7	Pick-8
Aurangabad	0.55	0.65	0.82	0.84	0.83	0.74	0.51	0.24
Jalgaon	0.44	0.73	0.82	0.86	0.83	0.70	0.49	-0.40
Jalna	0.65	0.77	0.86	0.86	0.77	0.73	0.60	0.77
Buldhana	0.66	0.69	0.82	0.81	0.72	0.61	0.44	0.30
Yavatmal	0.58	0.76	0.87	0.91	0.86	0.75	0.51	0.35

Table 3.2 - Picking-wise correlation with total yield in Andhra Pradesh (A.P.) for the year 2005-06

District	Pick-1	Pick-2	Pick-3	Pick-4	Pick-5	Pick-6	Pick-7
Adilabad	0.59	0.61	0.82	0.82	0.81	0.48	0.16
Guntur	0.30	0.60	0.86	0.81	0.71	0.50	0.30
Khammam	0.65	0.81	0.87	0.56	0.66	0.37	-0.24
Karimnagar	0.65	0.80	0.80	0.45	0.43	0.41	-
Warangal	0.70	0.81	0.81	0.23	0.27	0.26	0.20

Results of both the tables reveal that 3^{rd} and 2^{nd} pickings in A.P. and 4^{th}, 3^{rd}, 5^{th} and 6^{th} pickings in Maharashtra have high correlation with total yield. It is, therefore, desirable to use the yield of picking having highest correlation with total yield as auxiliary variable. Thus, there is an opportunity to use double sampling approach in this situation.

Estimation procedure using double sampling approach under stratified two stage samplingdesign framework The estimation procedure for estimation of average yield of cotton using double sampling approach under stratified two stage sampling design framework is as under:

Let

L = number of strata (mandals/taluks) in a district

N_h = total no. of fsu's (villages) in h-th stratum (h=1,2,...,L)

n_h' = no. of fsu's selected randomly in h-th stratum for observing yield for the p-th picking (p=1,2,...,P)

n_h = size of sub-sample selected randomly in h-th stratum for observing yield for the remaining pickings

m' = no. of ssu's (fields) selected for observing yield for the p-th picking in i-th village of h-th stratum (i=1,2,..., nh')

m = size of sub-sample for observing yield for remaining pickings of these m' ssu's

$y_{hij}(p)$ = yield of cotton in j-th field of i-th village (j=1,2,..., m') in h-th stratum corresponding to p-th picking.

An estimator of average yield corresponding to p-th picking, $\bar{y}_{nm}(p)$ for a district is given by

$$\bar{y}_{nm}(p) = \frac{1}{n_0 m}\sum_{h=1}^{L}\sum_{i=1}^{n_h}\sum_{j=1}^{m} y_{hij}(p) \quad \text{where } n0 = \sum_{h=1}^{L} n_h$$

An estimator of average yield, $\bar{y}_{nm}$ for a district is given by

$$\bar{y}_{nm} = \sum_{p=1}^{P} \bar{y}_{nm}(p)$$

This is a biased estimate of the population average discussed by Panse *et al.* (1966). However, investigations by Sukhatme and Panse (1951) into the magnitude of the bias from the data collected in district crop-cutting surveys has shown that the bias is negligible. A double sampling regression estimator of average yield of cotton under the proposed framework can be written as

$$\bar{y}_{ld}(2) = \bar{y}_{nm} + \hat{\beta}[\bar{y}_{n'm'}(p) - \bar{y}_{nm}(p)]$$

where $\bar{y}_{n'm'}(p) = \frac{1}{n_0' m'}\sum_{h=1}^{L}\sum_{i=1}^{n_h'}\sum_{j=1}^{m'} y_{hij}(p)$, $\quad n_0' = \sum_{h=1}^{L} n_h'$

$$\hat{\beta} = \frac{(\frac{1}{n_0} - \frac{1}{n_0'})s_{by(p)y} + \frac{1}{n_0'}(\frac{1}{m} - \frac{1}{m'})s_{wy(p)y}}{(\frac{1}{n_0} - \frac{1}{n_0'})s^2_{by(p)} + \frac{1}{n_0'}(\frac{1}{m} - \frac{1}{m'})s^2_{wy(p)}}$$

where

$$s_{by(p)y} = \frac{1}{L}\sum_{h=1}^{L}\frac{1}{(n_h-1)}\sum_{i=1}^{n_h}(\bar{y}_{hi.(p)} - \bar{y}_{h..(p)})(\bar{y}_{hi.} - \bar{y}_{h..})$$

$$s_{wy(p)y} = \frac{1}{n_O(m-1)}\sum_{h=1}^{L}\sum_{i=1}^{n_h}\sum_{j=1}^{m}(y_{hij(p)} - \bar{y}_{hi.(p)})(y_{hij} - \bar{y}_{hi.})$$

where $\bar{y}_{hi.}(p) = \frac{1}{m}\sum_{j=1}^{m} y_{hij}(p)$ and $\bar{y}_{h..}(p) = \frac{1}{n_h}\sum_{i=1}^{n_h}\bar{y}_{hi.}(p)$,

$$s^2_{by(p)} = \frac{1}{L}\sum_{h=1}^{L}\frac{1}{(n_h-1)}\sum_{i=1}^{n_h}(\bar{y}_{hi.}(p) - \bar{y}_{h..}(p))^2$$

An estimator of $MSE(\bar{y}_{ld}(2))$ is given by

$$\hat{MSE}(\bar{y}_{ld}(2)) = \left\{\left(\frac{1}{n_0} - \frac{1}{N_0}\right)s^2_{by} + \frac{1}{N_0 m}s^2_{wy}\right\}(1 - r^{*2}) + r^{*2}\left\{\left(\frac{1}{n_0'} - \frac{1}{N_0}\right)s^2_{by} + \left[\frac{1}{N_0 m} - \frac{1}{n_0'}\left(\frac{1}{m} - \frac{1}{m'}\right)s^2_{wy}\right]\right\}$$

where $N_0 = L\bar{N}$, and $\bar{N}$ is the harmonic mean of N_{hs}. This is the usual estimator in sub-sampling design.

$$s^2_{by} = \frac{1}{L}\sum_{h=1}^{L}\frac{1}{(n_h-1)}\sum_{i=1}^{n_h}(\bar{y}_{hi.} - \bar{y}_{h..})^2$$

$$s^2_{wy} = \frac{1}{n_0(m-1)}\sum_{h=1}^{L}\sum_{i=1}^{n_h}\sum_{j=1}^{m}(y_{hij} - \bar{y}_{hi.})^2$$

$$r^{*2} = \frac{q^2_{y(p)y}}{q_{y(p)y(p)}q_{yy}}$$

with

$$q_{y(p)y} = (\frac{1}{n_0} - \frac{1}{n_0'})s_{by(p)y} + \frac{1}{n_0}(\frac{1}{m} - \frac{1}{m'})s_{wy(p)y}$$

$$q_{y(p)y(p)} = (\frac{1}{n_0} - \frac{1}{n_0'})s^2_{by(p)} + \frac{1}{n_0}(\frac{1}{m} - \frac{1}{m'})s^2_{wy(p)}$$

$$q_{yy} = (\frac{1}{n_0} - \frac{1}{n_0'})s^2_{by} + \frac{1}{n_0}(\frac{1}{m} - \frac{1}{m'})s^2_{wy}$$

Validation of proposed methodology for estimation of average yield of cotton

For the validation of proposed methodology, surveys were planned for data collection in Amravati and Aurangabad districts of Maharashtra State while in Andhra Pradesh (A.P.) State planning was done in Adilabad and Guntur districts. In Maharashtra State, two additional fields were selected in 114 villages selected for CCE in Aurangabad district and 118 villages selected for CCE in Amravati district while in A.P., two additional fields were selected in 77 villages selected for CCE in Warangal district and 75 villages selected for CCE in Guntur district.

In addition to CCE data for the third picking from two additional fields from the selected CCE village of the selected districts of both the states, the regular CCE data of selected districts of both the states was also required for validation of the proposed double sampling procedure under stratified two stage sampling design framework.

The estimate of average yield of cotton along with % S.E. for the year 2012-13was obtained using proposed double sampling approach under stratified two stage sampling design framework. In order to compare the results, the estimate along with % S.E. was also obtained using existing GCES procedure.

For implementation purpose the selected CCE villages in the district have been treated as preliminary sample villages (n') for the third picking yield and a sub-sample of 40% and 30% CCE villages (n) were selected by SRSWOR from the preliminary sample villages for the remaining pickings and out of the four fields (m') for the third picking, in each of these sub-sample villages, two fields (m) were selected for observing yield pertaining to the remaining pickings from CCE plot. The estimate of average yield of cotton along with % S.E. was obtained for both the districts of Maharashtra State and both the districts of A.P. State. The results of the district wise analysis are presented in the Tables 4.1 to 4.4.

Table 4.1 - Estimates of average yield of cotton (Kg/ha) along with % S.E. using different approaches for Aurangabad district of Maharashtra State for the year 2012-13

Existing procedure			
No. of sampled villages	Average yield (Kg/ha)	% S.E.	Total no. of pickings involved
Total GCES villages (83)	202.027	5.49	1328
Double sampling regression procedure under stratified two stage sampling design framework			
n'=83 (for one picking) n=33 (40% of n') (for remaining pickings)	189.711	5.32	794
n'=83 (for one picking) n=26 (30% of n') (for remaining pickings)	188.966	6.39	696

A close perusal of the above table reveal that under the Double sampling regression procedure involving stratified two stage sampling design framework,the estimates of average yield of cotton was obtained with less than 3% standard error for Aurangabad district which is fairly reliable.

The estimate is almost at par with the estimate obtained using existing procedure. Further, as the sample size decreases i.e. from 40% to 30%, percentage standard error increases for both the proposed procedures. The alternative procedure is operationally more convenient than the existing GCES procedure and is expected to reduce the workload of the field staff significantly which in turn will lead to good quality CCE data from these limited number of plots.

It may be seen from the above table that in case of the proposed alternative procedure the estimate of average yield of cotton is obtained with less than 3% standard error for Amravati district which is fairly reliable. Further, as the sample size decreases i.e. from 40% to 30%, percentage standard error increases.

The analysis of data in respect of Guntur district reveals a similar trend as earlier i.e. the proposed estimator scores over the estimator currently used in terms of the criterion of percentage standard error. It may be observed from the Table that the estimate of average yield of cotton in case of existing GCES procedure is obtained based on data on 65 villages. But double sampling regression procedure under stratified two stage sampling design framework requires CCE villages data for all the mandals in the district. In most of the mandals only two villages data was available and at least two villages data is necessary for the analysis. Hence, there was not much scope for sub-sampling and accordingly, the 40% and 30% sub-sampling of villages could not be done. The results are presented based on the maximum possible reduced number of villages i.e. 52 villages. The improved performance of double sampling approach based estimator is evident.

Table 4.2 - Estimates of average yield of cotton (Kg/ha) along with % S.E. using different approaches for Amravati district of Maharashtra State for the year 2012-13

Existing procedure			
No. of sampled villages	Average yield (Kg/ha)	% S.E.	Total no. of pickings involved
Total GCES villages (111)	637.055	2.81	1776
Double sampling regression procedure under stratified two stage sampling design framework			
n'=111 (for one picking) n=43 (40% of n') (for remaining pickings)	529.168	2.85	1046
n'=111 (for one picking) n=34 (30% of n') (for remaining pickings)	511.038	2.92	920

Table 4.3 - Estimates of average yield of cotton (Kg/ha) along with % S.E. using different approaches for Guntur district of A.P. State for the year 2012-13

Existing procedure				
No. of sampled villages	Average yield (Kg/ha)	% S.E.	Total no. of pickings involved	
Total GCES villages (65)	629.399	3.95	910	
Double sampling regression procedure under stratified two stage sampling design framework				
n'=65 (for one picking) n=52 (for remaining pickings)	608.882	3.61	884	

Table 4.4 - Estimates of average yield of cotton (Kg/ha) along with % S.E. using different approaches for Warangal district of A.P. State for the year 2012-13

Existing procedure				
No. of sampled villages	Average yield (Kg/ha)	% S.E.	Total no. of pickings involved	Percentage reduction in cost
Total GCES villages (59)	371.034	1.63	708	
Double sampling regression procedure under stratified two stage sampling design framework				
n'=59 (for one picking) n=48 (for remaining pickings)	371.891	5.69	716	
Double sampling Regression procedure under stratified two stage sampling design framework				
n'=59 (for one picking) n=48 (for remaining pickings)	345.751	5.15	598	

The results of analysis of data in Warrangal district are bit different than earlier i.e. although the percentage standard errors are within permissible limits, the existing estimator scores over the proposed estimator in terms of the criterion of percentage standard error of the estimator. This highlights the need to compare the proposed estimator over the existing estimator using optimum sample sizes determined by minimizing expected cost for a fixed value of percentage standard error of the estimator.

5. Estimation of sample size (no. of villages to be selected in a district for the survey)

The guiding principle in the determination of optimum sample size is either to fix variance of the estimator and minimize cost or to fix cost and minimize variance of the estimator. We, in this paper, aimed at minimizing the cost by fixing the variance of the estimator. The optimum number of villages to be sampled in a district was determined by fixing the percentage standard to 5 and 7.

In order to estimate sample size in case of double sampling regression procedure, a simple cost function given by

$$C = c\, n_0\, m + c'\, n'_0\, m'$$

was considered, where

c = costs involved in conducting crop cutting experiment for all the pickings of a selected plot (e.g. travel, equipment, harvesting and drying, stationery) and

c' = costs involved in conducting crop cutting experiment for one picking (3rd picking) of a selected plot (e.g. travel, equipment, harvesting and drying, stationery)

= {1/(Total no. of pickings)} x c

By minimizing the cost subject to a fixed variance V_0, the optimum values of n_0 were obtained from the following relations

$$\frac{n_0}{n'_0} = \sqrt{\frac{c'(1-r^{*2})}{cr^{*2}}} = \theta$$

and

$$n_0 = \{(1-r^{*2}) + \theta r^{*2}\}\left(s_{by}^2 + \frac{1}{m}s_{wy}^2\right) \Big/ \left[\hat{V}_0 + \frac{s_{by}^2}{N_0}\right]$$

The proposed regression estimator, involving auxiliary information, was accordingly compared with the estimator which does not make use of auxiliary information on the basis of optimum sample sizes determined by minimizing the cost function subject to a fixed value of the percentage standard error (the optimum sample sizes were determined by fixing the percentage standard error to 5 and 7).

The estimated sample size and desired percentage standard error of the district level estimates of average yield of cotton for Maharashtra and A.P. states are presented in theTable.

Table 5.1 - Sample size (no. of villages per district) for district level estimates of average yield of cotton for 5% standard error

State	Districts	Calculated S.E. (%)	No. of villages (n)	No. of prel. sample villages (n')	Desired S.E. (%)	Estimated sample size (n_0)	c'/c	r	Estimated sample size (n'_0)
Double sampling regression procedure under stratified two stage sampling design framework									
Maharashtra	Aurangabad	6.39	26	83	5.00	48	0.125	0.7109	137
	Amravati	2.92	34	111		11	0.125	0.7867	30
Andhra Pradesh	Guntur	3.61	52	65		34	0.143	0.7681	102
	Warangal	5.69	48	59		45	0.167	0.7992	127
Recommended optimum sample size i.e maximum of estimated sample size						48			137

The optimum sample size is maximum of the estimated sample size used for estimation of average yield of cotton in both the States.

A close perusal of Table 5.1 reveal that the district level average yield of cotton can be estimated with less than or equal to 5% standard error, if 137 preliminary sample villages are selected for third picking and 48 sub-sample villages are selected for the remaining pickings from each selected district. Therefore, the recommended sample size i.e. no. of preliminary sample villages and sub-sample villages to be selected from a district are 137 (one hundred thirty seven) and 48 (forty eight) respectively. Further, the percentage standard error of the double sampling regression estimator is directly related to "r" i.e. greater the "r" value smaller the percentage standard error of the estimator.

Table 5.2 - Sample size (no. of villages per district) for district level estimates of average yield of cotton for 7% standard error

State	Districts	Calculated S.E. (%)	No. of villages (n)	No. of prel. sample villages (n')	Desired S.E. (%)	Estimated sample size (n_0)	c'/c	r	Estimated sample size (n_0')
Double sampling regression procedure under stratified two stage sampling design framework									
Maharashtra	Aurangabad	6.39	26	83	7.00	25	0.125	0.7109	71
	Amravati	2.92	34	111		6	0.125	0.7867	17
Andhra Pradesh	Guntur	3.61	52	65		18	0.143	0.7681	55
	Warangal	5.69	48	59		25	0.167	0.7992	70

The results of analysis of Table 5.2 reveals that at district level, the average yield of cotton can be estimated with less than or equal to 7% standard error, if 71 preliminary sample villages are selected for third picking and 25 sub-sample villages are selected for the remaining pickings from each selected district. Therefore, the recommended sample size i.e. no. of preliminary sample villages and sub-sample villages to be selected from a district are 71 (eighty one) and 25 (twenty five) respectively with minimum two sub-sample villages per mandal/taluka of the district as per requirement of the proposed alternative sampling methodology. As earlier, greater the r value, smaller the percentage standard error of the estimator.

The optimum values of sample size in the context of simple linear estimator (existing estimator) are given below

Table 5.3 - Sample size (no. of villages per district) for district level simple estimates (GCES estimates) of average yield of cotton for 5% standard error

State	Districts	Calculated S.E. (%)	No. of villages (n)	Desired S.E. (%)	Estimated sample size (n_0)
Maharashtra	Aurangabad	5.49	83	5.00	100
	Amravati	2.81	111		35
Andhra Pradesh	Guntur	3.95	65		41
	Warangal	1.63	59		6
Recommended optimum sample size i.e. maximum of estimated sample size					100

Table 5.4 - Sample size (no. of villages per district) for district level simple estimates (GCES estimates) of averageyield of cotton for 7% standard error

State	Districts	Calculated S.E. (%)	No. of villages (n)	Desired S.E. (%)	Estimated sample size (n_0)
Maharashtra	Aurangabad	5.49	83	7.00	51
	Amravati	2.81	111		18
Andhra Pradesh	Guntur	3.95	65		21
	Warangal	1.63	59		3
Recommended optimum sample size i.e. maximum of estimated sample size					51

Using the optimum values of sample sizes the percentage reduction in cost by using the double sampling regression estimator over an estimator which does not use auxiliary information are given in Table 5.5 and 5.6 by fixing the percentage standard error values to 5 and 7 percent respectively. Keeping in view the Indian scenario i.e. the manpower available, costs etc., the values of m and m' are fixed at 2 and 4 respectively.

Table 5.5 - Percentage reduction in cost using different approaches based on optimum sample size of villages required per district for obtaining district level estimates of average yield of cotton for Maharashtra and A.P. states for 5% standard error

Existing GCES procedure				
Optimum number of sample villages required per district		Average number of pickings based on four districts	Total number of pickings involved	Percentage reduction in cost
100		7	1400	
Double sampling regression procedure under stratified two stage sampling design framework				
Optimum no. of preliminary sample villagesrequired per district	Optimum no. of sub- sample villages required per district	Average number of pickings based on four districts	Total number of pickings involved	Percentage reduction in cost
137	48	7	1124	19.71

Table 5.6 - Percentage reduction in cost using different approaches based on optimum sample size of villages required per district for obtaining district level estimates of average yield of cotton for Maharashtra and A.P. states for 7% standard error

Existing GCES procedure				
Optimum number of sample villages required per district		Average number of pickings based on four districts	Total number of pickings involved	Percentage reduction in cost
51		7	714	
Double sampling regression procedure under stratified two stage sampling design framework				
Optimum no. of preliminary sample villages required per district	Optimum no. of sub- sample villages required per district	Average number of pickings based on four districts	Total number of pickings involved	Percentage reduction in cost
71	25	7	584	18.21

The results of analysis of Table 5.5 and 5.6 reveal that there is considerable reduction in cost using the double sampling procedure as compared to an estimator which does not make use of information on auxiliary variable. More and less the entire cotton area in the country has now been covered under Bt.

Cotton that requires only 2-3 pickings for the Crop Cutting Experiments. Therefore, in order to determine which picking should be used as an auxiliary variable, the CCE data of cotton pertaining to two major cotton growing districts namely,
Mansa and Muktsar Sahib of Punjab State and two districts namely, Hisar and Sirsa of Haryana State for the year 2012-13 was acquired. The data from both the states was available for four (4) pickings only. Picking-wise correlation with the total yield for the CCE data for all the four selected districts, two each Punjab and Haryana states, was obtained and are presented in the Tables 5.7 to 5.8.

Table 5.7 - Picking-wise correlation with total yield for plots in the selected districts of Punjab Statefor Desi and American Cotton (Combined) for the year 2012-13

State	Districts	Pick-1	Pick-2	Pick-3	Pick-4
Punjab	Mansa	0.652751	0.753949	0.80976	0.142816
	Muktsar Sahib	0.769401	0.731496	0.79637	0.364979

Table 5.8 - Picking-wise correlation with total yield for plots in the selected districts of Haryana Statefor the year 2012-13

State	Districts	Pick-1	Pick-2	Pick-3	Pick-4
Haryana	Hisar	0.467793	0.821971	0.651065	0.305694
	Sirsa	0.668537	0.679208	0.350899	0.004528

It can be inferred from the above two tables that 3rd picking has the highest correlation with total yield in both the districts of Punjab State while in Haryana State, 2nd picking has the highest correlation with total yield in both the districts. Thus, **3rd picking data is recommended for use as auxiliary variablein Punjab State while 2nd picking data is recommended for use in Haryana State** for estimation of average yield of cotton using double sampling regression estimator.

The CCE data of other cotton growing states was analysed to determine the picking having highest correlation with total yield. Accordingly, CCE data on cotton pertaining to two districts of each of the five states namely, Gujarat, Karnataka, Madhya Pradesh, Rajasthan and Tamil Nadu for the year 2012-13 was acquired. Picking-wise correlation with the total yield for the irrigated and unirrigated plots (combined) was obtained and results are presented in the Table 5.9.

Table 5.9 - Picking-wise correlation with total yield for irrigated and unirrigated plots (combined) in the selected districts of five States for the year 2012-13

State	District	Pick-1	Pick-2	Pick-3	Pick-4	Pick-5	Pick-6	Pick-7	Pick-8
Gujarat	Patan	0.6444	0.8942	0.9081*	0.8938*	0.7601*	0.4618*	0.2088*	**
	Mehsana	0.3514	0.6915	0.7967*	0.7423*	0.4863*	0.3832*	0.0559*	
Karnataka	Yadgir	0.6498	0.8384	0.8020*	0.2960*	0.0706*	**	**	**
	Haveri	0.6581	0.7973	0.8894*	0.8517*	0.4383	0.4931*	**	**
Madhya Pradesh	Khrgon	0.5849	0.8195	0.8398	0.8368	0.7248*	0.0473*	0.0467*	0.0529 *
	Dhar	0.5735	0.7948	0.8144	0.7048	0.5895*	0.5577*	**	**
Rajasthan	Ganganagar	0.6532	0.8647	0.6417*	0.7873*	**	**	**	**
	Hanumangarh	0.7626	0.6945	0.7225*	**	**	**	**	**
Tamil Nadu	Perambalur	0.4903	0.8081	0.8004	0.7257*	**	**	**	**
	Salem	0.3781	0.6307	0.8003	0.8301	0.7828	0.5595*	0.3492*	0.2481 *

Note: *Insufficient data available

**Data not available

The analysis reveals that 2nd picking has the highest correlation with total yield in both the districts of Gujarat and Karnataka States while in Madhya Pradesh State, 3rd picking has the highest correlation with total yield in both the districts. Further, in Rajasthan State, 2nd picking has the highest correlation with total yield in Ganganagar district and 1st picking has the highest correlation with total yield in Hanumangarh district followed by 2nd picking. Since the correlation coefficient for 2nd picking is significant in Hanumangarh district, t**herefore, 2nd picking is recommended to be used as auxiliary variablein Rajasthan State for the sake of uniformity**.

Similarly, in Tamil Nadu State, the correlation coefficient for 3rd picking is significant. **Therefore, 3rd picking should be treated as auxiliary variablein Tamil Nadu State**. The recommended picking, to be taken as auxiliary variable, in the nine states is given in Table 5.10.

Table 5.10 - Recommended picking to be used as auxiliary variable for analysis of cotton data usingdeveloped methodology in nine major cotton growing states of India

S. No.	State	Picking to be used as auxiliary variable
1	Andhra Pradesh	3rd Picking
2	Gujarat	2nd Picking
3	Haryana	2nd Picking
4	Karnataka	2nd Picking
5	Madhya Pradesh	3rd Picking
6	Maharashtra	3rd Picking
7	Punjab	3rd Picking
8	Rajasthan	2nd Picking
9	Tamil Nadu	3rd Picking

Conclusions

The present study has revealed very encouraging results as shown from the results of analysis and demonstrated the feasibility of estimating cotton production with limited number of pickings using the double sampling approach based regression estimator. In view of the above, it is recommended that the alternative sampling methodology using double sampling regression procedure under stratified two stage sampling design framework may be adopted in all the cotton growing states of the country for estimation of average yield of cotton which will not only provide reliable estimate of average yield of cotton but will significantly reduce cost of the survey and will also be operationally more convenient than the GCES procedure. Further, the workload of the field staff will be significantly reduced which in turn will lead to good quality CCE data from limited number of plots.

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Effect of data aggregation on inefficiency estimates

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ABSTRACT

The objective of this research is to determine the effects of data aggregation on firm-level efficiency measures. Aggregation creates heteroscedasticity since the error variance of average cost decreases as total output increases. Inefficiency indexes from stochastic frontier functions estimated assuming both heteroscedasticity and homoscedasticity are compared with those from data envelopment analysis (DEA) using a Monte Carlo study. Stochastic frontier functions hold up rather well in the presence of data aggregation, but efficiency measurement from DEA diverges from true efficiency measurement. In particular, DEA is biased towards finding more inefficiency in small firms.

Keywords: aggregation, cost function, data envelopment analysis, stochastic frontier.

PAPER

1. Introduction

Since Farrell (1957) developed his efficiency index using a deterministic frontier function, efficiency measurements from a stochastic frontier model and data envelopment analysis (DEA) have been frequently used to estimate firm-level efficiency measures. Stochastic frontier functions were suggested by Aigner et al. (1977), who allowed deviations from the frontier to arise from random factors where the disturbance term was the sum of symmetric normal and half-normal random variables. Jondrow et al. (1982) introduced firm-specific inefficiency measurement. DEA was introduced by Charnes et al. (1978), who assumed constant returns to scale (CRS). This idea was extended to variable returns to scale (VRS) by Banker et al. (1984). DEA is a nonparametric method and therefore does not require distributional assumptions about error terms. Also, DEA can handle multiple outputs and inputs. On the other hand, the fundamental merit of using a stochastic frontier function is to measure inefficiency in the presence of statistical noise, but it is subject to potential bias if an incorrect error structure is assumed.

One concern about the error structure is possible heteroscedasticity. Caudill and Ford (1993) find biases in frontier estimation due to heteroscedasticity of the one-sided error and later Caudill et al. (1995) find that the rankings of firms by efficiency measures are significantly affected by correcting for heteroscedasticity. These followed Schmidt's suggestion (1986) that a one-sided error can be associated with factors controlled by the firm while the random component can be associated with factors outside the firm's control. Hadri (1999) finds heteroscedasticity of both error terms with the same data of Caudill et al. (1995). This past research, however, has not formally derived how aggregation leads to heteroscedasticity.

Greene (2003) argues that the most common occurrence of heteroscedasticity is, in general, when data are aggregated, which is called "groupwise heteroscedasticity". Dickens (1990) shows that using data weighted by the square root of group size is only appropriate if individual error terms are not correlated within groups. In empirical work, disaggregated data are often not available so that economic research is often done using aggregated data. For example, the Macdonald and Michael (2000) study of the hog slaughter industry and the Ollinger et al. (2005) study of the poultry processing industry are aggregated over packing plants owned by the same firm. Adkins and Moomaw (2003) study public schools aggregated across teachers, while the Featherstone et al. (1997) study of beef cow farms uses data aggregated over cows. These studies typically conclude that small firms are much more inefficient than large firms. When the average cost (or average utput) function with aggregated data is estimated, the error variance of average cost decreases as group size increases, which raises the question as to how much of this finding of small-firm inefficiency is due to not considering heteroscedasticty created from using aggregate data.

This article uses a Monte Carlo study to estimate the biases in inefficiency measurement that are created from aggregate data. We begin with a disaggregate model with random effects, and the aggregate model is obtained by summing the disaggregate observations. The log cost model is obtained by a first order Taylor approximation. The resulting model is heteroscedastic. A Monte Carlo study compares inefficiency measurement in the presence of this heteroscedasticity with parameter estimates that both consider and disregard heteroscedasticity. With the same data, inefficiency indexes from DEA are also computed in order to provide comparisons with the stochastic frontier function.

2. Theory

Consider the following disaggregated cost function with random effects:

$$(1) \qquad C_{ij} = \mathbf{x}_{ij}'\beta + u_j + w_{ij}, \quad i = 1, \ldots, n_j, \; j = 1, \ldots, J,$$

$$u_j \sim iid\, N(0, \sigma_u^2),\; w_{ij} \sim iid\, N(0, \sigma_w^2),\; \mathrm{cov}(u_j, w_{ij}) = 0,$$

where C_{ij} is the cost of the ith unit in the jth firm, $\mathbf{x}_{ij}$ is a vector of explanatory variables including input prices, $\boldsymbol{\beta}$ is a vector of unknown parameters to be estimated, u_j is the random effect of the jth firm, and w_{ij} is the unexplained portion of the cost of the ith unit in the jth firm.

Examples of such a disaggregated cost function include a firm with multiple packing plants, a farmer with many fields, and a school with many teachers. The unit refers to each packing plant, each field, or each teacher. Note that the units within a firm all have the same random effect. The heteroscedasticity comes from the effects of w_{ij} being diversified away in larger firms.

In a stochastic frontier cost function, the inefficiency is represented with a one-sided error term (Aigner et al. 1977). Thus, a stochastic frontier cost function can be defined as

$$(2) \qquad C_{ij} = \mathbf{x}_{ij}'\beta + u_j + w_{ij} + v_j,\; v_j \sim iid\left|N(0, \sigma_v^2)\right|, \mathrm{cov}(u_j, v_j) = 0,$$

$$\mathrm{cov}(w_{ij}, v_j) = 0,$$

where v_j is the inefficiency and a one-sided error with $\mathrm{E}(v) = \sigma_v\sqrt{2/\pi}$ and $\mathrm{Var}(v) = \sigma_v^2(1 - 2/\pi)$. Especially, $\sigma_v\sqrt{2/\pi}$ is known as an average inefficiency measurement by Aigner et al. (1977). The term ($\mathbf{x}_{ij}'\beta$) can be interpreted as the minimum expected cost. Note that each unit within a firm is assumed to have the same inefficiency, which is consistent with Schmidt's (1986) view that the inefficiency error represents factors under control of the firm.

The (total) stochastic frontier cost function is the sum over all units of the firm:

$$(3) \qquad \sum_{i=1}^{n_j} C_{ij} = \sum_{i=1}^{n_j} \mathbf{x}'_{ij}\boldsymbol{\beta} + n_j u_j + \sum_{i=1}^{n_j} w_{ij} + n_j v_j,$$

where n_j is the number of units produced by the *j*th firm.

A dot subscript is the common notation to denote that the variable has been averaged over the corresponding index. A (total) stochastic frontier cost function (3) using the dot notation is

$$(4) \qquad TC_j = n_j \mathbf{x}'_{\bullet j}\beta + n_j(u_j + w_{\bullet j} + v_j), \; j = 1,\dots,J, \; w_{\bullet j} \sim N(0, \frac{\sigma_w^2}{n_j}),$$

where TC_j is the total cost for the *j*th firm, and the dot subscript indicates that the variable has been averaged over units. $\mathbf{x}_{\bullet j}$ is the averaged vector of explanatory variables over units, and $w_{\bullet j}$ is the averaged unexplained error over units.

Here, heteroscedasticity related with units is shown, which is typically called groupwise heteroscedasticity (Greene, 2003). Dickens (1990) showed similar heteroscedasticity in the presence of firm specific error, which is similar to the random effect shown here.

Logarithmic cost functions (translog or double log) are typically used in empirical work (Melton and Huffman, 1995) due to several conveniences such as including multiple outputs, calculating elasticities easily, and adjusting for heteroscedasticity. Taking the natural log of equation (4) gives

$$(5) \qquad \ln TC_j = \ln n_j + \ln\left(\mathbf{x}'_{\bullet j}\beta + u_j + w_{\bullet j} + v_j\right),$$

which is the double log cost function. Then, since error terms are the only random variables, applying a first-order Taylor approximation of $\ln\left(\mathbf{x}'_{\bullet j}\beta + u_j + w_{\bullet j} + v_j\right)$ around the mean of the random and unexplained error, and the frontier of inefficiency error such as $u_j = 0$, $w_{\bullet j} = 0$ and $v_{\bullet j} = 0$ gives the following model[1]:

$$(6) \quad \ln TC_j \approx \ln n_j + \ln \mathbf{x}'_{\bullet j}\beta + \frac{1}{\mathbf{x}'_{\bullet j}\beta}\left(u_j + w_{\bullet j} + v_j\right).$$

The variance of all error terms is $\left(1/\mathbf{x}'_{\bullet j}\beta\right)^2\left(\sigma_u^2 + \sigma_w^2/n_j + \sigma_v^2\right)$, which shows a combination of dependent variable heteroscedasticity and groupwise heteroscedasticity.

The usual stochastic frontier model is a special case of (3) where $\sigma_u^2 = 0$ and $n_j = 1, \forall j$. To define the usual model, let $e = w + v$ where w is unexplained error and v is the random inefficiency term. The density function for this case developed by Weinstein (1964) is

$$(7) \quad f(e) = \frac{2}{\sigma} f^*\left(\frac{e}{\sigma}\right) F^*\left(\frac{\lambda e}{\sigma}\right), -\infty < e < +\infty,$$

where $\sigma^2 = \sigma_w^2 + \sigma_v^2$, $\lambda = \sigma_v/\sigma_w$, and f^* and F^* are the standard normal probability density function and the standard normal cumulative density function, respectively. Note that the density function of a stochastic frontier function is a special case of skew normal distributions (Dominguez-Molina et al. 2003, Genton 2004; Gonzalez-Farias et al. 2004).

Here, λ is an indicator of the relative variability of error terms. As Aigner et al. (1977) argues, $\lambda \to 0$ means $\sigma_v \to 0$ and/or $\sigma_w \to \infty$, or that inefficiency error is dominated by random error. With data aggregation, λ increases as firms become larger since the variance of unexplained error does not increase as rapidly with firm size.

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[1] A second order Taylor approximation gives the following model:
$\ln TC_j \approx \ln n_j + \ln \mathrm{x}'_{\bullet j}\beta + \frac{1}{\mathrm{x}'_{\bullet j}\beta}\left(u_j + w_{\bullet j} + v_j\right) - \frac{1}{2}\left(\frac{1}{\mathrm{x}'_{\bullet j}\beta}\left(u_j + w_{\bullet j} + v_j\right)\right)^2$. This model is not considered here since the primary concern is to investigate heteroscedasticity easily in the stochastic frontier function. Also, first order Taylor approximation for an average cost function can be expressed as $\ln AC_j \approx \ln \mathrm{x}'_{\bullet j}\beta + \frac{1}{\mathrm{x}'_{\bullet j}\beta}\left(u_j + w_{\bullet j} + v_j\right)$, which has the same error structure.

Two measurements for the firm-specific inefficiency are given by Jondrow et al. (1982). Both are based on the conditional distribution of inefficiency error (v) given overall error (e). The first measure is given by

$$(8) \qquad \mathrm{E}(v|e) = \sigma_* \left[\left(\frac{\lambda e}{\sigma}\right) + f^*\left(\frac{\lambda e}{\sigma}\right) \Big/ F^*\left(\frac{\lambda e}{\sigma}\right)\right],$$

where $\sigma_*^2 = (\sigma_v \sigma_w / \sigma)^2$. The other variables are the same as in equation (7).

The second measure, which is based on the conditional mode, is given by

$$(9) \qquad \begin{aligned} \mathrm{M}(v|e) &= e(\sigma_v^2/\sigma^2) \quad \text{if } e \geq 0 \\ &= 0 \qquad\qquad\quad \text{if } e < 0. \end{aligned}$$

The log-likelihood function is derived from the density function in equation (7) by substituting the appropriate variances for the aggregated model:

$$(10) \qquad \sum_{j=1}^{J} \ln(f_j(e_j)) = \sum_{j=1}^{J} \ln \frac{2}{\sigma_j} f^*\left(\frac{e_j}{\sigma_j}\right) F^*\left(\frac{\lambda_j e_j}{\sigma_j}\right),$$

where $e_j = \frac{1}{\mathrm{x}'_{\bullet j}\beta}(u_j + w_{\bullet j} + v_j)$, $\sigma_j = \left(\frac{1}{\mathrm{x}'_{\bullet j}\beta}\right)\sqrt{\sigma_u^2 + \frac{\sigma_w^2}{n_j} + \sigma_v^2(1 - 2/\pi)}$, and $\lambda_j = \sqrt{\frac{\sigma_v^2(1-2/\pi)}{\sigma_u^2 + \sigma_w^2/n_j}}$.

Maximizing (10) gives maximum likelihood estimates for the stochastic frontier cost function with heteroscedasticty due to aggregation.

In the presence of data aggregation, two firm-specific inefficiency measurements like equation (8) and (9) are slightly modified. The first measurement can be expressed as

$$(11) \qquad \mathrm{E}(v_{*j}|e_j) = \sigma_{*j} \left[\left(\frac{\lambda_j e_j}{\sigma_j}\right) + f^*\left(\frac{\lambda_j e_j}{\sigma_j}\right) \Big/ F^*\left(\frac{\lambda_j e_j}{\sigma_j}\right)\right],$$

where $v_{*j} = v_j / \mathrm{x}'_{\bullet j}\beta$, $\sigma_{*j} = \left(\frac{1}{\mathrm{x}'_{\bullet j}\beta}\right)\sqrt{\frac{\sigma_v^2(1-2/\pi) \cdot \sigma_w^2/n_j}{\sigma_u^2 + \sigma_w^2/n_j + \sigma_v^2(1-2/\pi)}}$. The other variables are the same as in equation (10).

The second measure which is based on the conditional mode is given by

$$\text{(12)} \quad \begin{aligned} M(v_{*j} \mid e_j) &= e_j\left(\sigma_{*v}^2/\sigma_j^2\right) && \text{if } e_j \geq 0 \\ &= 0 && \text{if } e_j < 0, \end{aligned}$$

where $\sigma_{*v}^2 = \left(1/\mathrm{x}'_{\bullet j}\beta\right)^2 \sigma_v^2(1-2/\pi)$. The other variables are the same as in equation (10).

3. Data Envelopment Analysis (DEA)

Since input-oriented efficiency indexes with CRS and VRS were proposed by Charnes et al. (1978) and Banker et al. (1984), respectively, these two techniques have both been widely used (Fare et al. 1994) and therefore efficiency measurement with both CRS and VRS is discussed here.

Assuming M different outputs, N different inputs, and J different firms, the input-oriented model with VRS is

$$\text{(13)} \quad \begin{aligned} F_{\mathrm{j}}(\mathbf{x}_{\mathrm{j}},\mathbf{y}_{\mathrm{j}}) &= \min_{\theta_j,\boldsymbol{\lambda}} \ \theta_j \\ \text{s.t.} \ \ \mathbf{y}_{\mathrm{j}} \leq \mathbf{Y}\boldsymbol{\lambda}, \ \ \mathbf{X}\boldsymbol{\lambda} &\leq \theta_j \mathbf{x}_{\mathrm{j}}, \ \ \mathbf{j}'\boldsymbol{\lambda}=1, \ \ \boldsymbol{\lambda} \geq 0, \ \ j=1,\ldots,J \end{aligned},$$

where $F_{\mathrm{j}}(\mathbf{x}_{\mathrm{j}},\mathbf{y}_{\mathrm{j}})$ is the Farrell efficiency estimate (or technical efficiency) given a $N \times 1$ input vector ($\mathbf{x}_{\mathrm{j}}$) and a $M \times 1$ output vector ($\mathbf{y}_{\mathrm{j}}$) for the j^{th} firm, $\mathbf{Y}$ is a $M \times J$ matrix for outputs, $\mathbf{X}$ is a $N \times J$ matrix for inputs, θ_j is a shrinking factor, $\boldsymbol{\lambda}$ is a $J \times 1$ vector of weights for firms, and $\mathbf{j}$ is a vector of ones.

The Farrell efficiency estimate is the reciprocal of the input distance function with the input-oriented model. Also, if there is no restriction of $\mathbf{j}'\boldsymbol{\lambda}=1$, then the model is the case of CRS.

The cost minimization model with VRS can be specified as

$$\text{(14)} \quad \begin{aligned} &\min_{\boldsymbol{\lambda},\mathbf{x}_{\mathrm{j}}} \ \mathbf{r}_{\mathrm{j}}'\mathbf{x}_{\mathrm{j}}^* \\ &\text{s.t.} \ \ \mathbf{y}_{\mathrm{j}} \leq \mathbf{Y}\boldsymbol{\lambda}, \ \ \mathbf{X}\boldsymbol{\lambda} \leq \mathbf{x}_{\mathrm{j}}^*, \ \ \mathbf{j}'\boldsymbol{\lambda}=1, \ \ \boldsymbol{\lambda} \geq 0, \ \ j=1,\ldots,J, \end{aligned}$$

where $\mathbf{r}_{\mathrm{j}}$ is a $N \times 1$ vector of input prices for the j^{th} firm; $\mathbf{x}_{\mathrm{j}}^*$ is the cost-minimizing $N \times 1$ vector of input quantities for the j^{th} firm, which is calculated by the linear programming given a vector of output quantities for the j^{th} firm ($\mathbf{y}_j$) and a vector of input prices for the j^{th} firm ($\mathbf{r}_j$); and the other variables are the same as above.

Then, efficiency measurements for the j^{th} firm can be defined as

(15) $$CE = \frac{\text{minimized cost}}{\text{actual cost}} = \frac{\mathbf{r}_j' \mathbf{x}_j^*}{\mathbf{r}_j' \mathbf{x}_j}, \quad AE = \frac{CE}{TE}, \quad TE = \theta_j,$$

where CE is the cost efficiency, AE is the allocative efficiency, and TE is the technical efficiency derived from the linear programming problem in equation (13).

4. Data and procedures

A Monte Carlo study is used to examine the effects of heteroscedasticity due to data aggregation. Based on equation (2), our true model is assumed as

(16) $$C_{ij} = r_{ij} + u_j + w_{ij} + v_j,$$

where r_{ij} is the input price of the ith unit in the jth firm, while the other variables are as previously defined.

Aggregation over all units yields the following model:

(17) $$\sum_{1}^{n_j} C_{ij} = TC_j = n_j r_{\bullet j} + n_j (u_j + w_{\bullet j} + v_j).$$

Taking the natural log and a first-order Taylor series around the mean of random errors (u_j and $w_{\bullet j}$) and the frontier (zero) of inefficiency error (v_j) gives

(18) $$\ln TC_j \approx \ln(r_{\bullet j}) + \ln n_j + \frac{1}{r_{\bullet j}}(u_j + w_{\bullet j} + v_j).$$

So, our stochastic frontier cost function of equation (18) can be rewritten as

(19) $$\ln TC_j = \beta_1' \ln r_{\bullet j} + \beta_2' \ln n_j + (u_j' + w_{\bullet j}' + v_j'),$$

where heteroscedasticity is incorporated into the variances by assuming

$$\mathrm{var}\left(u_j' + w_{\bullet j}'\right) = \left(\sigma_u^2 + \frac{\sigma_w^2}{n_j}\right)\frac{1}{(r_{\bullet j})^2} \text{ and } \mathrm{var}\left(v_j'\right) = \left(\sigma_v^2(1-2/\pi)\right)\frac{1}{(r_{\bullet j})^2}$$

. Here, β'_1, β'_2, σ_u^2, σ_w^2, and σ_v^2 are unknown parameters to be estimated.

Input prices are generated as $r_{ij} \sim N(12,4)$. Also, numerous small firms and a few large firms are assumed by truncating a random number drawn from a distribution of $5*\exp(N(0,1))+1$; the mean units is 8.89 with variance around 112. To see the changes in relative variability of error terms, three scenarios of variances are considered: $[\sigma_u^2, \sigma_w^2, \sigma_v^2(1-2/\pi)] = [1, 4, 1.45]$, $[1, 4, 5.81]$, and $[1, 4, 13.08]$. The relative variability for these are, on average, $\lambda \approx 1$, $\lambda \approx 2$, and $\lambda \approx 3$, respectively. These scenarios show how much the inefficiency indexes change as the variability of inefficiency increases.

Using NLMIXED in SAS with 100 samples[2] of 100 observations, the stochastic frontier cost function with heteroscedasticity and without heteroscedasticity is estimated. Since one output and one input are assumed, cost inefficiency is the same as technical inefficiency from DEA. Inefficiency measurement of DEA using the data envelopment analysis program (DEAP) is also calculated and compared with those from the stochastic frontier cost function. Both constant return to scale (CRS) and variable return to scale (VRS) are used.

5. Results

Table 1 shows mean values of estimated parameters for the stochastic frontier cost function. In no case are the estimates significantly different from the true value. The variability of parameter estimates is slightly larger when homoscedasticity is incorrectly assumed. Certainly, the results

[2] The simulation takes considerable time and the differences between DEA and the stochastic efficiency measures are large enough that using one hundred samples is sufficient.

show that ignoring the effects of data aggregation does not create a serious problem for estimating a stochastic frontier cost function.

Table 1. Mean Parameter Estimates from Monte Carlo Trials

Parameters	Case 1			Case 2			Case 3		
	Expected Values	MLE w/ Hetero	MLE w/ Homo	Expected Values	MLE w/ Hetero	MLE w/ Homo	Expected Values	MLE w/ Hetero	MLE w/ Homo
β_1'	1	1.0207 (0.0220)	1.0235 (0.0222)	1	1.0330 (0.0301)	1.0332 (0.0312)	1	1.0415 (0.0366)	1.0418 (0.0419)
β_2'	1	1.0020 (0.0152)	1.0032 (0.0160)	1	1.0013 (0.0200)	1.0040 (0.0203)	1	1.0008 (0.0244)	1.0052 (0.0256)
σ_u^2	1	1.4232 (0.5697)		1	2.2525 (1.1257)		1	2.9857 (1.7572)	
σ_w^2	4	4.0161 (2.4111)		4	4.5953 (3.0724)		4	5.5293 (3.8383)	
$\sigma_v^2(1-2/\pi)$	1.45	1.3759 (1.3034)		5.81	5.2340 (3.1574)		13.08	10.7124 (5.2404)	
$\mathrm{Var}(u'+w')$	0.01	0.0160 (0.0043)	0.0166 (0.0048)	0.01	0.0210 (0.0085)	0.0215 (0.0092)	0.01	0.0255 (0.0131)	0.0268 (0.0146)
$\mathrm{Var}(v')$	0.01	0.0098 (0.0093)	0.0083 (0.0086)	0.04	0.0372 (0.0226)	0.0355 (0.0227)	0.09	0.0760 (0.0374)	0.0746 (0.0415)

Note: Simulated standard errors are reported in parentheses. In no case are the estimates significantly different from expected value.

1) Case 1 is the case of $[\sigma_u^2, \sigma_w^2, \sigma_v^2(1-2/\pi)] = [1, 4, 1.45]$.

2) Case 2 is the case of $[\sigma_u^2, \sigma_w^2, \sigma_v^2(1-2/\pi)] = [1, 4, 5.81]$.

3) Case 3 is the case of $[\sigma_u^2, \sigma_w^2, \sigma_v^2(1-2/\pi)] = [1, 4, 13.08]$.

Table 2 shows the mean of average inefficiency. Inefficiency indexes with heteroscedasticity are slightly bigger than those assuming homoscedasticity, which agrees with previous findings by Caudill, Ford, and Gropper (1995), but the differences between inefficiency indexes with and without heteroscedasticity are small. In no case are the estimates significantly different from true values, which agrees with Table 1. So, biases in terms of average inefficiency are also small.

Table 2. Mean of Average Inefficiency from Monte Carlo Trials

Methods	Case 1	Case 2	Case 3
True	0.1330	0.2656	0.3990
MLE w/ Hetero	0.1165 (0.0590)	0.2402 (0.0835)	0.3500 (0.0988)
MLE w/ Homo	0.1058 (0.0592)	0.2343 (0.0876)	0.3456 (0.1068)

Note: Simulated standard errors are in parentheses.

Table 3 shows correlations between true firm-specific inefficiency indexes based on the conditional mean in equation (11) and firm specific inefficiency indexes from each method. Since the units of firm specific inefficiency indexes resulting from parametric and non-parametric methods are different, it is better to look at their correlations to compare the two methods. Also, rank correlations are reported in parentheses because ranks are frequently used after estimating an efficiency index. The stochastic frontier inefficiency measures show high correlations (mostly greater than 0.9) with the true values. DEA, however, has much smaller correlations ranging from 0.4 to 0.6.

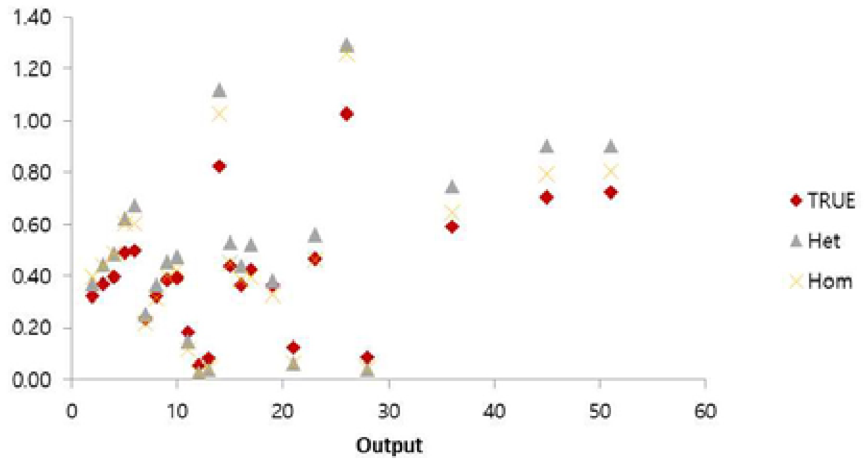
Table 3. Correlations from Monte Carlo Trials of True Inefficiency and Estimated Firm Specific Inefficiency

Methods	Case 1	Case 2	Case 3
MLE w/ Hetero	0.9155 (0.9784)	0.9259 (0.9876)	0.9331 (0.9891)
MLE w/ Homo	0.8959 (0.9717)	0.9217 (0.9880)	0.9265 (0.9914)
DEA-CRS	0.3767 (0.8518)	0.4839 (0.8371)	0.5614 (0.8300)
DEA-VRS	0.4044 (0.5720)	0.5202 (0.6537)	0.5899 (0.6985)

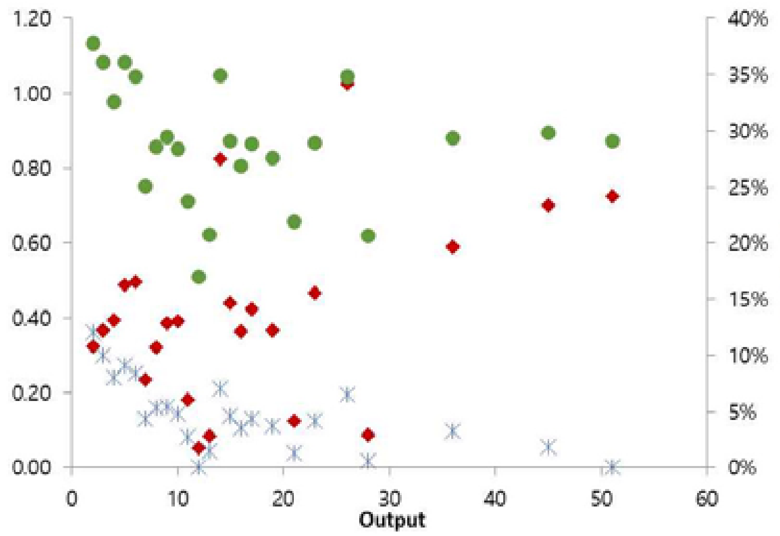
Note: Rank Correlations are reported in parentheses.

Figure 1 shows the relationship between firm-specific inefficiency indexes and output in the first sample in case 3 where variability of inefficiency error is high. The figure shows how data aggregation can affect estimates of inefficiency by size of firm. As shown in Figure 1(a), inefficiency indexes from stochastic frontier cost functions have a similar pattern regardless of whether heteroscedasticity is considered or not.

Figure 1 - Firm specific inefficiency index over averaged output in the 1st sample in case 3



(a) Inefficiency Index from Stochastic Frontier Cost Function



(b) Inefficiency Index from DEA of Constant Return to Scale and Variable Return to Scale

However as shown in Figure 1(b), inefficiency indexes from DEA with VRS have a much different pattern compared to true inefficiency indexes. DEA with CRS does not show greater inefficiency with small farms, but this result is due to imposing constant returns to scale. DEA with VRS, however, tends to have inefficient small firms relative to efficient large firms even though the true inefficiency indexes do not vary by size. Thus, as the example shows, DEA falsely leads to finding small firms having greater inefficiency, but this result is driven both by the heteroscedasticity and the larger number of small firms.

6. Conclusions

This article studies estimation of stochastic frontier (total) cost functions with heteroscedasticity from using aggregated data. Aggregation creates heteroscedasticity in the unexplained error. Each unit within a firm is assumed to have identical inefficiency. Future research may want to consider the effects of aggregation when the inefficiency varies by individual unit. The stochastic frontier functions hold up rather well in the presence of data aggregation, but DEA shows low correlations with actual inefficiency and also DEA with VRS incorrectly finds that small firms have more inefficiency.

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B07

Methodological experiment on measuring Cassava production, productivity, and variety identification in Malawi

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ABSTRACT

Statistics on cassava production and productivity present large gaps across the developing world. The deficiencies are rooted in the inability of the existing survey methodologies in accommodating continuous harvests that cut across agricultural seasons, with timelines that vary significantly by variety. This paper explores the results of a randomized household survey experiment testing 4 survey treatments that differed in the approach to data collection on production, namely (1) daily diary-keeping at the household-level for 12-months with in-person supervision visits twice per week, (2) daily diary keeping at the household-level for 12-months with supervisory mobile phone calls twice per week, (3) recall-based data collection at the plot-level for a 6-month reference period, administered twice during the 12 months, (4) recall-based data at the plot-level for a 12-month reference period (the prevailing practice in household and farm surveys collecting information on cassava production). In all households, 1 cassava plot was randomly for crop cutting and all cassava plot areas were recorded based on farmer self-reporting and handheld GPS units. Multivariate analyses will be undertaken within a multi-level framework comparing household-level annual cassava production and productivity estimates obtained from the different treatment arms and the crop cutting exercise. The heterogeneity of survey treatment effects, at the household- and plot-levels, will be explored by observable attributes, for instance, by clusters of districts in unique production systems, and by objectively identified improved cassava variety cultivation status, based on DNA fingerprinting of leaf samples obtained from the crop cut subplot. Additionally, household-level estimates of consumption of own cassava production obtained from D2, R1, and R2 will be compared to those based on D1.

Keywords: Agriculture, Harvest Diaries, Household Surveys

PAPER

1. Introduction

Cassava is the second most important staple crop to maize in Malawi and is cultivated in most parts of the county. Approximately 10 percent of the population depends on cassava as their main staple crop (Schoning and Mkumbira 2007) and with unpredictable weather patterns it is now garnering even more attention from policymakers because it performs better under poor soils, is drought tolerant and does not require the use of fertilizers. Cassava is mainly grown in districts along Lake Malawi where it is considered the main food staple crop and in other areas that rely primarily on maize, cassava is grown for commercial purposes or as a security measure in case of unforeseen events.

Despite the importance of cassava as a staple crop in Malawi and Sub-Saharan Africa, serious weaknesses still exist in obtaining accurate measures of crop production, land area, and variety identification. In Malawi, there is high level of variability in farm yields reported. Schoning and Mkumbira (2007) estimated that the average cassava root yield is estimated to be 19 tonnes per hectare ranging from 8 to 39 tonnes per hectare. and this high variation can be associated with challenges in estimating cassava yields arising from irregular and partial or piecemeal harvesting of cassava (Haggblade and Zulu 2003). In addition, farmers grow both improved and traditional varieties with varying yield potential thereby increasing yield variability.

2. Experimental Design

To help address the observed gaps in agricultural data and to test the relative accuracy and cost-effectiveness of old and new methods in the context of gold-standard approaches for the estimation of cassava yields and variety identification, the World Bank Living Standards Measurement Study (LSMS) and the Malawi National Statistical Office (NSO) are collaborating on a randomized household survey experiment. The experiment, formally known as CVIP: Methodological Experiment on Measuring Cassava Production, Productivity, and Variety Identification, has been implemented between July 2015 and August

2016 to compare different production measurement methods, land area measurement techniques, and methods of cassava variety identification.

2.1 Sampling

The target universe for CVIP includes households cultivating cassava in five major cassava producing districts in Central and Southern Malawi. To select the districts, key members of the LSMS and NSO teams working on the experiment embarked on a number of missions to consult with experts on agriculture and cassava production in Malawi throughout 2014. Topics discussed included, but were not limited to, production figures for cassava at the national and district levels, planting and harvesting times for cassava, the many different varieties cultivated, and approaches to cassava production estimation and the challenges faced with each. After meetings with key policy makers including the Ministry of Agriculture and Food Security, the Department of Agricultural Research Services, Lilongwe University of Agriculture and Food Security and the International Institute of Tropical Agriculture (IITA), five of the top cassava-producing districts were identified and chosen so that the sample includes one district from each agro-ecological zone or Agricultural Development Division across Malawi excluding Karonga ADD. Districts selected for this study are Nkhatabay, Nkhotakota, Lilongwe, Zomba and Mulanje. Although the Northern region of Malawi (more specifically the Karonga ADD) is also known for cassava, due to the location of the NSO headquarters in Zomba, Malawi, the experiment focused on the Central and Southern region so that regular supervision trips by NSO management team members were feasible from a cost and time management perspective.

After selecting the districts, the LSMS and NSO teams then met with the district agricultural development officers and the assistant agricultural development officers along with crop specialists in each of the five districts selected to gather more information. These individuals helped to identify areas within each district cultivating cassava and provided the production figures for the Extension Planning Areas which the agricultural sector in Malawi uses as project implementation areas so that NSO could identify the census Enumeration Areas (EAs) producing cassava.

The sampling frame for CVIP is based on the 2008 Population and Housing Census (PHC) and a stratified sampling procedure was used. The primary sampling unit was at the EA-level and the second sampling unit was cassava-producing households that were randomly selected from the 45 target EAs. A total of 9 EAs were sampled per district and after a complete listing of all cassava farming households in the selected EAs, 28 households were sampled per EA.

2.2 Treatment Arms

In each EA, CVIP randomly allocated 7 cassava households to 4 survey treatments that differed in the approach to data collection on production, namely (i) a diary-based method (D1) spanning the entire agricultural season administered by resident enumerators who visited this group of households twice a week to assist the selected respondents in keeping record of all cassava harvest events. This is assumed to be the gold standard for data collection on production. (ii) a second group (D2) of households were also given a diary to record their cassava harvest, along with a mobile phone with a solar charger as an incentive and to insure participation in the project. The resident enumerators visited D2 households once a month but these respondents also received calls twice a week from a call center located at NSO Headquarters in Zomba to check on the record keeping and provide assistance, if needed. The respondents also had the option to call an enumerator/supervisor, whenever needed. (iii) a recall-based approach that is commonly utilized in multi-topic household surveys and that governed the same length of time in comparison to the diary. This group (R1) was visited twice in the course of a 12 month period to collect information on cassava production based on a 6-month recall period. (iv) a second recall-based approach (R2) will be interviewed once using a 12-month recall period.

In all 1,260 households, 1 cassava plot was selected at random for crop cutting (CC), and a 5x5m subplot was set up in line with international best practices. The land areas of all cassava plots were recorded based on farmer self-reporting and handheld GPS units, and D1 and D2 households were given scales to measure their harvests in standard units.

2.3 Variety Identification

An additional component of the experiment focused on cassava variety identification. A number of different methods were tested for this purpose and compared against the gold standard: DNA testing of samples from the plots. Along with self-reporting the variety of cassava cultivated on a particular plot, during the administration of the agriculture questionnaire respondents were presented with questions regarding phenotypic or morphological characteristics of cassava and were required to answer these questions both before and after the enumerator presented the respondents with pictures of the different attributes of the cassava to the farmer. On the randomly selected sub-plots for crop cutting, leaf samples were also collected for DNA analysis. The samples were sent to the National Tuber and Roots Laboratory of Malawi for DNA extraction. The responses from the farmers were then compared with the standard descriptors for each cassava variety.

2.4 Fieldwork

The fieldwork for CVIP ran approximately 12 months starting in July 2016. In the first month of the operation, the resident enumerators administered a questionnaire collecting general information about each household and its members along with detailed information on the gardens and plots owned or cultivated by the respondents. These components of the questionnaire were identical across survey treatment groups and built on the questionnaires from Malawi's Integrated Household Survey Program. This complementary information enables the research team to explore whether the gender and other characteristics of the plot manager(s) and other household socioeconomic characteristics have any bearing on the results.

Also within the first month of fieldwork, enumerators introduced diary households to the concept of the production diary and enumerators assisted in showing them how to weigh the cassava harvested each day on the scale provided and then fill the required information in the diary. The call center located in Zomba, Malawi at NSO headquarters began calling the D2 households within the first 1-2 weeks of fieldwork as soon as an adequate number of households had received their diaries, and the resident enumerators began bi-weekly visits to the D1 households at this time, as well.

Although production information for the R1 and R2 households was not collected until later in the year, at the start of the fieldwork resident enumerators also began approaching households from all 4 treatment arms to randomly select one of their cassava plots for crop cutting and to lay the crop-cutting sub-plot. Enumerators instructed respondents to inform them as soon as the crop cutting sub-plots were ready for harvest and the enumerators worked with their crop cutting assistants in each EA to monitor this. R1 households received their first visit to collect production information for the period from August 2015 – January 2016 in February 2016 and for a second time in July/August 2016. Enumerators also visited R2 households to collect information on production for the full 12-month period in July/August 2016.

For all questions regarding agriculture and cassava, the enumerators attempted to interview the plot manager(s) or household member(s) most knowledgeable about decision-making on the gardens and plots owned and cultivated by the household. Harvest diaries were also to be filled by the plot manager(s); however, if the plot manager for a particular household was illiterate, then the enumerator assisted the respondent in identifying another literate household member or trusted colleague to assist them in weighing the cassava and filling the diary.

2.5 Data Entry and Quality Control

To ensure data quality and timely availability of data, CVIP was implemented using the World Bank's Survey Solutions CAPI software.1 Given the complex set-up of the experiment, a number of different questionnaires were administered covering information on households and plots from all treatment arms. All versions of these questionnaires along with the data from the crop cutting exercise were directly entered into the tablets. Enumerators distributed paper production diaries to the D1 and D2 households leading up to the start of each calendar month and after collecting the diaries from the prior month the Supervisors for each district entered the data into CAPI. A second data entry of the diary data will take place in September 2016. The use of CAPI also assisted in the accurate collection of leaf samples. Enumerators labelled leaf samples from each randomly selected sub-plot with a barcode and directly scanned this into the Survey Solutions questionnaire to enable the linkage between the DNA results and the households.

3. Summary Statistics

3.1 Land Area

Land area for all cassava plots was collected in hectares for all cassava plots using GPS measurement. Respondents were also asked to self-report the land area. The majority of respondents reported in acres, with approximately 5 percent reporting in hectares or square meters. Table 1 shows that the average farmer-reported area in hectares is .37 while the average GPS-based area measurement is is .19 hectares. The difference between self-reported and GPS-based represent represents 94% of the GPS area mean and does not exhibit statistically significant variation by survey treatment which is another indication that randomization was successful across survey treatment arms. To delve further into understanding this large gap between the GPS and self-reported area, Figure 2 shows the mean difference across plot area decile. The difference is largest in the 2nd decile and and shows an overall trend of decreasing as the plot size increases.

[1] For background and documentation on Survey Solutions, please visit www.worldbank.org/capi. The software platform is available free of charge and is being developed by the World Bank Development Data Group - Survey and Methods Unit (DECSM). To access Survey Solutions Designer, please visit and sign up as a user at www.solutions.worldbank.org.

3.2 Production

Given that the fieldwork is ongoing for the CVIP experiment, the analysis presented focuses on the first 6 months of cassava production computed in kilograms from the two diary treatment arms and the 6-month recall arm. Since all diary households were provided with a hanging scale, they were expected to record all entries in kilograms and production for these households is simply the total of the daily records from the first six months of fieldwork (August – January). The 6-month recall households were administered a module on cassava production in February. Although recall respondents were encouraged to report total production over the last 6 months in kilograms, the majority of households were unable to and instead reported in non-standard units. Recall respondents reported production for 19 percent of cassava plots in kilograms, 74 percent in 50 KG bags, 3 percent in 70 KG bags, and the few remaining plots in pails (small and large), and pieces (medium and large). To convert these non-standard units to kilograms, conversion factors were computed from the data on non-standard units collected in the diary records. For all diary entries, respondents weighed the cassava harvested in KGs, but also recorded the production in non-standard units. For the majority of harvest information the respondents reported production in 50 KG sacks as these are one of the most common units used by households and the NSO provided sacks as part of the experiment. Households that cultivated cassava for home consumption and harvested in small quantities reported in small, medium, and large pieces. Given the variation in the size of cassava across the 5 districts, EA-level averages were computed and used to calculate total production for recall households.

Table 2 shows the average 6 months of cassava production for households across the three treatment arms and by month for the two diary arms. The mean for total production is the highest for the D2 households at 829.3 KGs, and the lowest for R1 households at 529 KGs. D1 households, on average, reported 594.7 KGs harvested across the first 6 months.

4. Empirical Approach to Estimating Survey Treatment Effects

4.1 Production

This section provides a description of the empirical framework for estimating the relative survey treatment effects that CVIP was designed to isolate. Within-EA randomization of the systematically sampled households across treatment arms allows us to estimate the causal effects associated with each treatment arm. The core specification is:

$$y_i = \alpha + \beta_1 \mathrm{D2}_i + \beta_2 \mathrm{R1}_i + \gamma C + \varepsilon_i$$

where i represents household; y is the dependent variable; α and ε represent constant and error terms, respectively; D1, R1 and R2 are identifiers representing a household's assignment to diary-phone or 6-month recall, with diary-visit being the comparison category; and C is a vector of household attributes that is included with the intention of capturing any remaining unobserved heterogeneity that may be correlated with these controls and that may also jointly determine both the dependent variable and household survey treatment assignment.

The dependent variable of focus, as described in Section 3, is the total 6-month production in kilograms. The results from each regression are coupled with the full spectrum of tests of equality of for complete inter-arm comparisons. The standard errors are clustered at the EA-level.

4.2 Variety Identification

To determine the accuracy of the subjective methods (farmer elicitation and use of morphological attributes) of varietal identification, the DNA finger printing of the leaf samples serves as a gold standard. The DNA reference samples have been matched with the field samples and the subjective methods evaluated at three levels. The first level relates to assessing farmers' ability to predict or state the unique name of the variety. The second is the accuracy of the unique prediction or the number of matches of the stated or uniquely predicted varieties to the varieties in identified through DNA finger printing. The third is the accuracy in predicting or identifying improved or local varieties. After assessing the accuracy, we also extended the analysis to accuracy of adoption studies estimates of different methods. This analysis is done by first examining the adoption of individual varieties and secondly at the adoption of improved and local varieties. Statistical tests and discrete choice models are conducted to examine the determinants of misidentification of crop varieties by farmers.

5. Results

5.1 Production

If we assume that a respondent filling a harvest diary does not over report cassava production, then we can conclude that diary arm with the highest yield is provides the best estimate. As discussed in Section 4, the D2 households reported, on average, significantly higher production than D1 households. Relying on the assumption that respondents do not have an incentive to misreport daily entries as higher than the cassava they weighed, and that they do not record entries on days that they did not harvest any cassava, this implies that D2 households are closest to the true production value.

Table 5 shows the results of comparisons from the full sample of CVIP households. Taking our D1 households as the control group, we can see that total production reported by the D2 households is significantly higher than that of the D1 households as well as the R1 households. Total production as reported by the R1 households is not significantly different from that of the D1 households.

To investigate further, Table 4 shows results from comparisons by land area tercile. The first two terciles based on land holdings are consistent with the findings from the full sample in that D2 production is statistically significantly higher than both D1 and and R2. In the second tercile the D1 production is also significantly higher than R1. None of the results comparisons from Tercile 3 are significant.

Given the multiple production systems covered across the five CVIP districts, examining results from each district is imperative. Nkhatabay and Nkhotakota districts are both along the lakeshore and known for cultivating cassava as a staple crop. This is apparent in the percent of diary-based production allocated to consumption. 94 percent of the diary entries in Nkhatabay were intended for home consumption while 87 percent of diary entries in Nkhotakota were intended for the same. Lilongwe represents an area cultivating cassava almost exclusively for commercial purposes. In the case of Lilongwe, only 9 percent of the production diary entries were intended for consumption. The first three districts listed have similar production systems across their EAs, however, in the case of Zomba it varies more within the district. On the whole, 61 percent of diary entries from D1 and D2 households in Zomba were intended for consumption. Mulanje is the district furthest South in Malawi and geographically not far from the second largest city in Malawi, Blantyre, and in this area diary households reported 27 percent of their daily harvests as intended for consumption. Nkhatabay, Nkhotakota and Mulanje each represent the overall trend of highest production coming from D2 households, followed by D1 households, followed by R1 households. Lilongwe differs in that R1 production is higher than D1, though this difference is not significant. Zomba, where overall production is also the lowest, varies from the other districts the most in that R1 shows the highest production, then D1, then D2. None of the comparisons in Zomba are significant. D2 production is significantly higher than D1 production in Nkhatabay and Lilongwe. D2 production is significantly higher than R1 production in Nkhotakota, Lilongwe, and Mulanje. D1 is significantly higher than R1 in Nkhotakota and Mulanje.

5.2 Variety Identification

The results from the cassava DNA analysis reveal that only 31 percent of farmers correctly identified the variety in comparing the farmer-reported names with the DNA analysis. Beatrice and Manyokola, two of the most popular varieties, were more likely to be correctly identified by farmers as shown in Figure 3, whereas there was high misidentification for the less popular varieties. Incidence of correct varietal identification was only 5 percent based on the morphological protocol.

Furthermore, as shown in Table 6, according to DNA analysis only 10 percent of the varieties planted by farmers were improved varieties, however, the results from the farmer elicitation show that 79 percent of the households planted local varieties, 19 percent planted improved varieties and 2 percent did not know whether the variety was local or improved. About 99 percent of the varieties farmers stated as improved were found to be local and 12 percent of the varieties farmers stated as local were found to be improved varieties. This implies that only 1 percent of samples were correctly identified as improved and 88 percent correctly identified local varieties as local. The results also show that farmer elicitation over estimates adoption of improved cassava varieties and underestimates adoption of local varieties.

6. Key Preliminary Findings

In line with previous work on land area measurement, the results from self-reported and GPS-based measurement of cassava plots indicates the importance of relying on GPS-based land area measurement whenever possible to ensure accuracy.

The preliminary analysis of production data from the D1, D2, and R1 treatment arms indicates that, overall, the D2 approach to diary data collection through mobile phone monitoring attains potentially the best estimate of production. Given the variation of these results across land terciles and production systems, however, it is essential to explore these comparisons further and to do so using the complete data from the experiment set to conclude in September 2016. With only 31 percent of farmers correctly identifying the variety based on comparisons of farmer-reported names with DNA analysis, farmer-reported information is unreliable for accurate variety identification.

Table 1 - Average Area of Cassava Plots by Land Measurement Method

	Farmer-Reported (Ha)	GPS-Base (Ha)	Difference as a % of GPS Mean	P-Values (Mean Diff.)	P-Values (Distribution Diff.)
All Cassava Plots	0.37	0.19	131%	0.000	0.000

Figure 1 - Mean Self-Reported-GPS-Based Plot Area Difference (Has) by GPS-Base Plot Area Decile

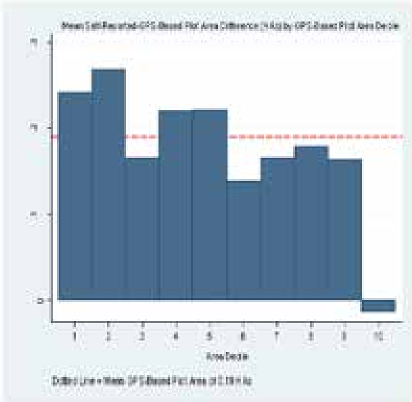

Table 2 - 6 months of Cassava Production in KGs

	D1		D2		R1
August	60.1		80.1		
September	162		149		
October	95.4		151.1		
November	106.1	**594.7**	184.1	**829.3**	**529**
December	112.1		160.4		
January	59		104.7		
Observations	**228**		**239**		**231**

Table 3 - Estimated Cassava Production (KG) Comparisons by Method (All Districts)

		P-Values (Mean Diff.)		P-Values (Distribution Diff.)	
All HHs	**Mean**	Diary-Visit	Diary-Phone	Diary-Visit	Diary-Phone
Diary-Visit	594.7				
Diary-Phone	829.3	**0.000**		**0.020**	
6-month Recall	529.3	0.211	**0.000**	0.175	**0.000**

Figure 2 - Kernel Density Estimation of 6-month Cassava Production by Survey Method

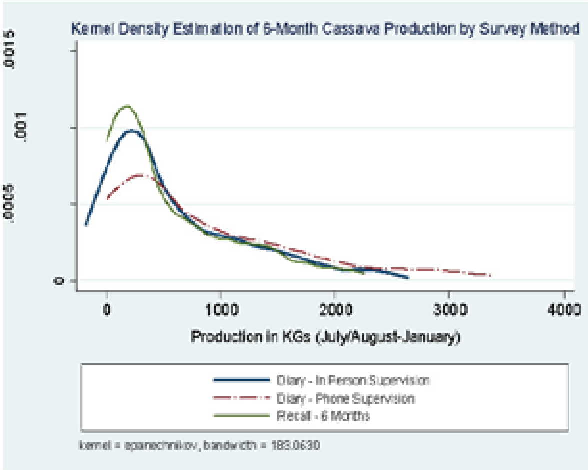

Table 4 - Estimated Cassava Production (KG) Comparisons by Land Tercile

		P-Values (Mean Diff.)		P-Values (Distribution Diff.)	
	Mean	Diary-Visit	Diary-Phone	Diary-Visit	Diary-Phone
Household Cassava Landholding Tercile 1 (0.001 ha – 0.145 ha)					
Diary-Visit	385.8				
Diary-Phone	688.8	**0.004**		**0.005**	
6-month Recall	330.4	0.422	**0.001**	0.406	**0.004**
Household Cassava Landholding Tercile 2 (0.146 ha – 0.269 ha)					
Diary-Visit	693.3				
Diary-Phone	932.2	**0.039**		0.183	
6-month Recall	539.3	**0.067**	**0.001**	0.144	**0.018**
Household Cassava Landholding Tercile 3 (0.269 ha – 1.469 ha)					
Diary-Visit	680.2				
Diary-Phone	886.2	0.105		0.522	
6-month Recall	745	0.533	0.274	0.846	0.721

Table 5 - Estimated Cassava Production (KG) Comparisons by District

		P-Values (Mean Diff.)		P-Values (Distribution Diff.)	
	Mean	Diary-Visit	Diary-Phone	Diary-Visit	Diary-Phone
Nkhata Bay (% of Diary-Based Production Allocated to Consumption: 94)					
Diary-Visit	952.4				
Diary-Phone	1305.4	**0.055**		0.208	
6-month Recall	776.1	0.154	0.029	0.267	**0.016**
Nkhotakota (% of Diary-Based Production Allocated to Consumption: 87)					
Diary-Visit	835.5				
Diary-Phone	1049.1	0.217		0.837	
6-month Recall	610.3	**0.050**	**0.098**	0.235	**0.037**
Lilongwe (% of Diary-Based Production Allocated to Consumption: 9)					
Diary-Visit	914.4				
Diary-Phone	1370.8	**0.004**		**0.020**	
6-month Recall	610.3	0.293	**0.073**	0.241	**0.055**
Zomba (% of Diary-Based Production Allocated to Consumption: 61)					
Diary-Visit	153.5				
Diary-Phone	133.7	0.614		0.982	
6-month Recall	200.6	0.667	0.526	0.332	0.149
Mulanje (% of Diary-Based Production Allocated to Consumption: 27)					
Diary-Visit	396.6				
Diary-Phone	519.7	0.256		**0.065**	
6-mnth Recall	183.7	**0.086**	**0.001**	**0.013**	**0.000**

Table 6 - Identification of Improved Cassava Varieties

Incidence of Cultivation	**Farmer Elicitation**	**Morphological Protocol (MP)**	**DNA Fingerprinting**
Local (%)	79	30	90
Improved (%)	19	70	10
Don't Know (%)	2	-	-

THEMATIC SET

B08

DETERMINANTS OF AGRICULTURAL PRODUCTIVITY

Session Organizer
Alberto Zezza | The World Bank | Rome |Italy

LIST OF PAPERS

Impact evaluation differentials of adoption of nerica on area cultivated, yield and income of rice producers, and determinants in Nigeria

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Spatial nonstationarity in the stochastic frontier model: an application to the Italian wine industry

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DOI: 10.1481/icasVII.2016.b08b

B08

Impact evaluation differentials of adoption of nerica on area cultivated, yield and income of rice producers, and determinants in Nigeria

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ABSTRACT

Adoption of new agricultural technology has different impacts. This study analyzed the different impacts of NERICA adoption on rice producers in Nigeria using the treatment effect estimation approach. It was a cross-sectional survey of 621 rice farmers through a multistage sampling procedure. Although a high percentage of rice farmers were aware of two main NERICA lines: NERICA I (82 percent) and NERICA II (76 percent), the actual adoption rate of these varieties is still very low (57%) in Nigeria. To control for endogeneity, the study used the local average treatment effect estimation methodology and the results showed that NERICA adoption significantly increased the area planted of rice by farmers,yield, and total farm income. The positive impact of NERICA adoption on rice yields and total farm income of farmers respectively is a clear indication that NERICA has the potential to increase rice productivity, reduce poverty and food insecurity. NERICA cultivation should still be further encouraged to rice farmers through the extension agents so as to raise rice yield, reduce rice importation and ensure a sustainable production.

Keywords: Counterfactual framework, sustainable production, productivity, farmers" welfare.

PAPER

1. Introduction

Rice is an extremely important food and cash crop in Nigeria. This strategic commodity is the fourth largest cereal crop grown in the country behind sorghum, millet and maize. Rice is widely cultivated under diverse ecosystems and a wide variety of climatic and soil conditions (rainfed lowland, irrigated lowland, mangrove swamp, upland)with a total annual production of about 2 million metric tons (MT). This annual production is far less than the total national rice consumption which exceeds 5 million MT per year, or more than 30 kg per capita per annum leading to an annual importation of about 2.5-3 million MT (USAID, 2009).Adoption of new technologies is an important issue developing countries have to put into consideration in order increase farm productivity. This study presents the empirical findings from Nigeria on the impact of NERICA adoption.

The study is necessary because it approaches the problem of estimation of adoption rates and their determinants from the perspective of modern evaluation theory (Imbens and Wooldridge, 2009; Imbens, 2004; Wooldridge, 2002; Heckman and Vytlacil 1999; Angrist et al., 1996).

2. Research Methodology

This study draws its methodology from previous surveys conducted in other West African countries. These include among others:Wiredu et al., 2014 in Ghana; Ojehomon et al., 2012, Awotide et al. 2012, Dontsopet al., 2011 in Nigeria; Diagne et al., 2009a,b, Diagne, 2006 in Cote D„lvoire; Spencer et al., 2006, Diagne et al., 2007 in Guinea.

This study was conducted in selected states in Nigeria, in 2012. The states were: Kaduna (located in the Northwestern Nigeria), Nasarawa (located in the Northcentral Nigeria), Ondo Osun, Ogun and Ekiti States (located in the Southwestern Nigeria). Data for the study were generated mainly from primary sources. The primary data were collected using a Focus Group Discussion across the rice growing communities to obtain prior information on their livelihoods and rice farming system. The semi-structured questionnaire was also administered to elicit information on the farmer"s socio-economic conditions, the farm"s characteristics, participation in the new rice variety selection, and experience with NERICA adoption, farm productivity, and income etc.

2.1 Sampling procedure

A multi-stage random sampling technique was used to select rice farmers from the six baseline states. The six states were selected purposively because no study as far as we know has evaluated the adoption rate of this variety in all the baseline states in Nigeria since the official release in 2005. In the second stage (due to the difficulty of getting the list of rice-producing farmers in the selected states as a result of lack of rice farmers" census), the lists of all the rice growing Local Government Areas (LGAs) where rice is grown and NERICA seeds have been disseminated were collected from the respective Agricultural Development Programme (ADPs) officers. This was followed by a random selection of the villages where NERICA dissemination activities have taken place, known as PVS villages. For every two NERICA villages selected, one adjacent village (that is within 15 to 20km radius) where NERICA is yet to be disseminated was also randomly selected as control. The selections were based on the fact that the more the number of control villages in the research sample, the more the number of non-adopters that is expected to be selected. The distance was chosen because the closer the non NERICA village is to the NERICA village, the greater the possibility of farmers" knowledge of the variety through other means apart from official means of dissemination. In each state, six villages were selected (two PVS villages and one non-PVS village per LGA). The chance of selecting a non-PVS village was based on the selection of a NERICA village within that vicinity. The selection of the PVS villages within each state was based on the ADP zones. However, non- rice producing ADP zones were not selected.

The third stage of the sampling involved the random selection of at least a hundred (100) rice farmers in each of the selected states. A total of 12 LGAs and 36 villages were selected for the study; and a total of 621 rice farmers were selected from the list of rice farmers in selected villages. The distribution of rice farmers interviewed per selected villages was based on the availability of rice farmers" guided by the NERICA field extension worker covering the selected villages. The sample size would have been based on the population size of rice farmers but this was not available.

2.2 Econometric procedures

This study used treatment effect estimation approach (counterfactual framework)to determine the impact of NERICA adoption on rice farmer"s income, yield, expenditure and per capita expenditure. The choice of this approach was based on the ability of the methods to produce consistent estimates (Imbens and Wooldridge, 2009). Also, we used the framework in order to overcome "non-exposure" bias and "selection" bias of the traditional procedures.This approach detects two important sources of bias in the estimation of treatment effects. These include the initial differences between on adopters and non-adopters in the absence of treatment, and the difference between the two groups. The parameters of interest are the average treatment effect (ATE) which is the expected effect of treatment on a randomly drawn person from the population, the average effect of the treatment on the treated (ATT) which represents the mean effect for those who actually participate in the treatment, and the average effect of treatment on the untreated (ATU) that measures the expected treatment effect for an individual drawn from the population of non-participants. By the counterfactual outcome framework a randomly selected rice producing household had two potential outcomes of adopting NERICA varieties .That is

$$Y = Y_1 \; if T = 1 \; and Y = Y_0 \; if T = 0 \text{ -- } 1$$

In equation 1, Y is the outcomes of interest such as total farm income. T is the adoption status. For the sample of randomly selected rice producing households the average effect of adoption, which is also known as ATE is generally given by:

$$ATE = E(Y_1 - Y_0) \text{ -- } 2$$

Differences in knowledge and access to information, physical accessibility as well as socioeconomic condition were expected to present unequal opportunities for adoption (Tambo and Abdoulaye, 2011). The impact parameter given adoption status, also known as the ATT is also given by:

$$ATT = E(Y_1 - Y_0) \,|T = 1) \text{ -- } 3$$

In this study access to the NERICA varieties was considered the most satisfactory condition for adoption. However, it was possible that some farmers had access to the seeds but did not plant the seeds. This implies that some farmers may have complied while others did not comply. In this case the impact on the farmers who received the seeds and subsequently planted, which is the local average treatment effect (LATE) is a more useful estimate of impact.

The non-parametric LATE framework was used to estimate the causal effect of the adoption of NERICA on total farm income, yield, expenditure, poverty status. The LATE parameter was expressed as;

$$LATE = E(Y_1 - Y_0)|P = 1, T = 1)\text{------}4$$

In addition to NERICA adoption, the incomes of the rice producers were assumed to be also affected by some exogenous factors, X, such that the potential outcomes of adoption in terms of X and the unaccounted factor, μ, was given by

$$Y = Y_1 = X\beta_1 + \mu_1 if T = 1\ and Y = Y_0 = X\beta_0 + \mu_0\ if T = 0\text{------}5$$

The LATE was re-expressed as:

$$LATE = X\beta_1 - X\beta_0 + E(\mu_1 - \mu_0|\ X, T = 1, P = 1)\text{------}6$$

Subsequently, the observed income, $= Y_1 + Y_0$, was expressed following Wiredu *et al.*, (2014) in terms of the LATE as:

$$Y = X\beta_0 + T * LATE + \varepsilon_{LATE}\text{------}7$$

The estimation of the LATE parameter in equation 7 followed a two stage instrumental variable regression procedure In the first stage a model of adoption was estimated with access to seeds of NERICA, P, as an instrument, W, as additional explanatory variables, and γ, as coefficient estimates. The model for adoption was specified as:

$$Prob(T = 1) = \emptyset(PW_\gamma)\text{------}8$$

The second stage involved the estimation of the LATE model with the predicted probability of adoption. The model was also specified as;

$$Y = X\beta_0 + \hat{T} * LATE\ (X) + \varepsilon_{LATE}\text{------}9$$

To analyze the various factors influencing the adoption of NERICA, we employed the ATE-Probit model.

$$T = E\ (y\,|\ x, w) = \alpha w + \delta w\ (x\text{-}X)\text{------}11$$

Where T = Status of adoption(1 = if adopted and 0 otherwise); y = outcome of exposure to treatment; w = a binary indicator variable for NERICA exposure (w =1 indicates exposure and w = 0 otherwise.); x = a vector of explanatory variablesX_1 = the gender of farmers (1 = male and 0 = female); X_2 = the age of farmers (years); X_3 = Education of farmers (1 = formal education and 0 Otherwise); X_4 = the Household size which is the number of people living under the same roof; X_5 = past participation in PVS trials (PVS participation = 1 and 0 otherwise); X_6 = contact with extension agent where (extension contact = 1 and 0 otherwise); X_7 = access to phone (where access to phone = 1 and 0 otherwise); X_8 = growing upland rice (growing upland=1, and 0 otherwise); X_9 = growing lowland rice (lowland rice = 1 and 0 otherwise); X_{10} = Distance to market (km); X_{11} = No of livestock; X_{12} = Kaduna State dummy (Kaduna state =1 and 0 otherwise); X_{13} = Ekiti State dummy(Ekiti State =1, otherwise 0); X_{14} = Nasarawa State dummy (Nasarawa = 1 and 0 otherwise); X_{15} = Ogun State dummy (Ogun =1 and 0 otherwise); X_{16} = Access to radio (access to radio =1 and 0 otherwise); X_{17} = access to television (access to television =1 and 0 otherwise); X_{18} = Ondo State dummy (Ondo=1 and 0 otherwise); X = vector of sample means of x; α and δ = are the parameters to be estimated

3. Results and Discussion

3.1 Adoption rates of NERICA varieties

The actual adoption rate of was 57 percent (Table 1). Across the individual states, the actual adoption rate was 77 percent, 67 percent, 62 percent, 62 percent, 47 percent and 8 percent in Ondo, Ekiti, Nasarawa, Ogun, Kadunaand Osun States respectively. The potential population adoption rate (ATE), which represent the true demand for NERICA varieties by the target population was estimated to be 80 percent for the study area, and 98 percent, 90 percent, 86 percent, 84 percent, 82 percent and 13 percent in Nasarawa, Ondo, Ekiti, Ogun, Kaduna, and Osun States respectively. This suggest that if the whole population was aware of, and have access to NERICA seed before the time of the survey, the NERICA adoption rate in the study area (Nigeria) could have been 80 percent instead of the actual 57 percent. Thus, for entire study area (six states), the estimate of the population adoption gap is accordingly 23 percent, and is statistically significant at 1 percent level. The corresponding estimates of the population adoption gap (i.e., the non-awareness bias) for Nasarawa, Kaduna, Ogun, Ekiti, Ondo, and Osun States are 36 percent, 35 percent, 22 percent, 19 percent, 14 percent, and 5 percent respectively, and all are statistically significant at 1 percent level. At the time of this study, the adoption rates among the NERICA exposed subpopulation (ATE1) in the study area was 81 percent while in Nasarawa, Ondo, Ekiti, Ogun, Kaduna, and Osun States, the adoption rate were estimated to be 98 percent, 90 percent, 86 percent, 85 percent, , 83 percent and 12 percent respectively.It is also instructive to compare adoption rates estimated in this study with estimates from other studies conducted in Nigeria and elsewhere in Africa. Although the adoption rate of 57 percent was considerably higher than the 4 percent reported by Diagne (2006) for Cote d‟Ivoire, greater than 18 percent reported by Adegbola et al., (2005) for Benin republic, 30 and 40 percent reported for Ekiti and Kaduna (Nigeria) States respectively by Spencer et al., (2006), and 20 percent reported by Dontsop et al.,(2011) for Osun State (Nigeria), the 23 percent adoption gap estimates imply that there is still a potential for significantly increasing NERICA adoption rates in Nigeria.

3.2 Comparative farm-level economic benefits from NERICA adoption

The difference statistical test shows a productivity difference in NERICA yields and also a difference in variable production costs between adopters and non-adopters (Table 2). NERICA adopters were about 14 per cent more productive compared to the non-adopters. Variable costs for adopters were 61.6 percent lower than non-adopters on average, suggesting greater benefits from this source. The simple comparisons between adopters and non-adopters demonstrate that the adopters are distinguishable in terms of considerably higher NERICA net income. This result agrees with the finding of Ojehomon et al., (2012) who reported that investment in NERICA rice production in Ekiti State, Nigeria is more profitable than the other non-NERICA varieties grown in the area. This suggests that NERICA can really be considered as a poverty alleviating crop (Table 3).

Table 2 - Comparative physical and economic benefits in NERICA Adopters production in Nigeria

Variables	Adopters (n =292)	Non-adopters (n=329)	Difference (percent)
Area cultivated (ha)	2.6	1.5	1.1 (42.3)***
Yield (Kg /ha)	1412.0	1220.9	191.1(13.5)
Gross value of production ('000 ₦/ ha)	358.4	221.9	136.5 (38.1)***
Variable costs ('000 ₦/ ha)	8667.7	3330.1	5337.6(61.6)***
NERICA net-income ('000 ₦/ ha)	663.9	274.8	389.1(58.6)***

Note: The figures in parenthesis are in percentage

Table 1: Estimation of Population Adoption Incidence Rates

Variables	Ekiti	Kaduna	Nassarawa	Ogun	Ondo	Osun	Pooled sample
ATE	0.859***	0.815***	0.980***	0.839***	0.904***	0.132***	0.799***
	(0.038)	(0.041)	(0.017)	(0.043)	(0.031)	(0.034)	(0.017)
ATE1	0.859***	0.834***	0.983***	0.852***	0.904***	0.120***	0.810***
	(0.038)	(0.041)	(0.015)	(0.039)	(0.031)	(0.031)	(0.015)
ATE0	0.860***	0.790***	0.976***	0.806***	0.908***	0.157***	0.775***
	(0.042)	(0.063)	(0.021)	(0.058)	(0.034)	(0.051)	(0.025)
JAA	0.667***	0.467***	0.624***	0.622***	0.766***	0.084***	0.569***
	(0.029)	(0.023)	(0.010)	(0.029)	(0.026)	(0.022)	(0.011)
GAP	-0.192***	-0.348***	-0.356***	-0.218***	-0.138***	-0.048***	-0.230***
	(0.009)	(0.028)	(0.008)	(0.016)	(0.005)	(0.015)	(0.007)
PSB	-0.000 (0.004)	0.019 (0.018)	0.003 (0.004)	0.012 (0.009)	-0.001	-0.012	0.010* (0.005)
					(0.002)	(0.011)	
Observed							
NE/N	0.777***	0.560***	0.635***	0.730***	0.848***	0.700***	0.703***
	(0.412)	(0.048)	(0.047)	(0.045)	(0.035)	(0.046)	(0.020)
NA/N	0.631***	0.468***	0.644***	0.620***	0.762***	0.060***	0.569***
	(0.048)	(0.048)	(0.048)	(0.0488)	(0.042)	(0.024)	(0.021)
NA/NE	0.813***	0.836***	0.985***	0.849***	0.899***	0.086***	0.809***
	(0.062)	(0.086)	(0.076)	(0.067)	(0.049)	(0.034)	(0.030)
N	103	109	101	100	105	100	552
NE	80	61	66	73	89	70	388
NA	65	51	65	62	80	6	314

Note: Figures in parentheses are standard errors.
ATE = Population potential adoption rate; ATE 1 = Adoption rate among exposed and access to seed; ATE0 = Adoption rate among non-exposed; JAA = Actual adoption rate; GAP = JAA – ATE ; PBS = Population selection bias ; N = number observed
NE = number of exposed; NA = number of adopters
*** = $p < 0.01$ ** = $p < 0.05$ * = $p < 0.10$

Table 3 - Comparative economic benefit of NERICA production (disaggregated by sampled States)

Variables	Kaduna State		
	Adopters (n =51)	Non-adopters (n=58)	Difference (percent)
Area cultivated (ha)	1.3	1.1	0.2(15.4)
Yield (Kg per ha)	2324.1	2272.4	51.7 (2.2)
Gross value of production ('000 ₦/ ha)	261.8	271.1	-9.3(3.6)
Variable costs ('000 ₦/ ha)	4.8	3.7	1.1 (22.9)***
NERICA net-income ('000 ₦/ ha)	252.2	229.7	22.5(8.9)
	Nasarawa State		
	Adopters (n =65)	Non-adopters (n=36)	Difference (percent)
Area cultivated (ha)	3.1	2.1	1.0(32.3)***
Yield (Kg per ha)	1061.0	1330.3	269.3(25.4)
Gross value of production ('000 ₦/ ha)	310.3	212.2	98.1(31.6)***
Variable costs ('000 ₦/ ha)	31.0	21.2	10.2(31.6)
NERICA net-income ('000 ₦/ ha)	324.9	201.7	123.2(37.9)
	Ogun State		
	Adopters (n = 62)	Non-adopters (n=38)	Difference (percent)
Area cultivated (ha)	1.9	1.5	0.4(21.1)
Yield (Kg per ha)	1811.9	1433.8	378.1(20.9)***
Gross value of production ('000 ₦/ ha)	474.4	413.7	60.7(12.8)
Variable costs ('000 ₦/ ha)	285.2	237.7	47.5 (16.7)
NERICA net-income ('000 ₦/ ha)	192.5	160.6	31.9(16.6)
	Ekiti State		
	Adopters (n =65)	Non-adopters (n= 38)	Difference (percent)
Area cultivated (ha)	4.3	3.6	0.7(16.3)
Yield (Kg per ha)	1379.9	1315.7	64.2 (4.7)
Gross value of production ('000 ₦/ ha)	379.9	357.9	22.0 (5.8)
Variable costs ('000 ₦/ ha)	449.9	274.3	175.6(39.0)**
NERICA net-income ('000 ₦/ ha)	126.7	38.1	88.6(69.9)
	Ondo State		
	Adopters (n =80)	Non-adopters (n= 25)	Difference (percent)
Area cultivated (ha)	2.3	2.1	0.2(8.7)
Yield (Kg per ha)	754.6	990.4	-235.8 (31.2)
Gross value of production ('000 ₦/ ha)	375.2	296.4	78.8(21.0)
Variable costs ('000 naira per ha)	6139.6	3484.8	2654.8 (43.2)
NERICA net-income ('000 ₦/ ha)	532.7	329.1	203.6(38.2)

Table 3 segue **- Comparative economic benefit of NERICA production (disaggregated by sampled States)**

	Osun State		
	Adopters (n =6)	Non-adopters (n=94)	Difference (percent)
Area cultivated (ha)	0.6	0.5	0.1(16.7)
Yield (Kg per ha)	425.0	505.1	-80.1 (18.8)
Gross value of production ('000 ₦/ ha)	48.5	45.3	3.2(6.6)
Variable costs ('000 ₦/ ha)	114.0	547.8	-433.8 (380.5)
NERICA net-income ('000 ₦/ ha)	642.9	447.7	195.2(30.4)

Note: The figures in parenthesis are in percentage

3.3 Determinants of NERICA adoption in Nigeria

In Table 4, the results of the log-likelihood of -122.3, the Pseudo R2 of 0.353 and the LR (chi2) of 0.0000 (significant at 1 percent level), imply that the overall model fitted and the explanatory variables used in the model collectively explain the adoption of NERICA decision among the rice farming households in Nigeria. The analysis showed that only gender and farmers access to radio were statistically significant. Men were more aware of NERICA than the women probably due to the large difference between men and women in rice farming in Nigeria (84 percent to 16 percent as indicated). This is in line with Dontsop et al.,(2011) findings who observed that though women were more likely to be aware of NERICA existence in Osun, Niger and Kaduna States of Nigeria, their men counterpart were most likely to adopt NERICA. The findings of the study also revealed that farmers that did not have access to radio were more likely aware of NERICA than those that have radio. This result however differs from other countries in Africa such as Côte d'Ivoire where factors like the household size, growing upland rice, past participation in PVS trials, age of the farmers have significant effects on adoption of NERICA (Diagne 2006).

The marginal effect shows that a unit decrease in number of those that have access to radio leads to 0.13 decreased in the likelihood of being aware of the NERICA varieties (Table 4). The significance of the dummy variables (Ekiti, Nasarawa, Ogun, Kaduna and Ondo) at 1 percent level in positive direction in Table 4 is an indication that there are differences in the determinants of NERICA adoption across the states in the study area. This result corroborate with the information obtained from the Focus Group Discussions (FGDs) in Sabon-Girke (Pako) in Igbebi Local Government Area (one of the PVS villages) of Kaduna State that farmers preferred, and adopt NERICA due to its high productivity and market value Similarly, in Ondo State, the outcome of the FGD at Eleyowo village showed that farmers adopt and preferred NERICA to other rice varieties due to its early maturity and its high yield, short stature, stability, and inability of the paddy to get dislodged before harvest and even after maturity. In Nasarawa State, the FGD revealed that farmers adopt NERICA because of the low fertilizer requirements; high tolerant to most diseases, better tastes, better than other cultivars and early maturity given room to farmers to harvest two to three times a year

Table 4 - Determinants of adoption of NERICA

Variables	Coefficient	Marginal effect
Constant	-1.5116** (0.7516)	
Gender	0.5509** (0.2306)	0.1437** (0.0681)
Age	0.0031 (0.0088)	0.0007 (0.0019)
Educational level	0.1236 (0.1812)	0.0262 (0.0374)
Household size	-0.0333 (0.0231)	-0.0072 (0.0049)
Access to credit	-0.2268 (0.2296)	-0.0508 (0.0544)
Contact to NGO extension services	0.1171 (0.2557)	0.0245 (0.0521)
Source of credit	-0.1739 (0.2062)	-0.0385 (0.0464)
Past participation in. PVS trials	0.2905 (0.2345)	0.0597 (0.0464)
Distance to market	0.0185 (0.0138)	0.0040 (0.0030)
Mobile phone	0.1180 (0.2121)	0.0263 (0.0484)

Table 4 segue **- Determinants of adoption of NERICA**

Access to radio	-0.9744 ** (0.4422)	-0.1256*** (0.0320)
Access to television	0.1972 (0.2343)	0.0447 (0.0560)
No of livestock	-0.0733 (0.2137)	-0.0157 (0.0450)
Growing upland rice	0.4327 (0.3007)	0.1038 (0.0797)
Growing lowland rice	0.3838 (0.2652)	0.0810 (0.0558)
Ekiti dummy	2.5902*** (0.3966)	0.2483*** (0.0393)
Kaduna dummy	2.2023*** (0.4325)	0.2407*** (0.0413)
Nasarawa dummy	3.4473*** (0.5765)	0.3109*** (0.0390)
Ogun dummy	2.2628*** (0.4152)	0.2419*** (0.0421)
Ondo dummy	2.7148*** (0.3962)	0.2726*** (0.0418)
Sample size = 388		
LRchi^2 = 0.0000		
Pseudo R^2 = 0.3533		
Log Likelihood = -122.2629		
Wald Chi^2 = 92.74		

NB: Figures in parentheses are robust standard errors. *** = $p < 0.01$ ** = $p < 0.05$

4. Conclusion and Recommendations

This study explored the impact of new agricultural technology (NERICA) on farm yield, total farm income/expenditure in Nigeria. The study uses the average treatment framework for its estimations. The key findings reveal that the Nigerian government is promoting the adoption of the new rice varieties to help boost rice production through her rice transformation agenda. Average farm size for NERICA farmers is 2.6ha. This shows that in spite of evident of the adoption of NERICA varieties; rice production in Nigeria is still at the small scale level. The adoption of NERICA varieties was observed as being relatively high in the study area compared to the reported values for other countries such as Côte d"Ivoire (9% by Diagne, 2006). Adoption of NERICA significantly increase (at 1percent level) the area of land cultivated, farm output, yield, household expenditure, per capita expenditure and total farm income. The positive impact of NERICA adoption on rice yields is a clear indication that NERICA has the potential to increase rice productivity significantly among NERICA farmers. The positive impact on income signifies that NERICA has potential to reduce poverty while the significant effects on food expenditure reveals that NERICA can help solve food insecurity. NERICA adoption has great potential for poverty reduction and improved livelihood of rice farmers in Nigeria. The estimates for the sub-population of exposed farmers (ATE1) and that of the non-exposed farmers (ATE0) suggest that there is still a potential for significantly increasing NERICA adoption rates in Nigeria. The federal, state and local governments in collaboration with agricultural research institutes and other NGOs should upgrade rice farmers" knowledge base, improve knowledge sharing, and close the gap between science, technology and innovation and development practice in order to make the best use of NERICA technology.

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Spatial nonstationarity in the stochastic frontier model: an application to the Italian wine industry

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ABSTRACT

This research estimates the efficiency of a representative sample of Italian wine producers from the Italian FADN survey following a recent spatial stochastic frontier framework that allows to isolate the spatial dependence among units and to evaluate the role of intangible local factors in influencing the economic performance of firms. The empirical exercise shows that the specific territorial patterns in the data cannot be merely explained using a standard set of contextual factors. This intangible component can be interpreted as the role of the local business climate: in most localities, the presence of an embedded community stimulates a process of local learning that generates the diffusion of tacit knowledge through continuous interaction among the local actors. This effect is found to be different across firm size, with a larger impact on small firms

Keywords: Spatial nonstationarity, Spatial Stochastic Frontier Model, Wine, Efficiency

PAPER

1. Introduction

The globalization of productive processes and liberalization of trade activities have generated a strong competition between regional economic systems: paradoxically, rather than drastically reducing the role of spatial proximity, this new open scenario has shed new light on the key relevance of local and agglomeration externalities in the generation of competitive advantage (Porter, 2000). The relevance of these aspects is particularly evident in certain sectors, such as wine production, where the rapid transformations occurred in the last few decades have fostered a rapid process of technological change in which firms are constantly required to be at the forefront of the productive process in order to survive in the competitive arena (Cusmano et al., 2010). In this context, the role of intangible factors associated with the 'business climate' is crucial in stimulating the process of knowledge accumulation and learning through continuous interaction with peers located in close proximity: in several circumstances, the presence of these mechanisms ensures the diffusion of new productive practices that prevents local firms from increasing their gap with the technological frontier.

The classical stream of the literature linking productive efficiency to the territorial determinants assumes that the dynamic process leading firms to concentrate in specific subregions is only associated to specific tangible aspects: this assumption leads to neglect the role of spatial non-stationarity, intended as "a condition in which a simple global model cannot explain the relationships between some sets of variables" (Brunsdon et al., 1996). This problem is particularly evident in the parametric frontier framework, where it is essential to specify a priori an explicit functional form of the boundary of the production set: however, in the early contributions the spatial dependence among productive units has often been ignored and associated to the stochastic error. A number of recent works have attempted to address this issue by specifically including a set of contextual factors in the model (see e.g. Hughes et al., 2011,Brehm, 2013): however, such a strategy is not always effective as it ignores the fact that the relationship between the dependent variable and the covariates (a) tends to vary in a continuous rather than a discrete manner among spatial units and (b) may not be necessarily related to measurable local factors. This problem is particularly evident in specific spatial contexts, such as industrial districts, characterized by the presence of global intangible factors that cannot be measured empirically (Vidoli and Canello, 2016).

Ignoring spatial autocorrelation among residuals limits the validity of the empirical investigation for several reasons. First, it causes serious consequences to statistical inference, reducing both the efficiency and consistency of the estimations and generating a negative impact on the validity of testing procedures and on the predicting capability of the model. This drawback generates significant distortions in the interpretation of the stochastic frontier model, as higher values of the inefficiency term may be associated with a territorial effect rather than the ability of a productive unit to generate more output with the same amount of inputs. In this respect, the inclusion of spatial autocorrelation into the stochastic frontier production framework has been the subject of a lively debate in the econometrics literature in the recent past, generating a multitude of approaches aimed to address this issue: in this context, the specification proposed by Fusco and Vidoli (2013) appears to be particularly suitable in that the spatial autoregressive specification is modelled in the error term, generating results that can be directly compared with those of the classic stochastic frontier approach.

In this paper, the above mentioned spatial stochastic frontier approach is implemented on a sample of Italian firms specialized in wine production, using data extracted from the 2013 FADN Survey. This archive is particularly suitable for the scope of the analysis, as it allows to account for a wide variety of structural and economic factors that are believed to influence the territorial effects: moreover, the presence of specific reference to a wide variety of inputs allows to build a solid production function with several benefits for the estimation process. The aim of the empirical exercise proposed in this paper is to evaluate the contribution of both tangible and intangible factors in influencing the performance of these firms, discussing how the space can play a different role for the different members of a local network. In this respect, the specification proposed is of particular use as it allows to isolate the local intangible factors, often statistically and economically difficult to capture through specific proxies, that nonetheless are determinant in influencing the firms productivity. The role of tangible factors is nonetheless evaluated through a second stage estimation.

The remainder of the paper is structured as follows: section 2 presents the main features of the Italian wine sector, highlighting how the recent technological and structural changes have increased the importance of local learning and continuous access to new knowledge. In section 3, a brief review of the parametric frontier models is introduced, stressing on the recent debate on spatial approaches and presenting the proposed method and the benefits deriving for its application in the present context. In section 4, the focus is moved to the empirical application: after the main features of the database used for the analysis are introduced and discussed, the results of the spatial stochastic frontier model are introduced, comparing them with those of the traditional approach and highlighting the effectiveness of the Spatial Stochastic Frontier (SSFA) specification (see section 3) in isolating the spatial dependence that are present in the data. Finally, the structural features of the spatial effect are inspected and evaluated through the analysis of territorial imbalances, showing that the mere use of contextual variables is not sufficient to explain the variability of local effect: this result provides evidence of the existence of an intangible local effect in the wine industry that influence firm performances in different ways. Section 5 summarizes the main finding of the paper and proposes some concluding remarks and possible directions for future research.

2. The recent trends in the Italian wine industry and the role of agglomeration effects

Italy has played, together with France, a key role in the wine industry for several decades, dominating the international scenario in terms of both exported volumes and values. This established pattern has radically changed since the 1990s, when the entrance of the New World producers (United States, Australia, Chile, Argentina, South Africa) in the global market has fostered a radical transformation of the existing competitive arena (Cusmano et al., 2010). The increased complexity of the new global environment has further been influenced by several exogenous risk factors, such as the increased climate variability and the radical changes in wine consumption habits, with a shift in preferences towards high quality wines (Bardaji and Iraizoz, 2015). In this context, the sector has experienced a process of rapid modernization and technological change, identified by Crowley, 2000 as a "wine revolution". This radical transformation process is pushing wine producers to adopt improvement strategies in the quality and production process and acquire new knowledge in order to effectively respond to the volatile needs of the global markets. The potential gains from selecting an effective strategy are especially important in the wine sector where, despite the existence of a moderate correlation between price and quality, several price setting possibilities are available for wine producers given the incomplete quality information held by consumers (Oczkowski and Doucouliagos, 2015).

The current scenario generates several challenges for the Italian wine sector, which has recently faced a significant downturn in domestic demand and is characterized by a higher degree of fragmentation relative to other countries, such as Australia or Chile (Cusmano et al., 2010). Italian wine producers are often small and medium businesses that lack the financial and managerial resources to handle the increased complexity of the surrounding environment. This limit is especially problematic in the new global context, characterized by the constant need to update productive knowledge and acquire new skills and competences. In fact, small businesses are not generally equipped to gather relevant information outside the locality in which they are embedded; moreover, they cannot rely on the same formal channels used by leader firms, such as formal collaborations with research institutions (Giuliani et al., 2010) and interaction with foreign competitors, often through the presence of foreign subsidiaries (Felzensztein and Deans, 2013) or simply through the creation of relational networks with producers that are at the forefront of the industry (Turner, 2010). Given these opportunities are not generally accessible to small producers, the main source of learning and developing new competencies is the community in which these entrepreneurs are embedded. The role of this factor is especially relevant in Italy, where contrary to other countries, such as Australia, the wine sector cannot count on institutional assets and top-down measures to stimulate the above mentioned upgrading process.

Although several contributions have stressed the increasing importance of codified knowledge in the wine industry (e.g. Giuliani, 2007), the sector is still dependent on context-specific and localized informal practices of learning, that are crucial to take advantage of the specificities of each terroir (Turner, 2010). The effect generated by the local business climate and the informal interaction among local actors can be explained through the concept of "industrial atmosphere", that has generally been used in the industrial districts literature (Marshall, 1920): other than generating tangible benefits such as reputation, greater international demand and access to skilled labour pool, spatial proximity among wine producers stimulates everyday interaction, facilitating the opportunities for face-to-face contacts that are crucial to generate tacit knowledge flows and incremental learning. In this respect, wine clusters can be seen as communitarian networks, characterized by resource sharing and continuous informal interaction (Turner, 2010). The presence of interpersonal networks can be beneficial in many respects: producers can be rapidly informed of the presence of new business opportunities, but also of new sellers or providers that can form new partnerships and generate further spillovers. Inter-firms market cooperation can also foster marketing collaboration strategies, facilitating development of joint sales in foreign markets and allowing to overcome the limited exporting capabilities of several small and medium firms (Felzensztein and Deans, 2013). More importantly, the presence of a collaborative environment can allow small producers to fill the technological gap with competitors, as collaboration can foster the shared use of new technology, exchange of technical advices and information on the effective use of machinery and inputs (Morrison and Rabellotti, 2009).

A certain number of agglomeration externalities generates spontaneously as a consequence of spatial proximity between wine producers. For example, the successful performance of neighbouring wineries stimulates the development of positive marketing-related externalities for the whole area (Giuliani and Bell, 2005): these positive spillovers in terms of reputation for the neighbouring producers have been classified by Beebe et al. (2013) as "halo" effect. However, spatial proximity itself is not sufficient to guarantee the diffusion of agglomeration externalities among all the members of a local community. Indeed, two elements are required to enhance this process, i.e. the willingness of givers to share their knowledge and the absorptive capacity of the receiver: these conditions are generally meet when the cognitive proximity among the members of a network is present (Boschmaa, 2005). The presence of diversified abilities/attitudes to access to local informal knowledge has been documented in different regional contexts in the wine industry (Giuliani and Bell, 2005; Morrison and Rabellotti, 2009): according to Giuliani and Bell (2005), the presence of barriers to knowledge exchange is testified by the presence of different production methods within the same wine cluster.

What is the profile of those firms which are more often engaged in networking activities? The core of these local networks is generally represented by small firms, which are generally more inclined to cooperate and share information in order to overcome their structural limits: the lack of competencies among small firms act as stimulus to share different experiences and spread knowledge among the community. On the other hand, large firms tend to be located at the periphery of the local network and provide a limited contribution to the local learning system: these actors generally have stronger connections with external sources of knowledge and often prefer to share the acquired competencies with a restricted number of partners that are directly involved in their production process (Morrison and Rabellotti, 2009). This trend is confirmed by the empirical investigation of Turner (2010), who has shown that small wine producers are more interested with marketing practices associated with the territory while large firms are more interested in developing their own brand.

The brief review presented in this section has shown that the tangible and intangible local effects play a key role in determining the performance of wine producers. Against this background, the aim of the following section is to propose an empirical framework that can be effectively used to account for both effects in the estimation of productive efficiency, allowing evaluate the role of the different spatial factors in a consistent manner.

3 Disentangling the role of spatial effects on firm efficiency: the spatial stochastic frontier models

Efficiency estimation has been subject to considerable research during the last decades, generating important contributions both in the econometrics (see e.g. Aigner et al., 1977; Meeusen and van den Broeck, 1977; Aigner and Chu, 1968) and operational research literature (see e.g. Farrell, 1957; Charnes et al., 1978; Deprins et al., 1984; Grosskopf, 1996; Daraio and Simar, 2007). In this context, one of the most widely used parametric models is the Stochastic Frontier Analysis (SFA), which was originally proposed in two different contexts by Aigner et al. (1977) and Meeusen and van den Broeck (1977): under specific assumptions, this specification allows to estimate the parameters of the frontier production function and to perform hypothesis testing procedures to validate the model (see. g. Kumbhakar and Lovell, 2000 for a detailed introduction to frontier analysis).

In a cross-sectional framework, the productive process of the i^{th} firm using N inputs $\mathbf{x} = (x_1, ..., x_N)$ to produce M outputs $\mathbf{y} = (y_1, ..., y_M)$ can be specified as follows:

$$log(\mathbf{y}) = log(f(\mathbf{x}; \beta)) + \mathbf{v} - \mathbf{u} \quad (1)$$

where:

- $\mathbf{v} \sim \; iid \; N(\mathbf{0}, \sigma_v^2 \mathbf{I})$ is the random term;
- $\mathbf{u} \sim \; iid \; N^+(\mathbf{0}, \sigma_u^2 \mathbf{I})$ is the inefficiency term;
- $\mathbf{v}$ and $\mathbf{u}$ are assumed to be independently and identically distributed.

The traditional SFA specification estimates firm-level efficiency from the residuals, assuming that all producers in the sample are independent: however, this assumption rules out the possibility to account for spatial effects in the theoretical model. The limitations of this approach were already known in early contributions, considering Farrell (1957) highlighted the importance of incorporating the correlation between technical efficiency and variables representing location, temperature and rainfall. In his analysis, focused on the efficiency patterns in US agricultural firms, he argued that "the apparent differences in efficiency [...] reflect factors like climate, location and fertility that have not been included in the analysis, as well as genuine differences in efficiency".

When spatial effects are significant, the traditional techniques used to estimate the SFA (MLE or its variants) generate biased results: indeed, if the disturbances are spatially correlated, the assumption of a spherical error covariance matrix is violated, leading to biased and inconsistent estimators (LeSage, 1997). In order to overcome these issues, a number of recent contributions in frontier analysis have proposed alternative specifications aiming to incorporate spatial effects in the baseline models. This literature stream follows the approach used by spatial econometrics, a specific branch of econometrics that deals with spatial interaction (spatial autocorrelation) and spatial structure (spatial heterogeneity) in both cross-sectional and panel data (Paelinck and Klaassen, 1979; Anselin, 1988).

Subsequently, given the need to consider for spatial dependence also in frontier analysis, some models have been developed; they can be divided in two major fields distinguishing those that explain inefficiency/efficiency in terms of exogenous determinants analysing the heterogeneity from those that consider the spatial dependence by including in the model a spatial autoregressive specification.

As far as the first stream is concerned, some authors have proposed to analyse heterogeneity by including contextual factors as regressors or to modelling the inefficiency term. In particular, Lavado and Barrios (2010) used contextual factors to modelling the inefficiency part of a stochastic frontier model embedding a sparse spatial autoregression (SAR) in the deterministic part and a general linear mixed model into the efficiency equation; Hughes et al. (2011) considered specific spatial effects in the stochastic production frontier by adding climate effects as dependent variables; Jeleskovic and Schwanebeck (2012) proposed a two step deterministic estimation model to differentiate heterogeneity and inefficiency in world healthcare systems: (i) in the first step different fixed effects panel spatial models have been estimated; (ii) in the second step the obtained inefficiency has been regressed (also with various fixed effects panel spatial models) as dependent variable onto country specific variables that identify the heterogeneity; finally, Brehm (2013) proposed a correction of the SFA error term for panel data by introducing spatially correlated factors variables that affect the production process.

In the second set of analysis, others proposals consider spatial dependence by including a spatial lag into the dependent variable or into the covariates. More specifically, Affuso (2010) included spatial lag on the dependent variable reformulating the stochastic frontier density function; Glass et al. (2013), Glass et al. (2014) and Glass et al. (2016) introduced the concept of efficiency spillover, extending the non-spatial Cornwell et al. (1990) model to the case of spatial autoregressive dependence; Adetutu et al. (2015) proposed a local spatial stochastic frontier model that accounts for spatial interaction by allowing spatial lags on the inputs and on the exogenous variables to shift the production frontier technology; Han et al. (2013) proposed a method for investigating spillovers effects in panel data by maintaining the Schmidt and Sickles (1984) hypothesis of time-invariant inefficiency, but allowing global spatial dependence through the introduction of a spatial lag on the dependent variable.

Finally, others papers proposed to consider spatial dependence by including a spatial lag on the inefficiency term. Druska and Horrace (2004) extended the Kelejian and Prucha (1999) specification for cross-sectional data based on a standard fixed effects model by assuming an autoregressive specification of the error term and estimating inefficiency with the Generalized Moments Method; Schmidt et al. (2009) used a Bayesian approach to include latent spatial effects, that explain geographical variation of firms' outputs and inefficiency, dependent on a parameter that captures the unobserved spatial characteristics; e.g. Areal et al. (2010) suggested, with the aim of measuring the overall effect of spatial factors that affect the production, to include a spatial lag directly into inefficiency allowing the splitting of the inefficiency into a spatial component and into a specific term for every firm through a Bayesian procedure. Instead, Pavlyuk (2010) proposed to include spatial lags on the overall standard SFA model (see also recent enhancements, Pavlyuk, 2012, 2013). Following the approach implemented by Areal et al. (2010), Fusco and Vidoli (2013) have proposed to measure the global effect of spatial factors by including a spatial lag only in the inefficiency term of a stochastic frontier (SFA), not using a Bayesian procedure but by reformulating the SFA density function with a spatial error autoregressive specification (SEM). The Spatial Stochastic Frontier model (SSFA) is defined as:

$$\begin{aligned} log(\mathbf{y}) &= log(f(\mathbf{x};\beta)) + \mathbf{v} - \mathbf{u} \\ &= log(f(\mathbf{x};\beta)) + \mathbf{v} - (\mathbf{I} - \rho\mathbf{W})^{-1}\tilde{\mathbf{u}} \end{aligned} \tag{2}$$

where:

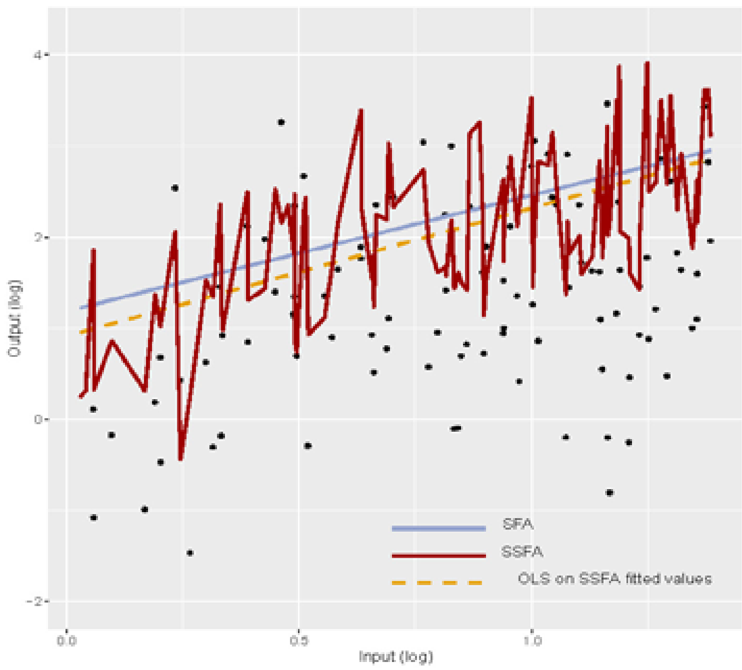
- $\mathbf{v} \sim iid\ N(\mathbf{0}, \sigma_v^2\mathbf{I})$;
- $\mathbf{u} \sim N^+(\mathbf{0}, \left[(\mathbf{I}-\rho\mathbf{W})^{-1}(\mathbf{I}-\rho\mathbf{W}')^{-1}\right]\sigma_{\tilde{u}}^2)$;
- $\mathbf{v}$ and $\mathbf{u}$ are independent of each other and of the regressors;
- $\tilde{\mathbf{u}} \sim iid\ N(\mathbf{0}, \sigma_{\tilde{u}}^2\mathbf{I})$.

In this paper, an empirical application of the SSFA has been proposed in order to avoid the subjective choice of the exogenous determinants and to focus the analysis of the spatial dependence only on the inefficiency term; this approach reduces the complexity of the model and makes the estimation easier computationally[1] as well as to be immediately comparable with the classical SFA model when no spatial autocorrelation is assumed on the error term.

It is important to note, moreover, that the formulation of equation (2) hide an interesting property: the identification of the error part imputable to the spatial proximities different for each unit allows to change (positively or negatively) the intercept of the model; therefore, in the SSFA framework the intercept is to be understood only as the "medium level" cleansed by the individual spatial effect.

Figure 1 clarifies the issue: departing from high spatial correlated simulated data (one input vs one output), OLS, SFA and SSFA has been estimated; in particular it can be noted that the SSFA specification impact both on the specific estimation of each unit (red continue line) both on the average slope (orange dashed line).

Figure 1 - OLS, SFA, and SSFA fitted values, simulated data



[1] Thanks to the SSFA R package (Fusco and Vidoli, 2015b, Fusco and Vidoli, 2015a).

4. Application

In this section, the spatial stochastic frontier specification introduced in section 3 is used to evaluate the role of local effects in the Italian wine industry: as highlighted in section 2, the recent technologica advances in the sector has increased the importance of both the tangible and intangible factors associated with the specific territorial effects that cannot always be captured by the inclusion of ontextual variables. In this respect, the spatial technique proposed in the previous section appears to be especially effective to account for these factors and evaluate their role in influencing firm-level ef ficiency. The empirical investigation is focused on year 2013 and is implemented on a detailed database that includes a wide variety of economic and structural variables: the main features of this database are presented in the following subsection.

4.1 Italian FADN survey: the data source used for the empirical analysis

The Farm Accountancy Data Network (FADN) is a yearly survey carried out by the Member States of the European Union and established in 1965 by the Council Regulation No 79/65/EEC: this measure was aimed to establish a network for the systematic collection of accountancy data on incomes and usiness operations of agricultural holdings in the European Economic Community. According to Regulation n. 1859/82, this database includes all the agricultural holdings having an economic size equal to or greater than a minimum threshold, i.e. that identified to be considered commercial: in Italy, this threshold is set on 4,000 eof standard output. The selection of the holdings that take part to the survey is carried out according to sampling plans defined at the national level, following the guidelines and recommendations provided by the European Commission. The sampling procedure must ensure the representativeness of the identified subset and defines the number of farms to be selected, specifying the approach followed to select the productive units. According to FADN methodology, stratification variables are territorial location, economic size and type of farming.

The Italian section of the survey is based on the Agricultural Census, updated on a two-year basis by the Farm Structure Survey (FSS) carried out by ISTAT: this main data source is complemented with further sources of agricultural statistics. The Italian FADN sample is selected using the stratified random sampling technique described above: in particular, the territorial location corresponds to the 21 administrative regions; the economic size is expressed in terms of Standard Output and defined through several classes, the lowest of which starts from 4.000 eand the highest refers to those with more than 3 million e; the type of farming corresponds to the particular level grouped according to the importance of the specific agricultural activity in the region. According to the procedure, some types of farming and some classes of Standard Output could be aggregated in order to have a sufficient number of observation in each strata. Following the above mentioned approach, the 2013 version of the Italian FADN survey, which is the one used in this paper, includes a total number of about 700.000 farms. The productive units of the survey are allocated in each stratum according to strategic variables such as Standard Output, Utilized Agricultural Area, Livestock Units and Working days. To get the desired level of precision for each strategic variable are fixed sampling errors, in terms of percentage of coefficients of variation[2], they represent the errors that is possible to make, with a fixed probability, estimating a variable compared to its real value, hence they determine the reliability of estimates. Sample size and its distribution among the strata are established by setting the precision required in terms of percentage of coefficients of variation for strategic variables, both at national and at regional level. The methodology used to allocate the sample among the strata is a combination of Neyman and Bethel methods (Bethel, 1989). The main benefits associated with the use of this database can be summarized by the following two aspects:

- harmonization: FADN is the only source of micro-economic data that is harmonised at European level, i.e. the book-keeping principles are the same in all countries, and it represents an important tool for the evaluation of the income of agricultural holdings and the impacts of the Common Agricultural Policy. In Italy the FADN survey is carried out by the Center for Policy and Bio-economy of the Council for Research in Agriculture and the Agricultural Economics Analysis - CREA[3], as liaison agency between EU and Member State.

- information assets: The FADN survey collects more than 1,000 variables that refer to physical and structural data, such as location, crop areas, livestock units, labour force. It also contain economic and financial data, such as the value of production of the different crops, stocks, sales and purchases, production costs, assets, liabilities, production quotas and subsidies, including those connected with the application of CAP measures and recently were added also information linked to environmental aspects. These variables are extremely convenient for the purpose of this paper, as they allow to create both a solid production function and include a wide variety of local effects that are associable with the performance of these firms.

[2] The coefficient of variation of a variable is the ratio between the standard deviation of the variable layer and the estimate of the total layer of variable.
[3] Previously National Institute of Agricultural Economics - INEA

In this paper a sub sample of 853 wineries has been extracted from the Italian FADN database, which includes a total number of 11.319 farms in year 2013. Using this data, the application presented in the following sections compares the results of the traditional specifications of the production function with those of the SSFA model, showing the benefits associated with the use of the latter approach. An important caveat relates to the variable used to evaluate output, i.e. the litres of wine produced by each unit: given the information at disposal does not allow to evaluate the qualitative aspects of production (which are nonetheless relevant in the sector), the concept of efficiency should be interpreted from a technical point of view, avoiding any considerations on the quality of output produced.

4.2 Production function

The production function of the Italian wine firms has been initially estimated using a simple OLS approach, choosing a Cobb-Douglas[4] log-log functional from and relating the produced quantity of output with labour, machinery, water-energy-fuel and land capital inputs. The results of the estimation[5] (Table 1) appear to confirm the validity of the specification, given the significance of all covariates and the high R2 = 0:593; it is also worth noting that the intercept is negative and statistically significant.

Table 1 - Wine production function - OLS estimators

	Dependent variable: production output (log)
Intercept	−2.068*** (0.309)
Labour input	0.641*** (0.055)
Machinery capital input	0.307*** (0.045)
Water, energy and fuel input	0.067*** (0.014)
Land capital input	0.245*** (0.037)
Observations	853
R^2	0.593
Adjusted R^2	0.591
Note:	*p<0.1; **p<0.05; ***p<0.01

Using OLS as baseline for the analysis, the stochastic frontier model has been estimated (Table 2) and the results of the two specifications compared: the analysis confirms the stability of the latter model, since the values of the coefficients are similar in the two cases, except for the intercept that decreases in absolute value. This trend is expected and can be explained by the fact that the production function has been shifted from the average values to efficient ones without affecting the relationship between output and inputs. The specific parameters of SFA (σ^2, γ and the average efficiency equal to 0:59) confirm the validity of the proposed model. In particular, $\gamma = \sigma^2 \upsilon/\sigma^2$ depends on two relevant parameters, σ^2 u and σ^2 ϖ , that are the variances of the noise and inefficiency effects. Note that g varies from 0 to 1: when the value is close to zero deviations from the frontier are attributed to noise, while in the opposite case the deviations are entirely explained by the technical inefficiency of the firm. As discussed in Section 3, the stochastic frontier model is based on the hypothesis of mutual independence among the productive units: therefore, this specification ignores the role of any spatial effects that may be present in the data. However, the evolutionary trends emerged from the brief overview of the Italian wine industry presented in this paper suggests that efficiency in this sector could be influenced by a multiplicity of tangible and intangible local factors.

Table 2 - Wine production function - SFA estimator

	Dependent variable: production output (log)			
	Estimate	Std. Error	*z* value	$Pr(>\|z\|)$
Intercept	-1.411159	0.322292	-4.3785	1.195e-05 ***
Labour input	0.637796	0.055230	11.5480	< 2.2e-16 ***
Machinery capital input	0.314146	0.044574	7.0477	1.819e-12 ***
Water, energy and fuel input	0.071348	0.013375	5.3346	9.573e-08 ***
Land capital input	0.233026	0.037678	6.1847	6.224e-10 ***
σ^2	1.003306	0.116481	8.6135	< 2.2e-16 ***
γ	0.581710	0.097161	5.9871	2.136e-09 ***
Note:				*p<0.1; **p<0.05; ***p<0.01

[4]This model has been also estimated using a Translog specification for the production function. However, given the lack of significance of composite terms, a simpler model has been chosen for this part of the analysis.

[5]The basic statistics of the variables used in the analysis and the relative units of measurement are given in Annex, Table 5.

To evaluate the role of these effects, a formal statistical test has been implemented to verify the presence of spatial correlation mong residuals: specifically, the global and local indicators proposed by Geary (1954) have been used, previously specifying a distance matrix to map the neighbourhood of each production unit. The correct definition of the matrix is crucial to ensure the consistency of the spatial analysis: in this respect, the identification of a correct unit of distance must be driven by economic considerations associated with the peculiarities of the sector under investigation. In this specific case, characterized by the presence of productive units often concentrated in narrow geographical areas, a particularly close neighbourhood (nearest neighbour, n = 10) has been chosen in order to account for the specificities of the wine industry: the contiguity matrix resulting from the application of this criterion is graphically represented in Figure 2.

Figure 2 - Contiguity matrix, nearest neighbour (n = 10)

Using this distance matrix, the presence of spatial autocorrelation among residuals for the SFA model has been formally tested using the Geary C statistic[6]: the estimated value of this variable (0:733) leads to reject the null hypothesis of mutual independence among firms, confirming the presence of a positive neighbourhood effect among the Italian wineries that cannot be isolated and estimated through the traditional stochastic frontier model. This scenario motivates the need to use a spatial stochastic frontier approach with the data at disposal: in this respect, the SSFA model proposed in equation (2) seems a particularly effective tool to isolate and evaluate the territorial component separately from the individual performance of the productive units. The results of the estimation are reported in Table 3: in all cases, the value of the coefficients for the inputs are consistent with those obtained from the SFA specification, with the expectation of the intercept that becomes not significant; however, this result is expected as the spatial specification generates a further shift in the production curve with respect to the SFA as a consequence of the isolation of the spatial effect, transforming the average value of $\beta 0$ into a multiplicity of individual effects. This pattern as already been shown in section 3 (Figure 1). Interestingly, the value of the γ parameter (0:433) is lower than the one estimated with the SFA model: this evidence supports the hypothesis that part of the technical inefficiency was mistakenly attributed to the production process rather than to neighbourhood effects.

Table 3 - Wine production function - SFA estimator

	Dependent variable: production output (log)			
	Estimate	Std. Error	z value	Pr(> |z|)
Intercept	-0.0707772	0.7387170	-0.09581	0.923671
Labour input	0.6081372	0.0525574	11.57091	< 2e-16 ***
Machinery capital input	0.3328368	0.0436632	7.62282	< 2e-16 ***
Water, energy and fuel input	0.0500784	0.0132213	3.78770	0.000152 ***
Land capital input	0.3250007	0.0401612	8.09240	< 2e-16 ***
σ^2_{dmu}	0.3253159	0.1250316	2.60187	0.009272 **
σ^2_v	0.3591916	0.0456068	7.87584	< 2e-16 ***
Note:				*p<0.1; **p<0.05; ***p<0.01

[6] The value of Geary C lies between 0 and 2. Values lower than 1 demonstrate increasing positive spatial autocorrelation, whereas values higher than 1 indicate increasing negative spatial autocorrelation. C=1 is consistent with no spatial autocorrelation in the data.

The benefits of the proposed framework are also evident in terms of global and local spatial autocorrelation: indeed, the global Geary C statistic equal to 1.048 suggests that global autocorrelation has been effectively removed from the residuals, while local ci (for each unit i) associated with the SSFA estimates is significantly lower with respect to the unconditional SFA scenario (Figure 3).

4.2.1 Explaining the spatial effect through the analysis of territorial imbalances

The analysis presented in the previous section has confirmed the presence of a spatial effect in the data that has been successfully isolated using the SSFA specification proposed in section 3. In this part of the empirical investigation, the focus is moved to the spatial effect itself, in an attempt to explain its structural characteristics and interpret its nature in light of the considerations emerged in the brief review of the wine sector presented in section 2. In order to do so, the analysis is focused on the territorial imbalances, defined as the difference between the efficiency term estimated in the SFA specification and that identified with the SSFA approach[7]: in general, higher values of territorial imbalance suggest the presence of a stronger territorial component.

A geographical representation of the territorial imbalances is presented in (Figure 4): the map shows the presence of a heterogeneous distribution of the spatial effect, with areas characterized by a strong territorial factors while in other case the role of the locality appears to be negligible in determining the performance of the productive units.

Figure 3 - Local ci kernel density of the SFA and SSFA efficiency

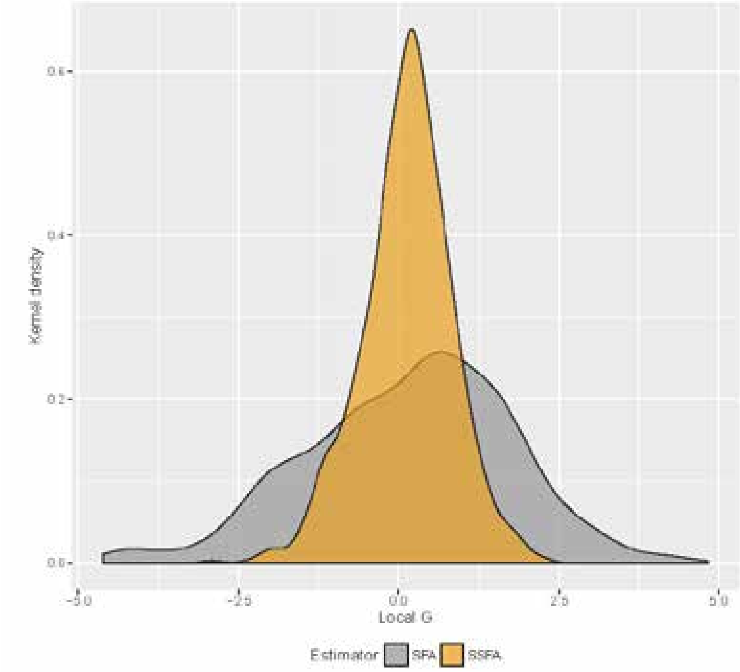
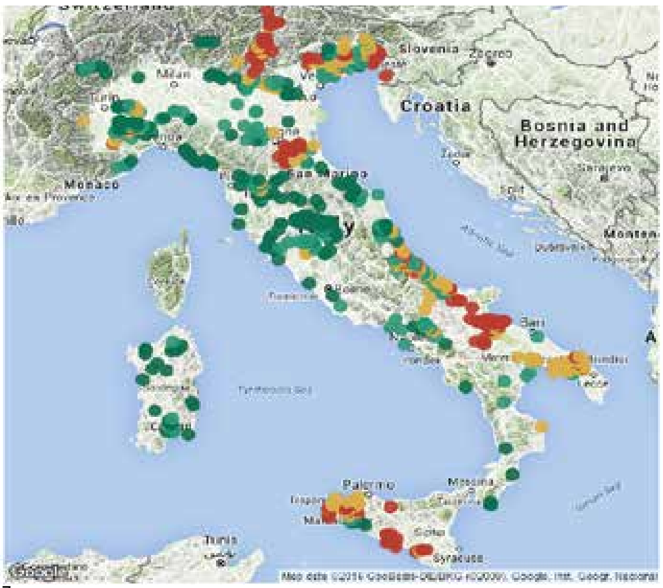


Figure 4 - Differences between SFA and SSFA efficiencies per quantile, q = 4



[7] this term is generally positive, given in the SFA the spatial effect is mistakenly incorporated into the error term, generating higher values relative to those estimated with the SSFA

Having established the presence of a relevant and heterogeneous spatial effect in the Italian wine industry, the immediate question is whether this effect can be satisfactorily explained by a plurality of tangible local factors. To address this issue, a second stage analysis has been implemented regressing the territorial imbalances on a plurality of contextual variables, following previous findings in earlier studies (see e.g. Hani et al., 2003, Reig-Martinez et al., 2011 and Bardaji and Iraizoz, 2015) and incorporating other determinants that are believed to have an impact on firm-level productivity in agriculture. In this respect, the wide variety of variables available in the FADN database can be effectively used to incorporate a number of relevant factors that are believed to explain the spatial effect in the wine industry8: specifically, the set of covariates include (i) endogenous factors linked to the productive process or to the corporate characteristics, (ii) exogenous physical factors and (iii) exogenous economical indicators related to the local supply factors.

The results of the estimation are reported in Table 4: in most cases, the coefficients are significant and the sign is that expected. As far as the endogenous factors are concerned, the first interesting result is determined by the key role played by quality and reputation: in fact, firms producing a better wine quality (OTE = 3510, wineries specialized in the production of quality wine) appear to benefit from a larger territorial effect. Moreover, being located in an area characterized by a higher reputation of the production process (i.e. DOCG production area) is also associable with an increase in territorial imbalances, irrespective of the quality of wine produced by the firm. The data also reveals the importance of the territorial effect for family-owned firms (Family owned) and those productive units characterized by an higher degree of product differentiation. Regarding the exogenous physical factors[9] it is worth noting that the coefficients of both Physical disadvantage (climate) and the Biophysical disadvantage are negative and statistically significant: this result is not surprising considering the beneficial effects associated with a temperate climate, an advantageous slope inclination and slope exposure on wine production. Finally, a set of exogenous economical factors[10] have been included in the model, in order to account for the role of elements external to firms and internal to the region that generate a competitive advantage among economic agents. The results are consistent with the expectations, showing that a higher level of the surrounding economic and network infrastructure has an indirect beneficial effects for the productive units specialized in wine production; on the other hand, the presence of a lower level of human capital in the region (higher Scholastic drop-out indicator) has a negative impact on the territorial imbalances. Despite the results of the estimation confirm the important role played by the above mentioned variables, it is worth noting that the presence of these tangible factors is not sufficient itself to explain the variance of the territorial imbalances (R2 =0:214). This evidence indirectly confirms the presence of intangible factors associated with context specific and informal practices of learning that cannot be evaluated through the mere inclusion of specific contextual variables in the model: in this respect, the implementation of a SSFA approach can effectively address this issue, allowing to isolate the intangible effects associated with tacit knowledge flows and incremental learning that are peculiar of the wine industry and cannot be merely proxied through the inclusion of specific contextual variables.

4.2.2 Do spatial effects vary with size? The different role played by the local network in small and large firms' efficiency

The analysis implemented in the previous section has highlighted that a combination of tangible and intangible factors explain the presence of a spatial effect in the Italian wine industry. In this scenario, the role of intangible effects appears to be particularly significant and possibly associable with the local business climate and informal interaction among local actors that has been discussed in Section 2: in this respect, the results support the empirical evidence emerged in previous contributions focused on case studies in specific wine regions, suggesting the presence of communitarian networks, characterized by resource sharing and informal interaction.

Table 4 - Determinant of the SFA - SSFA differences, OLS estimator

	Dependent variable: Difference between SSFA and SFA efficiency
Constant	0.076*** (0.012)
Endogenous factors	
OTE = 3510 (yes=1)	0.021*** (0.005)
DOCG production area (yes=1)	0.016*** (0.004)
Gender (M=1)	−0.018*** (0.005)
Family owned	0.015*** (0.004)
Diversified production (yes=1)	0.014** (0.006)
EU subsidies (1,000 €)	0.001** (0.0002)
Financial charges (1,000 €)	−0.0004 (0.001)
Young owner (yes=1)	−0.005 (0.006)
Organic production (yes=1)	0.001 (0.010)
Exogenous physical factors	
Physical disadvantage (slope)	0.022*** (0.005)
Physical disadvantage (climate)	−0.030*** (0.006)
Biophysical disadvantage	−0.011** (0.005)
Exogenous economical factors	
Economic infrastructure indicator	0.0001** (0.00004)
Network infrastructure indicator	0.0002** (0.0001)
Scholastic drop-out indicator	−0.002*** (0.001)
Observations	853
R^2	0.214
Adjusted R^2	0.200
Note:	*p<0.1; **p<0.05; ***p<0.01

[8] Note that the physical/contextual data used in the estimation do not exhaust the multiplicity of issues that characterize the production within a territory.

[9] This data are available at an extremely detailed territorial level, i.e. the municipality (CREA, 2013).

[10] These composite indicators are present in the Istituto Tagliacarne (2013) database and defined at a narrow territorial level, i.e the municipality.

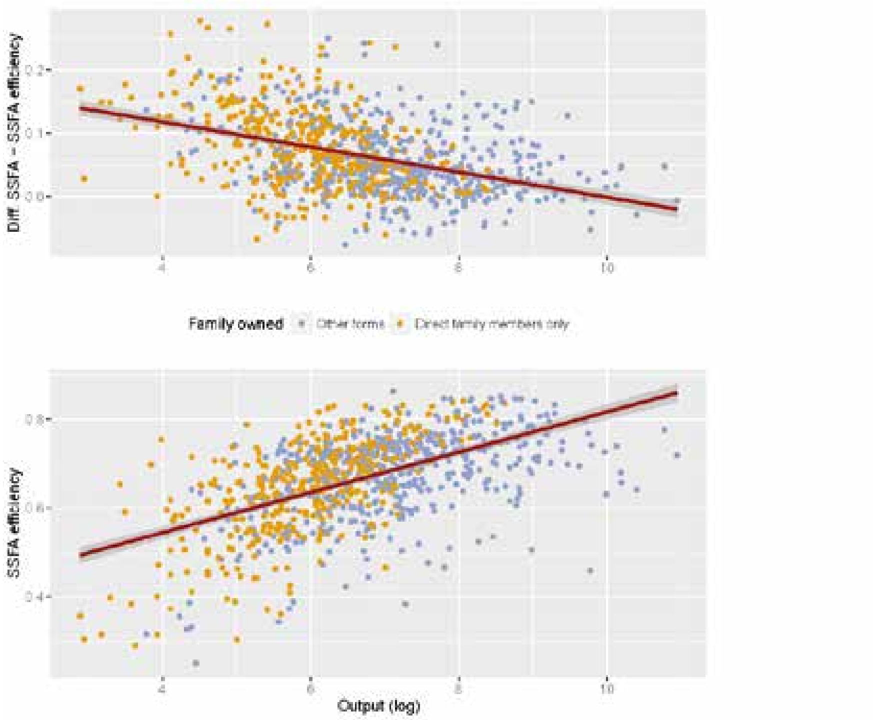
However, as several recent contributions have shown, access to these networks appears not to be uniform among local actors: not infrequently, small firms tend to be more inclined to engage in informal interaction practices with local peers, given the higher expected benefits, while large firms tend to acquire new knowledge from external sources, using the wide variety of formal channels at their disposal.

The possible presence of this differential has been evaluated by plotting the difference between the SFA and the SSFA efficiencies against the size of the firm. Figure 5 confirms that an inverse relationship exists between the two variables, with a higher territorial effect for small firms that tends to decrease when firm size become larger: however, the presence of a negligible spatial effect among large wine producers seems not to be associated with lower levels of technical efficiency: in fact, Figure 5 shows that these firms are more efficient than small producers.

This apparently contrasting trend can be easily interpreted in light of the patterns already identified in Section 2: the presence of a negligible spatial effect among large firms should not be motivated by their difficulty to access to local networks, but rather by a voluntary choice aimed at focusing on alternative sources of knowledge, such as internal learning, interaction with producers located outside the neighbourhoods and formal collaborations with institutional actors. The choice of these alternative forms of learning enables these firms to stay at the forefront of technical development, focusing on the most efficient technologies and maintaining high levels of technical efficiency. On the other hand, small producers who cannot access to external knowledge are required to rely on the informal learning practices associated with continuous interaction with the local community, generating the spatial effect identified for this subset of the firm population in the model. Although these intangible factors allow to reduce the gap with the leaders, small firms still display a lower level of efficiency relative to the larger ones.

The main finding introduced in this section confirms that spatial proximity does not necessarily generate knowledge spillovers. The main reasons explaining this pattern are probably two: on the one hand, large producers generally do not need to link to local networks to access informal sources of learning; on the other hand, leader firms may not be willing to share the knowledge acquired through access to external of formal sources, generating positive externalities for small firms located in the close neighbourhood. In this respect, the behaviour of large firms could be interpreted as a rational strategy aimed at retaining a competitive advantage in the production process, ensuring higher levels of technical efficiency.

Figure 5 - SSFA efficiency and difference with SFA per produced output (log) and ownership.



5. Final remarks

The empirical exercise, implemented on a sample of wine producers extracted from the Italian FADN survey, shows that the spatial specification proposed by Fusco and Vidoli (2013) is extremely effective in disentangling the spatial effect that is present in the data, isolating a specific component that is erroneously attributed to the error term in the standard SFA approach.

The main features of the spatial effect are evaluated through a second stage analysis, in which the territorial imbalances (i.e. the difference between the inefficiency term calculated with the SFA specification and that identified with the SSFA approach) are regressed against a set of contextual variables that are generally associated with the presence of a stronger effect: although the role of these factors is confirmed by the results of the estimation, a relevant share of the variance in the model remains unexplained, suggesting that a key role is played by intangible factors that cannot be formally included in the model. Following the recent findings in the literature, it is reasonable to assume that this intangible component is the consequence of a network effect associable with the local business climate: in most localities, the presence of an embedded community stimulates a process of local learning that generates the diffusion of tacit knowledge through continuous interaction among the local actors. Although the investigation does not allow to evaluate whether this flow relates more to business information of technical knowledge, the identification of such aspect is by itself a key finding of the contribution.

The analysis of the degree to which the spatial effect varies with firm size provides evidence of a clear tendency of this effect to be significantly lower among large firms. This finding is in line with previous research, confirming that firms interacting in economic networks are not an homogeneous entity, but play different roles in the local scenario: although it is not a direct consequence of the results of the paper, it can be speculated that the different size of the territorial effect found in small and large wine producers is associated with different abilities and willingness to interact and share knowledge with neighbours located in close vicinity: such a scenario would confirm the trend already identified in case studies on wine sector (Giuliani, 2007; Morrison and Rabellotti, 2009), showing that large firms have a strong tendency to access to external and formal sources of knowledge, sharing the information acquired from outside with a small number of firms with which they collaborate on a regular basis. The regular interaction with external sources of knowledge enable these firms to stay at the forefront of the technological frontier, enabling them to face the challenges required by the rapid technological change: such a trend would be consistent with the higher levels of technical efficiency found among large firms in the empirical analysis.

The results of this investigation open some interesting avenues for further research. The SSFA specification can be extended to accommodate the use of panel data: the implementation of such an approach would be particularly convenient to control for seasonal or other unobserved factors that can influence harvesting in a particular year, such as the presence of parasites or other transient factors.

Table 5 - Production function variables - main statistics

Annex

Statistic	N	Mean	St. Dev.	Min	Max
Production output (Physical units) (log)	853	6.599	1.236	2.890	10.953
Labour input (Hours) (log)	853	8.071	0.746	6.125	11.613
Machinery capital input (Kw) (log)	853	4.672	0.786	1.609	7.553
Water, energy and fuel input (€) (log)	853	5.837	2.331	0.000	12.468
Land capital input (Ha) (log)	853	6.806	1.097	3.434	10.787
OTE = 3510 (yes)	853	0.715	0.452	0	1
Physical disadvantage (slope) (yes=1)	853	0.216	0.412	0	1
Physical disadvantage (climate) (yes=1)	853	0.284	0.451	0	1
Biophysical disadvantage (yes=1)	853	0.699	0.459	0	1
Economic infrastructure indicator (index)	853	96.038	57.679	26.668	397.647
Network infrastructure indicator (index)	853	86.356	30.926	18.400	187.976
Scholastic drop-out indicator (index)	853	13.499	4.482	8.394	24.026
DOCG production area (yes=1)	853	0.356	0.479	0	1
EU subsidies (1,000 €)	853	3.339	8.093	0.000	87.108
Financial charges (1,000 €)	853	−0.313	2.771	−51.183	0.000
Family owned (Direct family members=1)	853	0.431	0.496	0	1
Gender (M=1)	853	0.779	0.415	0	1
Young owner (yes=1)	853	0.117	0.322	0	1
Diversified production (yes=1)	853	0.109	0.312	0	1
Organic production (yes=1)	853	0.036	0.187	0	1

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THEMATIC SET

B09

FINDING THE NEEDLE IN THE HAYSTACK: ESTIMATING COMMODITIES THAT ARE DIFFICULT TO CAPTURE IN OFFICIAL AGRICULTURALSTATISTICS (ILLICIT COMMODITIES AND NOMADIC LIVESTOCK)

Session Organizer
C. Bussink | United Nations Office on Drugs and Crime | Statistics and Surveys Section, Trends Monitoring and Analysis Programme | Vienna | Austria

ABSTRACT

Statistics on illicit crops, illegal fishing, illegal hunting and wildlife trade, illegal logging and nomadic livestock have their specific challenges due to the illicit, transient and hidden nature. Thes e populations are often scarce, the units can be small in size (for example fields with illicit crops), present in low densities and/or in clusters, transitory nature and isolation with poor access to surveyors. These challenges require a different approach in terms of survey design and data collection methods from those used for official agricultural statistics. In this session, solutions are presented for overcoming these challenges. Possible topics for papers include: how to deal with data scarcity and uncertainties; zero-inflated data; survey design (e.g. line transect sampling, adaptive sampling); spatial risk maps; the use of remote sensing and overflights; ground-truth data collection and accuracy assessments.

LIST OF PAPERS

Comparing dot grid sampling versus full area mapping for illicit crop monitoring in Bolivia
T. Bauer | University of Natural Resources and Life Sciences, Vienna/Institute ofSurveying, Remote Sensing and Land Information | Vienna | Austria
W. Schneider | University of Natural Resources and Life Sciences, Vienna/Institute ofSurveying, Remote Sensing and Land Information | Vienna | Austria
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H. Catari | United Nations Office on Drugs and Crime | La Paz | Bolivia
DOI: 10.1481/icasVII.2016.b09

Using law enforcement data to estimate illicit activity in an internationally traded illegal commodity
F. M Underwood | Independent Statistical Consultant/Researcher | Taunton | UK
DOI: 10.1481/icasVII.2016.b09b

Opium yield estimates in Afghanistan using remote sensing
D. M. Simms | Cranfield University | Cranfield, Bedfordshire | UK
T. W. Waine | Cranfield University | Cranfield, Bedfordshire | UK
DOI: 10.1481/icasVII.2016.b09c

Survey methods for the Enumeration of Nomadic and Semi-Nomadic (Transhumant) Livestock
N. Keita | Food and Agriculture Organisation (FAO), ESS division | Rome | Italy
N. Georgieva | Food and Agriculture Organisation (FAO), ESS division | Rome | Italy
D. Bako | Food and Agriculture Organisation (FAO), ESS division | Rome | Italy
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B09

Comparing dot grid sampling versus full area mapping for illicit crop monitoring in Bolivia

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ABSTRACT

Since 2002, the United Nations Office on Drugs and Crime (UNODC) has continuously supported annual surveys of coca cultivation in Bolivia. The mapping of coca fields is based on the visual interpretation of very high and high resolution satellite imagery. A full area mapping approach is applied, i.e. all fields where illicit crops are grown in a certain geographic region are visually interpreted and delineated on screen. The process bears the risk of several types of biases in the interpretation results and is time consuming. As an alternative a dot grid sampling approach was tested in order to diminish biases and to optimize the cost-accuracy-ratio of the visual interpretation in comparison to full area mapping. The paper summarizes the experiences and discusses the pros and cons of the approach for illicit crop monitoring under given conditions.

Keywords: remote sensing, illicit crop monitoring, dot grid sampling, coca cultivation, area estimates

PAPER

1. Introduction

The United Nations Office on Drugs and Crime (UNODC) supports monitoring systems of illicit crop production in the main drug-growing countries of the world. Jointly with the respective governments, UNODC produces annual illicit crop surveys for specific countries. The results are used for monitoring measures to reduce coca cultivation and global analysis of the drug situation, e.g. in the World Drug Report (UNODC, 2015).A key component to estimate plant-based drug production is the assessment of the area under cultivation. This is based on the visual interpretation of remotely sensed images. A full area mapping approach is followed. In such a case, all fields where illicit crops are grown are identified in the whole country or in pre-defined geographic regions. Polygons are visually interpreted and delineated on screen by qualified and trained staff who use classification keys to guarantee consistency between interpreters. Nevertheless, this process is time consuming and bears the risk of several types of bias in the interpretation results. Apart from thematic errors, systematic errors may occur when drawing the boundaries of the polygons, leading to inaccurate results.

Various internal tests have been carried out by UNODC and the University of Natural Resources and Life Sciences,Vienna (BOKU) to automatize the interpretation process using image processing techniques. These tests have shown that it is difficult to replace visual interpretation due to various reasons. On the one hand the characteristics of the plant (perennial, up to 4 harvests per year, with fields at different stages of development at any observation time, no unique spectral signature) make it difficult to detect plantations automatically.On the other hand the interpretation of fields strongly relies on the experience of the interpreter (knowledge of the geographic region, inclusion of context information) which makes it difficult to derive rules for an automated approach.

This study attempts to overcome the specific problem of one type of bias, with regard to the digitizing of the field boundaries (geometric errors), by using a sampling approach widely known as (squared) dot grid sampling.

Sampling methods are often applied successfully in the fields of forest inventory and agricultural statistics. The dot grid method originally was used in aerial photo interpretation as a simple and inexpensive tool for measuring land cover areas of irregularly shaped features (Lillesand et al., 2007). Forest areas are obtained in many national forest inventory schemes with aerial photo dot grid methods (Tomppo et al., 2010). An example for a method with points as sampling units in agricultural statistics is the EU-project LUCAS (Land Use/Cover Area frame statistical Survey; Bettio et al., 2002).

The assumption is that the dot grid estimate can bemore accurate than full area mapping due to the gain of time for the decision to classify the crop and due to the avoidance of delineation inaccuracies. No time has to be spent for delineating the boundaries. In case of illicit crop monitoring, dot grid sampling therefore could optimize the cost-accuracy-ratio of the visual interpretation in comparison to full area mapping.

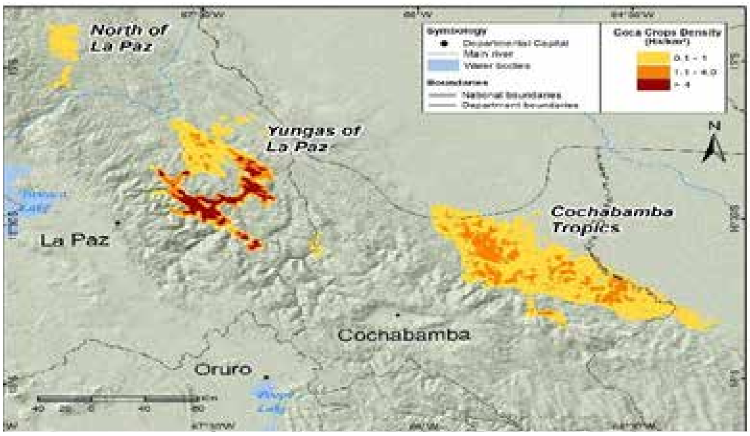
For testing the methodology two test sites were selected. One objective was to test the effect of different image types with different spatial resolutions on the interpretation process and accuracy. Secondly, the grid method was tested for different densities of coca fields, whichwill require different densities of dots to achieve the same accuracy and thuseffect the time to spend on conducting the interpretations.

It should be noted that interpretation errors (mistakes in the identification of coca crops) which may occur in the same way in the interpretation of full parcels and in the interpretation of (the surroundings of) single points (dots) are not considered in this report. The term "error" in this article refers to "sampling errors".

2. Coca growing in Bolivia

In Bolivia a monitoring system was established in 2001, resulting in first estimates in 2002. Coca is mainly grown in three geographic regions: Yungas ofLa Paz, Cochabamba Tropics and Norte of La Paz. In 2011 an area of 13.760 km² was covered with different types of very high spatial resolution satellite images (UNODC, 2012). The programme has used satellite images such asIkonos-GeoEye, Pleiades, Spot, RapidEye and WorldView and occasionally aerial photos. The satellite images are visually interpreted on screen supported by extensive field work. In 2012, 27.200 hectares of the area monitored were under coca bush cultivation. The density and sizes of the fields vary from region to region. Whereas in the Yungas ofLa Paz large fields or clusters of coca fields can be found (ranging from0.25 hectaresupto coca groupsof surfaces with 5 ha), fields in Cochabamba Tropics are relatively small (usually coca crops of 0.16 hectares) and are found dispersed in the landscape. Figure 1 shows a map of the main coca growing areas in Bolivia and the density given in hectares per km² calculated on the basis of a visual interpretation (UNODC,2012).

Figure 1 - Coca growing areas in Bolivia



3. Dot grid sampling

In the dotgrid method, the sample units to be interpreted are drawn in the form of a regular grid of points (dots). The population is assumed to be infinite, consisting of infinitesimal areal units (points) covering the area of interest. This infinite population is not really related to the pixels of the image: in visual interpretation of a digital image, the interpreter usually locates parcel boundaries with subpixel accuracy, taking into account a neighbourhood of pixels. Therefore, the interpreter does not assign pixels as a whole to a certain land cover class. Rather, a dot is assigned to a land cover class depending on its exact position within a pixel in a certain surrounding pixel pattern.Systematic sampling in a regular grid can be treated like simple random sampling if the units of the population can be assumed to be randomly distributed (Thompson, 1992). For actual land cover distribution patterns one cannot assume a truly random distribution of the units. The consequences of this will be mentioned below. The number of dots falling on the land cover class (crop type) to be monitored, divided by the total number of dots, gives an estimate of the proportion of the area covered by the specific land cover class. Applying this proportion to the surveyed area leads to the total crop area in the study area. We assume a square grid of dots superimposed to a total area of arbitrary shape.

$$p = \frac{A}{F}, \quad \hat{p} = \frac{\hat{n}_c}{n}, \quad \hat{A} = \hat{p} \cdot F$$

F…total area, A…crop area, p…fraction of crop area in total area (coca density), n…total number of dots (i.e. number of dots falling upon total area), n_c …number of dots falling upon coca fields. The hat symbol denotes a random variable.

The probability distribution of n_c is the binomial distribution. Its variance is calculated with:

$$\sigma_{\hat{n}_c}^2 = \mathrm{var}(\hat{n}_c) = n \cdot p \cdot (1-p), \quad \sigma_{\hat{p}}^2 = \mathrm{var}(\hat{p}) = \frac{p(1-p)}{n}, \quad \sigma_{\hat{A}} = \sigma_{\hat{p}} \cdot F$$

$\sigma_{\hat{n}_c}^2$ …variance of the number of dots falling upon coca

$\sigma_{\hat{A}}$… standard deviation of the crop area A due to sampling error

The required size of the sample (number of dots) to obtain a certain precision of area estimates with a certain confidence is the critical decision during the set up. The selection of an appropriate spacing between the dots depends on the coca density of the total area of investigation and on the error of the result that is acceptable.

In order to obtain a result (an estimate) for the coca area A with a standard deviation σ_A, i.e. a relative error (σ_A/A) of the coca area estimate, one has to use a grid with n dots in total:

$$n = \frac{p(1-p)}{\sigma_p^2} = \frac{p(1-p)}{\sigma_A^2 p^2} A^2 = \frac{1-p}{p}\left(\frac{A}{\sigma_A}\right)^2$$

The space between dots (dot grid spacing, s) thus has to be chosen according to

$$n \cdot s^2 = F = \frac{A}{p}, \quad s = \sqrt{\frac{A}{p \cdot n}} = \sigma_A \sqrt{\frac{1}{(1-p) \cdot A}} = \left(\frac{\sigma_A}{A}\right)\sqrt{\frac{p \cdot F}{(1-p)}}$$

The precision of the estimate will be higher for narrower dot grid spacing, with a larger sample.

Of course, at the start of a project, the fraction of crop area in total area, p, which is required to calculate a proper value of s, is not known. A likely, expected value for p has to be assumed here, e.g. the coca density determined in previous years.

This equation can also be used to calculate the relative sampling error (A/A) for a given dot grid spacing and a given fraction of crop area in total area, p (if this has finally been determined).It should be noted that there is a certain spatial correlation in land cover distribution patterns. Nearby units tend to have similar attributes. The assumption of random distribution of the units in the sample as mentioned above therefore is not quite justified. As a consequence, the dot grid method will tend to overestimate the variance of the area estimates. We are "on the safe side", underestimating the precision of the result rather than overestimating it. The area estimate itself is unbiased. There are various methods to obtain a better estimate of its variance in the case of spatial correlations (see e.g. Wolter, 1984).

If different coca cultivation densities prevail in different parts of the total area, a stratification approach might be followed.

4. Case studies

4.1 Test of different satellite imagery

The first test site is located in the Yungas ofla La Paz area which, is characterized by large fields, often clustered into larger areas.

A small area was selected where cloud free images of WorldView-2 (Acquisition date: 03-10-2011; spatial resolution: 0.5 meters) and RapidEye (Acquisition date: 31-05-2011; spatial resolution: 5 meters) were available; the images were orthorectified before doing the interpretations. As the area under crop is stable, the two different acquisition dates are comparable. The total area of interest comprises 1,259 ha of which 210 ha were used for coca plantations according to the results of the survey 2011 which was based on the visual interpretation of the WorldView-2 imagery. This serves as a reference data set. The two different types of images are shown in figure 2. Interpretations applying dot grid sampling were carried out by one interpreter familiar with the geographic region.

Two different settings for dot grid sampling were defined to demonstrate the effect of different dot spacings using different imagery. The parameters were selected to keep the amount of time necessary for the interpretation within an acceptable range. Two different distances between the dots were independently tested: 200 meters and 100 meters. The features of the grids and the results are shown in table 1.

Figure 2 - Dot grid sampling on WorldView-2 and RapidEye of the same coca growing area (yellow polygons: coca fields resulting from a visual interpretation of WV-2 data)

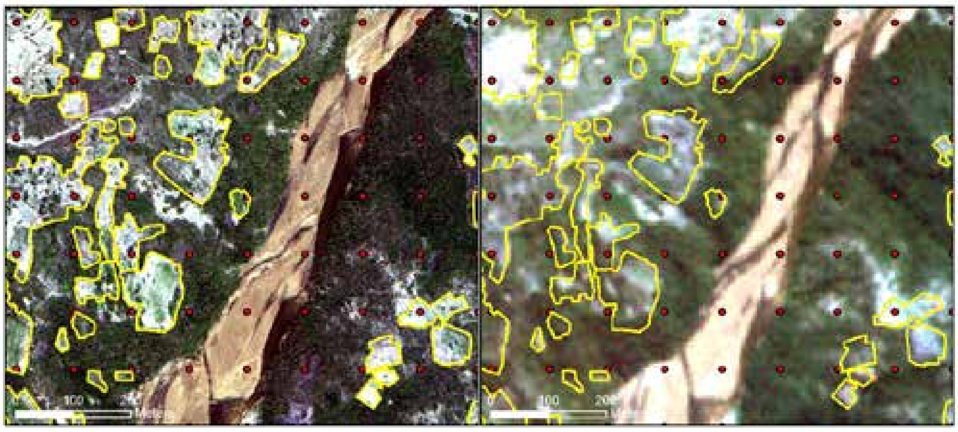


Table 1 - Interpretation results; case study 1, comparing images with different spatial resolution and two different grid spacings

Reference	Visual interpretation of WorldView-2 image (polygons)
Total area (ha)	547
Crop area from polygon interpret. (ha)	130.7
Number of polygons	187
Time needed for polygon interpretation	80 min

Results:

Sensor	WorldView-2		RapidEye	
Dot spacing (m)	100	200	100	200
Total number of dots	547	137	547	137
Number of dots falling upon coca fields	117	29	105	27
Estimated fraction of crop area in total area	0.2139	0.2117	0.1919	0.1971
Estimated crop area (ha)	117.00	115.79	105.00	107.80
Standard dev. of crop area	9.59	19.09	9.21	18.59
Relative sampling error (%)	8.20	16.49	8.77	17.24
Difference to polygon interpretation (%)	-10.48	-11.41	-19.66	-17.52
Time needed for dot interpretation	20min.	6 min.	15 min.	7 min.

4.2 Test in areas with different densities of coca fields

The objective of the second exercise was to test the dot grid approach in geographic regions with different coca field densities. The test areas are located in the Cochabamba Tropics which is characterized by small fields. An IKONOS image with a spatial resolution of 1 meterwas used. Each area comprises 10,000 ha. A 250 meter dot spacing was chosen as an example for dot grid interpretation with extreme time saving under the assumption that a relative sampling error of approximately 20% still might be acceptable for a first estimate.

Table 2 - Interpretation results; case study 2, with an Ikonos image and three areas with different coca density levels

Sensor	Low density	Medium density	High density
Total area (ha)	10000	10000	10000
Crop area from polygon interpret. (ha)	85.18	149.82	240.55
Number of polygons	718	1103	1766
Time needed for polygon interpretation	264 min	198 min	168 min
Dot spacing (m)	250	250	250
Total number of dots	1600	1600	1600
Results:			
Number of dots falling upon crop	15	23	29
Estimated fraction of crop area in total area	0.009	0.014	0.018
Estimated crop area (ha)	93.75	143.75	181.25
Standard dev. of crop area	24.09	29.76	33.35
Relative sampling error (%)	25.70	20.70	18.40
Difference to polygon interpretation (%)	+ 10.06	- 4,05	- 24.65
Time needed for dot interpretation	44.5 min	55.5 min	41.5 min

5. Discussion

The results show that the dot grid method severely reduces the time required for interpretation. In the examples given here, between approximately 10% (Table 1, 200meter spacing) and around 25% (Table 2) of the time required for full area (polygon) interpretation are sufficient for dot interpretation. The time saving obviously is higher for coarser dot grids (where fewer dots have to be interpreted) and for higher coca field densities (where more polygons have to be delineated). The time needed for the interpretation of 1 dot is approximately 2 seconds in all cases. The time needed to interpret and delineate 1 polygon is between 10 seconds (for smaller polygons) and 20 seconds (for larger polygons). The time saving is obtained at the expense of a certain sampling error. Basically, three types of errors have to be distinguished: interpretation errors, delineation errors, and sampling errors. We can assume that interpretation errors are of a similar magnitude in full area interpretation and in dot grid interpretation, if performed by the same interpreters. However, no information on this is at hand here, as exact data on the true coca areas are not available. In all cases with exception of the 100meter dot grid interpretation of RapidEye, the differences between polygon interpretation and dot grid interpretation can be assumed to be sampling errors:as can be seen from the tables, these differences between polygon interpretation and dot grid interpretation are usually smaller than 2 times the standard deviation of the crop area due to the sampling error.Taking the normal distribution as approximation to the binomial distribution, 95% of the results of dot grid interpretation should lie within this interval around the true value (here assumed to be the polygon result). The larger difference for the 100meter dot grid interpretation of RapidEye obviously is due to the systematic interpretation differences between WorldView-2 and on RapidEye. Most likely, the WorldView-2 results are more reliable, which is also supported by the assertions of the interpreters that it is more difficult to interpret coca on images of lower spatial resolution.

Fig. 3 - Comparison spacing/time for dot grid interpretation and time needed for interpretation and delineation of polygons in "Tropico de Cochabamba"

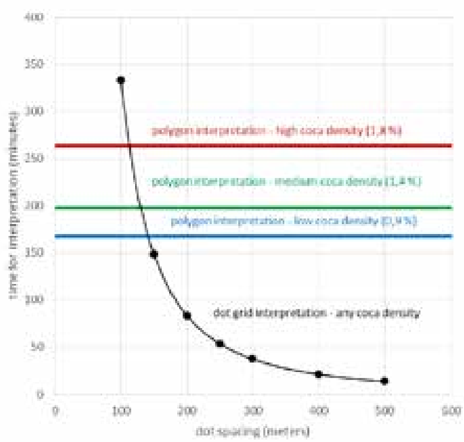


Fig. 4 - Comparison betweenrelative errors of different dot grid spacings for different coca density areas.

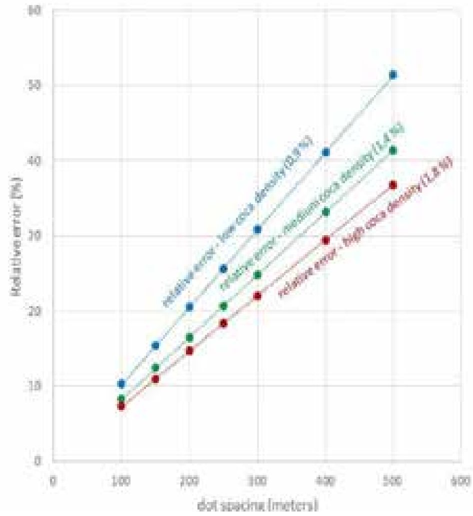


Figure 3 compares the time necessary to interpret dots compared to the time needed to interpret polygons for different coca field densities in the second test area. It can be seen that the dot grid interpretation becomes faster than polygon interpretation when the spacing between dots is larger than about 125 to 160 meters, depending on the coca field density. Of course, at the same time the relative sampling erroralso increases. It changes for low coca field densities from 10% (100 meter spacing) to 50% (500 meter spacing), for medium coca field densities from 8% (100 meter spacing) to 40% (500 meter spacing) and for high coca densities from 7% (100 meter spacing) to 37% (500 meter spacing). It follows from experiences in many fields of land cover mapping that it is hardly possible to reach thematic accuracies above the range of 80% to 90% (see e.g. Büttner and Maucha, 2006). Therefore, additional sampling errors up to 10% usually should be tolerable. Nevertheless, the additional sampling errors (figure 4) should be evaluated against the expected improvements for the interpretation accuracy, which can be considerably high but have not been quantified in this study.

6. Conclusion

Illicit crop area is usually determined by digitizing polygons on remotely sensed images, and by calculating the areas of the polygons. A map showing the crop areas is produced by this method. The method is time consuming and potentially inaccurate, as there may be systematic errors in delimiting the fields (drawing the boundaries of the polygons). If a detailed parcelmap is not needed, or if a sort of "soft map" (map of the density of coca plantations, without showing the exact locationsand boundaries of individual fields) is sufficient, a sampling approach (dot grid method) may give results of a higher accuracy than polygon delineation. Even if polygons are still required, dot-grid sampling can be an efficient method to test and train interpreters or to carry outa quick quality control.

The case studies have shown the pros and cons of the dot grid approach.The dot grid method is particularly favourable when interpreting areas with a high density of fields: in this case, a larger spacing ofthe dots can be chosen, and the substantial effort and time necessary for the polygon delineationisavoided. The tests in theYungas of La Paz area show that thedot grid interpretation can be more than 10 times faster than the full area interpretation with delineation of single fields. Interestingly there are hardly any time differences using the dot grid method for coca areas with different densities.

With the given crop densities for this case study, the maximum additional relative error of 10%, the following distances would be beneficial from a time-gaining point of view: 115 to 270 m for high density, 125 to 240 m for medium density, 140 to 190 m for low density.

An option to further speed up the dot grid interpretation is a pre-selection of points. Based on an automated land cover classification, a mask can be generated which includes for example dense forested areas, water bodies, built-up areas, rocks, etc.. Points falling upon such land cover units donot have to be interpreted.

Further research is necessary (a) on the variance that exist in polygon delineation, which has to be compared with the sampling error inthe dot grid method, and (b) on the potentials to quantify systematic biases by different interpreters and on methods to correct for that.

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B09

Using law enforcement data to estimate illicit activity in an internationally traded illegal commodity

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ABSTRACT

Estimating illicit activity of an internationally traded illegal commodity is challenging because of the hidden nature of the trade. This makes it difficult to observe and to collect data. One source of data is that collected by law enforcement agencies, from seizures of illicit goods. But this data does not represent a random sample of illicit activities. Instead it represents those activities that have come to the attention of law enforcement agencies either due to intelligence or via routine activities. To be able to use law enforcement data to understand patterns in illicit activity, for example estimate trends through time or compare activity in different countries, it is therefore necessary to account for the mechanisms by which the data is obtained and reported.

In this paper I describe a strategy for dealing with the biases in seizures data using the example of the illegal ivory trade. Countries are mandated to report seizures of illicit ivory to the Elephant Trade Information System (ETIS) which holds over 20,000 records of illegal ivory seizures from 1989 onwards. Countries differ in their ability to make and report seizures and in the quality of the information they provide to ETIS. A suite of proxy variables was identified that could potentially explain differences in reporting and seizure rates between countries and over time. By fitting Bayesian hierarchical latent variable models to the data, the proxy variables that best explained the variability in the data were selected. The model was used to produce relative indicators of the number of transactions and the total weight of ivory over time for individual countries for different sizes and types (raw or worked ivory) of ivory shipments.

In addition to outlining the methodology I also discuss the more general implications of this strategy on data collection and analysis to learn about international trade in an illicit commodity.

Keywords: Illegal ivory seizures data, Bayesian hierarchical latent variable models, bias adjustment

PAPER

1. Introduction

Records of seizures of illicit products are sometimes used to learn about trade in illicit activities. For example, the UNODC's World Drugs Report (UNODC, 2015) reports on numbers and sizes of seizures and changes in numbers of seizures of different drugs by region and transportation methods. Similarly, the World Customs Organisation reports on seizures of many different items including drugs, endangered species, counterfeit goods, highly taxed goods such as tobacco, and weapons (WCO, 2015). A major difficulty with seizures data is understanding what these figures say about the relative importance of different countries in the trade and trends in the trade over time.

This paper describes ivory seizures data collected by the Elephant Trade Information System (ETIS), the biases in these data and strategies for accounting for these biases. An overviewof a methodology described in detail in Underwood et al (2013) to estimate trends in the illicit trade using seizures data is given. This paper then reflects on key features of the methodology and data that need consideration when applying to other commodities.

Ivory seizures data

Demand for ivory is mainly for high status decorative and artistic purposes. Elephants are the main source of ivory and are killed to remove the tusks. Raw ivory, tusks or pieces of tusks, are taken to processing plants where the ivory is carved into finished objects, now defined as worked ivory, and then reshipped and sold wholesale or retail to consumers. A single piece of worked ivory may have been involved in multiple transactions and passed through several countries in shipments of varying sizes. Typically, ivory is sourced from Africa and "consumed" in Asia.

In 1997, the Convention for International Trade in Endangered Species of Wild Fauna and Flora (CITES) set up the Elephant Trade Information System (ETIS) database to monitor status and trends in the illegal ivory trade. The data were to be used to report to CITES meetings to inform decision making on elephants and trade in elephant products. These decisions may require specific countries to strengthen control of their ivory trade and commit to legislative and enforcement actions. As such analyses are needed to identify trends in the trade and key players in the trade and how these change over time.

ETIS includes data on seizures that have been made all along the trade chain. Seizures might be made (1) at various locations such as national parks with elephant populations, warehouses, or ports with ivory waiting to be consolidated into shipments, ivory processing plants or ivory markets or (2) when the ivory is in transit between countries either by air, sea or road in containers, luggage or the mail. Law enforcement organisations that make seizures include national park rangers, customs officers, and local police.

A country's CITES Management Authority (CMA), rather than the organisations that make the seizures, have the responsibility of reporting seizures to the CITES Secretariat or ETIS directly. CMAs are mandated to report ivory seizures within 90 days but in practice this does not happen. Some CMAs send information regularly, for example quarterly or annually, others send records when prompted by CITES notifications which are sent to all CITES Parties and others only in response to direct questions from ETIS, for example about specific seizures that have been noted in the press. Some countries do not report any seizures to ETIS even though it is suspected that seizures might be made in that country. ETIS also receives reports from World Customs Organisation and NGOs. In the past ETIS staff, in collaboration with government officials have carried out focused data collection exercises to ensure that a country's backlog of ivory seizure records is entered into ETIS.

There is a standard pro-forma for seizure records but not all of this information is provided for each seizure. Data for all records used in the main analyses include the country that made the seizure, the year in which the seizure was made, whether the seizure was of raw or worked ivory and an estimate of the quantity – either weight or number of pieces. The information on quantity is of mixed quality. Only about half the seizures record the weight and these can range from a few grammes to several tonnes (the maximum recorded being 6.4 tonnes). In many cases the weights, in particular of large seizures, are only approximately recorded – for example four tonnes. For seizures that only reported the number of pieces of ivory the ivory class was predicted based on statistical models fitted to seizures data where both the number of pieces and weight of the seizure were recorded. Conversion of raw ivory into worked pieces leads to some wastage of ivory. To account for this the weight of worked pieces of ivory is converted to an equivalent raw weight, the Raw Ivory Equivalent (RIE). Additional information that is requested includes other countries in the trade chain, that is the other countries through which the shipment has passed, originates from or is on route to, the methods of concealment and detection and the nationality of suspects. Most of this additional information is reported in less than a quarter of the reported seizures.

The ETIS database currently holds over 20,000 records from over 90 CITES Parties (countries or territories that have signed up to CITES). Approximately half of the CITES Parties have not reported any seizures themselves. The aim of the trends analyses is to describe the main trends and countries involved in the trade. As such it is necessary to consider both countries that have made seizures themselves and countries that have been implicated in seizures. To make the analysis tractable countries that play a minor role should not be included. Thus a threshold for inclusion in analysis is defined based on the total number of seizures and estimated weights of seizures that a country has made or has been implicated in over the time period of the analysis. For example, for early analyses this threshold was at least 30 seizures or seizures with a combined weight of 300 kg.

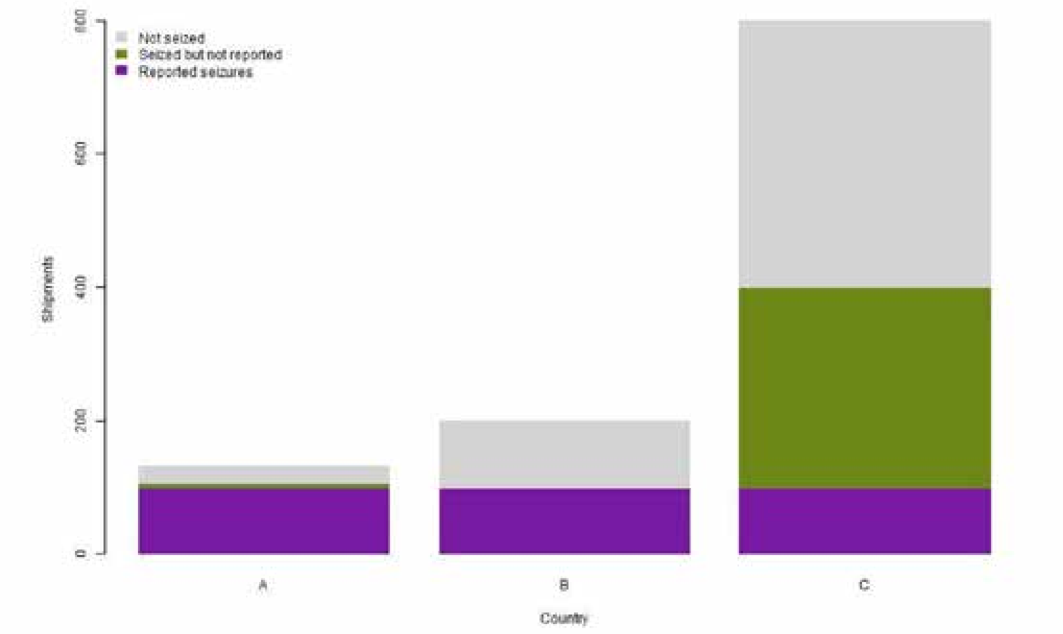
Over the period 1996 – 2011,68 countries met the threshold described above with a total of nearly 12,000 seizures. The USA and China both reported around 2,000 seizures, although the USA's were relatively evenly spread over the whole time period, but over 1,500 of China's reported seizures were from 2009 and onwards. Over the same time period Germany, France, Kenya and Switzerland each reported around 500 seizures in total and at least twenty countries reported between one and ten seizures. Other countries such as Angola, Laos and Togo did not report any seizures but met the threshold for inclusion because of the seizures they had been implicated in.

Biases in seizures data

The difficulty with seizures data is that simplesummaries of the total number, or weight, of seizures do not provide an accurate description of the trends and patterns in the illicit trade. Seizures do not represent a random sample of illicit transaction. Instead they represent the dysfunctional part of the trade and are themselves an intervention in the trafficking process. The mechanisms by which data are obtained, in particular the differences in how seizures are made and reported both between countries and over time, needs to be accounted for.

In particular, we cannot assume that changes in the number of seizures over time or differences in the number of seizures reported by two countries represent actual differences in the trade. For example, consider three countries which all report 100 seizures in one year as shown in Figure 1. For now, let's ignore the size of these shipments.

Figure 1 - Total number of shipments disaggregated by number of reported seizures, unreported seizures and unseized shipments under different scenarios. Although the number of reported seizures is the same in each case the total number of shipments, varies greatly between the three countries.

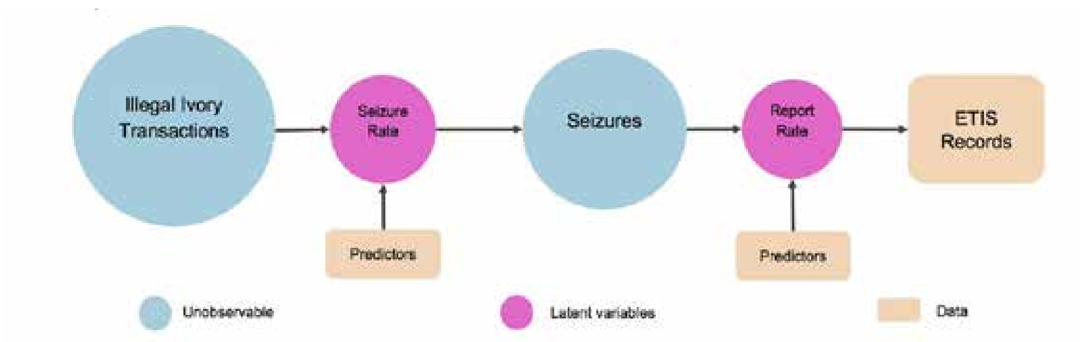


If all countries were equally good at making seizures (we call the proportion that are seized the seizure rate), and reporting these seizures (we call the proportion of seizures that are reported the reporting rate), then we could assume that the illegal trade in each of the three countries is the same. But Country A seized 80% of the shipments that passes through their country and reported 95% of these to ETIS. Countries B and C only seized half of the ivory shipments that passed through their countries. Of these Country B reported all of these seizures and Country C reported one quarter of the seizures. Although A, B and C all report the same number of seizures they represent 76%, 50% and 12.5% of the transactions within each country. The total number of shipments, or transactions, are then 132, 200 and 800 respectively for the three countries. That is, the observed number of seizures is a product of the number of transactions, seizure and reporting rate for each country.

Accounting for biases in seizure and reporting rates

In practice, it is not possible to know the actual seizures and reporting rates for any country, or how the rates vary over time.An alternative approach is to obtain estimates of relative seizure and reporting rates, by identifying the reasons why these rates might vary over time or differ between countries and finding predictor variables that describe aspects of the reasons. Using these relative rates and knowledge of the number of reported seizures it is then possible to estimate the relative number of transactions, as shown in Figure 2.In the Figure 1 example relative rates would indicate that Country C has four times as much trade as Country B and Country B has 50% more activity than Country A. The estimates of the relative number of transactions can be used to describe trends in the trade over time and the relative importance or roles of different countries in the trade.

Figure 2 - Conceptual model of seizures data. From Underwood et al. (2013)



It can be challenging to find data on variables that potentially describe the reasons why countries differ in their ability to make and report seizures.In particular,to find variables on comparable scales across multiple countries. For example, countries may differ in their ability to make seizures because of the effort expended on law enforcement, such as the resources to make seizures, and the effectiveness of this effort. Direct measures of law enforcement, for example the number of staff and the availability of equipment, are not readily available for all countries that report or are implicated in ivory seizures.

Instead, proxy variables are sought. These proxies are not perfect descriptors of a country's ability to make or report a seizure but potentially capture some aspect of their abilities. For example, the effectiveness of a country's ability to make seizures may depend on the socio-economic environment within which law enforcement agencies operate. In countries with poor governance and little relevant legislation one might expect fewer seizures to be made. World Governance Indicators, UNDP's Human Development Index, and the IMF's per capita GDP were used as background measures of effectiveness and a score from the CITES National Legislation Project used as a measure of the strength of wildlife trade legislation.

For law enforcement effort, data on the number of staff and the availability of equipment is not available for all countries. Instead an internally generated variable – lagged law enforcement ratio – was used as a proxy. This variable is the number of seizures that a country has made divided by the number of seizures that have passed through that country – i.e.both those the country has made and those made by other countries but passed through the country of interest before seizure. A low score, close to zero suggests that a country has low law enforcement effort whereas a high score, close to one suggests much more effort.

Differences in the reporting rate may depend on both the ability of a country to submit records to ETIS and actions made by ETIS to acquire information. The mechanism by which each seizure entered the database was captured to create the data collection score. This was summarised to represent the proportion of records in any year that were either actively sought by ETIS or obtained via automated and regular reporting systems. A high score might suggest that most seizures are reported.A low score, obtained when most records are obtained in ad-hoc methods, possibly from sources other than the CMA such as the media or other organisations,might suggest thatmany seizures are not being reported by that country. A second measure, the CITES reporting score, was derived as the proportion of years that a country fulfilled their reporting obligations to CITES (including ETIS) divided by the number of years that the country had been a CITES Party. A high score, close to one, might indicate that a country takes their reporting requirements to CITES seriously and so could suggest that the seizures reported to ETIS represent most of the seizures that have been made by that country. The socio-economic variables used as proxies for the seizure rate were also considered as possible proxies for reporting rate.

Statistical modelling

The number of transactions that a country is involved in is modelled using the general framework described above with a Bayesian hierarchical latent variable model. We do not expect trading patterns to be the same for raw and worked ivory or for shipments of very different sizes. For example, we might expect different countries to be involved in shipments of raw and worked ivory and trends over time to differ between small and large shipments. Because of the uncertainty with the weights data we categorize the seizures into six ivory classes representing three weight categories, small (less than 10kg), medium (10kg to less than 100kg) and large (at least 100kg) and the two ivory types.

We want to be able to compare the relative number of transactions between the different ivory classes so we jointly model all six ivory classes together. Let y_{ijt} represent the number of seizures made by country i of ivory class j in year t. Then the number of seizures is modelled as a negative binomial distribution with mean μ_{ijt}.

$$y_{ijt} \sim NegBinom(\mu_{ijt})$$

The mean of this distribution is the product of three latent variables. The key variable of interest, λ_{ijt}, the number of ivory class j transactions for country i in year t, the relative seizure rate, θ_{it}, and reporting rate, ϕ_{it}.

$$\mu_{ijt} = \lambda_{ijt}\,\theta_{it}\,\phi_{it}$$

The seizure and reporting rates are common across ivory classes for each country because of identifiability issues and because not all countries report seizures in each ivory class. The seizure and reporting rates are functions of relevant covariates. Because of identifiability issues the relative seizure and reporting rates have no intercepts and by standardising variables the average country has a reporting and seizure rate of 0.5.

$$logit(\theta_{it}) = \sum_{l} b_l x_{lit}\; logit(\phi_{it}) = \sum_{m} c_m z_{mit}$$

The number of transactions for each country in each ivory class is modelled as a smooth function over time. The intercept and linear trend were allowed to vary between countries but remained correlated across ivory classes within each country. Higher order terms are shared across all countries in each ivory class to reduce the number of model parameters and because of the lack of data in many cases.

$$log(\lambda_{ijt}) = a_{0ij} + a_{1ij} f_1(t) + \sum_{k} a_{kj}\, f_k(t)$$

$$\underline{a}_{0i} \sim MVN(\underline{\alpha}_{0i}, \Sigma_0)\underline{a}_{1i} \sim MVN(\underline{\alpha}_{1i}, \Sigma_1)$$

Model selection was carried out using the Deviance Information Criterion and inspection of credible intervals. The order of fitting was to first identify which covariates best described the seizure and reporting rate, when $log(\lambda_{ijt}) = a_{0ij}$. Given these variables the number of polynomial terms for the trend was identified.

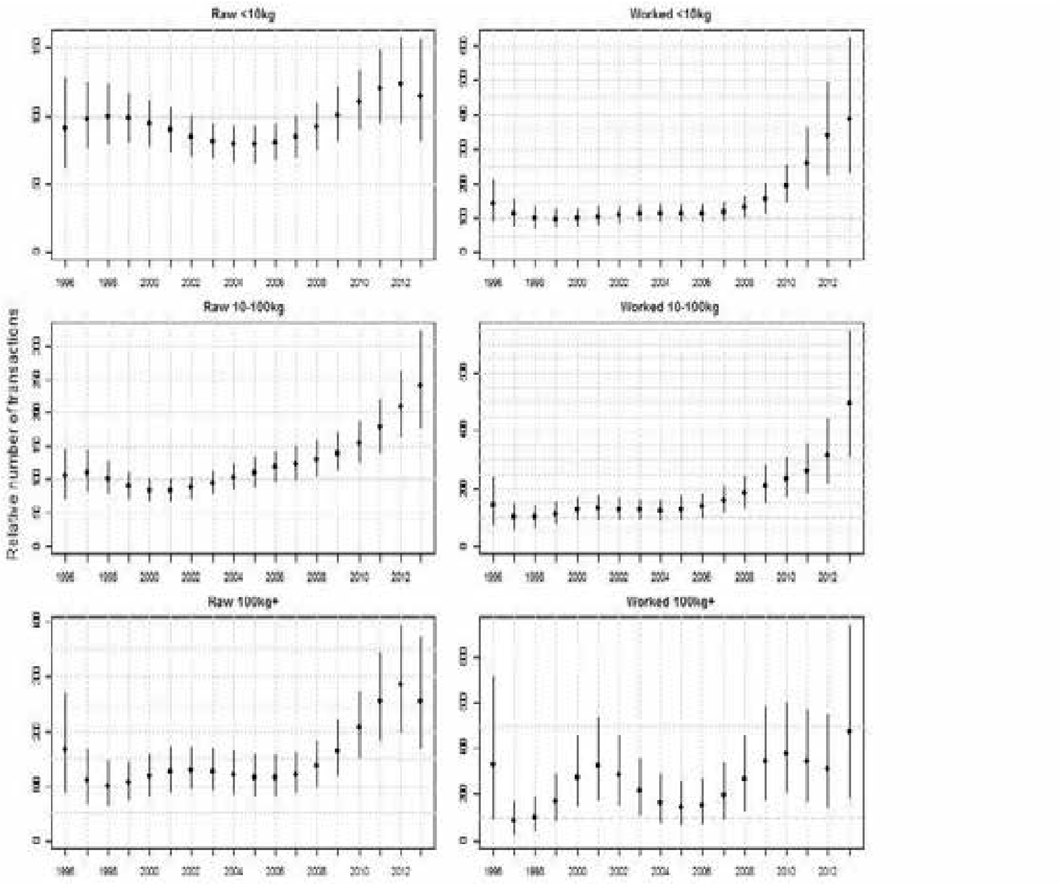
In addition to modelling the number of transactions a relative weights index is calculated. First the rounded values of the λ_{ijt} s are interpreted as the number of illegal ivory transactions in each ivory class for each country and year. By fitting statistical distributions to the weights of shipments for raw and worked ivory separately we simulated weights of each of the λ_{ijt} s.

Further details of the modelling, and the creation of proxy variables, are provided in Underwood et al (2013) and Burn and Underwood (2013) and results in Milliken et al (2o13).

Modelling outputs

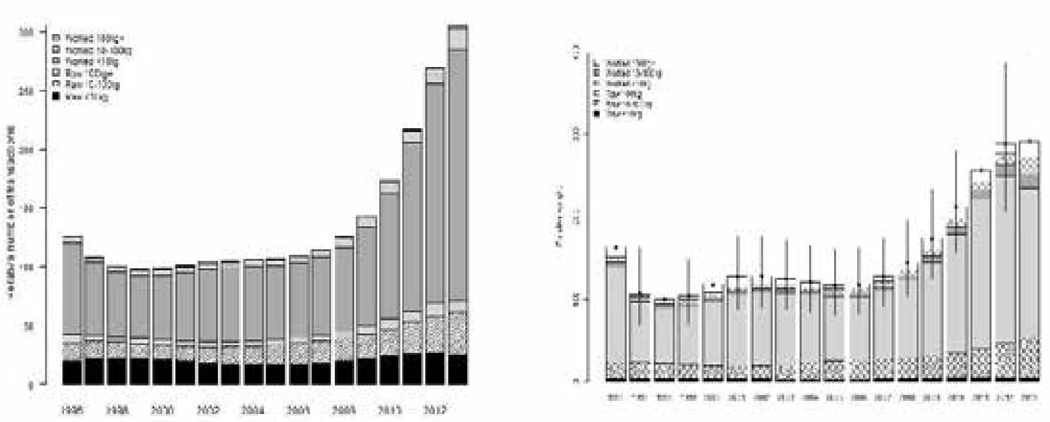
The λ_{ijt} sare the relative number of illegal ivory transactions for each country in each year in each ivory class. These indices represent the number of seizures that we might expect from each country in each year if they were all equally good at making and reporting seizures.

Figure 3 - Transactions Index for each ivory class. From SC66 (2015). Some but not all ivory classes show an increase in trade over time.



For reporting purposes, the relative number of transactions is summarised across countries to show (1) trends in the number of transactions in each ivory class (Figure 3) (2) the relative contribution of each ivory class to the total number of transactions (Figure 4a) and (3) a global Transactions Index. There are different trends in these six ivory classes and the global Transactions Index is dominated by the small worked ivory class whereas most of the weight of ivory in circulation is dominated by the large raw ivory class (Figure 4b).

Figure 4 - Relative contribution of each ivory class to (a) Transactions Index (b) Weights Index. From SC66 (2015). Note how the small worked ivory class contributes most to the Transactions Index and the large raw ivory class most to the Weights Index.



We also obtain estimates of the relative seizure and reporting rates for each country over time. The important variables for seizure rate were the lagged LE ratio and, except in the most recent analysis, rule of law. For reporting rate,the main variable was the data collection score and the CITES reporting score. Examination of the relative rates show considerable variation between countries and over time. The relative importance of different countries and different years using the Transactions index can be considerably different to an interpretation based only on the unadjusted seizures data. This can encourage countries to report their seizures because reportingmore seizures does not necessarily make them more likely to be implicated as major players in the illicit trafficking of ivory.

Requirements for modelling trends in seizures data

The strategy has been developed to describerelative trends in the illegal ivory trade. Here I reflect on some of the data characteristics needed to transfer the approach to other commodities.

The analysis needs a large number of seizures to be able to model trends over time, especially if trade dynamics are thought to vary across different commodities or shipment size. Modelling the trend in each category as a combination of a random intercept and slope for each country and polynomials shared across countries for higher order terms overcomes the problems of very small numbers that are reported by some countries in anycategory. Not all countries can report only small numbers of seizures for this approach to work

The key challenge is dealing with the biases in the seizures data. In the ETIS analyses it is the data collection score which describes how seizures enter the database, that contributes most to bias adjustment. For ETIS, it was possible to identify the different mechanisms by which records enter the database partly because countries are mandated to report ivory seizures to ETIS. If there is no mandate for reporting it can be difficult to identify proxies to represent the reporting process. For example, there are a number of databases where individuals or organisations have tried to capture information about seizures of particular species without any mandate, procedure or requirement for countries to report their seizures. In these cases, seizures data have been obtained by scouring the internet for official and unofficial reports of seizures and by building up networks of people within law enforcement agencies to supply information. The challenge then is to identify proxy variables for the reporting rate that capture the different ways in which searches and networks are used.

To make global statements about the illicit ivory trade, national level seizures data is required. Conversely, it is not possible to make statements about trade at the level of individual countries without the global analysis. This is because the law enforcement ratio, one of the variables that adjusts for biases in seizure rate, uses information about seizures that implicate a country. This would not work without a significant number of seizures recordinginformation about the trade route.

The lack of good quality weights information for all seizures meant that categorizing seizures into only three broad weight categories was an obvious choice. If the weights data had been more accurate and complete, a strategy that directly modelled weights and numbers of seizures together might have been considered. This is a more challenging exercise than has been described here.

Conclusion

Biases in seizures data mean that changes in the number of seizures are not necessarily a good indication of changes in the illegal trade. By identifying the reasons why countries differ in their ability to make and report seizures and seeking out, or creating, predictor variables it is possible to extract useful information out of the data, to be able to make comparisons over time and between countries.

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Opium yield estimates in Afghanistan using remote sensing

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ABSTRACT

Accurate estimates of opium production are essential for informing counter-narcotics policy in Afghanistan. The cultivated area of opium poppy is estimated remotely by interpretation or digital classification of very high resolution (VHR) satellite imagery at sample locations. Obtaining an accurate estimate of average yield is more challenging as poor security prevents access to a sufficient number of field locations to collect a representative sample. Previous work carried out in the UK developed a regression estimator methodology using the empirical relationship between the remotely sensed normalised difference vegetation index (NDVI) and the yield indicator mature capsule volume. The application of the remote sensing approach was investigated in the context of the existing annual opium survey conducted by the United Nations Office on Drugs and Crime and Afghanistan's Ministry of Counter Narcotics (UNODC/MCN) and indicated the potential for bias correction of yield estimates from a small targeted field sample. In this study we test the approach in Afghanistan using yield data and VHR satellite imagery collected by the UNODC/MCN surveys in 2013 and 2014.

Field averaged measurements of capsule volume were compared to field averaged NDVI extracted using visual interpretation of poppy fields. The study compares the empirical relationships from the UK field trials with the Afghanistan data and discusses the challenges of developing an operational methodology for accurate opium yield estimation from the limited sample possible in Afghanistan.

Keywords: Opium poppy, remote sensing, yield bias correction

PAPER

1. Introduction

The United Nations Office on Drugs and Crime and Afghanistan's Ministry of Counter Narcotics (UNODC/MCN) produce annual opium production estimates based on survey data collected across Afghanistan. The opium yield estimate is based on the empirical relationship of dry opium gum to mature capsule volume per unit area, measured at sample locations. The indirect yield measurement of mature capsule volume is used as it is quicker than removing and drying capsules for weighing.

Sample sites are chosen randomly from a sample frame of the villages located in the poppy producing provinces. At each selected village three fields are subjectively chosen by a field surveyor representing a poor, average and good quality poppy crop. In each field, measurements of capsule volume (capsule height and diameter) and the number of yielding capsules are made within three 1 m^2 quadrats arranged randomly along a transect. The average dry opium gum yield (Y) in kg ha^{-1} is calculated for each quadrat using the model (UNDCP, 2001)

where Vc is the mature capsule volume ($cm^3\ m^{-2}$). The average yield per unit area weighted by province area is then calculated and multiplied by the cultivated area of poppy to estimate the total production.

$$Y = \frac{(V_c + 1495) - ((V_c + 1495)^2 - 395.259 \cdot V_c)^{0.5}}{1.795} \quad (1)$$

There are difficulties with implementing the yield survey because security limits access to poppy fields within the major opium producing areas. Surveyors are unable to access many of the field locations from the sample frame which results in a low number of surveyed fields and a non-random distribution of samples (UNODC, 2012). The statistically un-representative sampling will bias the average dry opium yield and hence the yearly estimate of opium production.

A methodology for bias correction of opium yield estimates was proposed by Waine et al.(2014) using the existing very high resolution (VHR) imagery and the non-random field observations from the opium yield survey. The approach makes use of VHR imagery collected at random sample locations for visual interpretation of poppy crops as part of the cultivation component of the UN-ODC's annual opium survey. For each image, a bias-corrected estimate is made by substituting the field average Normalised Difference Vegetation Index (NDVI) of all poppy fields (population) into the linear regression of NDVI and mature capsule volume determined using a small number of high-quality field observations. As each image is randomly selected an unbiased estimate of opium yield can then be made.

Remote sensing of yield exploits the relationship between linear combinations of red and near-infrared reflectance, known as vegetation indices (VI), and crop biophysical parameters. VIs such as the NDVI are correlated to leaf area index and above-ground biomass which are in turn correlated to final yield in crops such as wheat, millet, soybean, cotton, barley, and maize (Domenikiotis et al., 2004; Liu and Kogan, 2002; Prasad et al., 2006; Rasmussen, 1997; Tucker et al., 1980; Weissteiner and Kühbauch, 2005).

Wood et al. (2003) demonstrated how image derived NDVI could be used for mapping within-field variability in crops of wheat (Triticum aestivum) and barley (Hordeum vulgare L.) using a small number of ground samples to construct a regression based model. They found as few as eight sample observations could be used to correlate yield indicators to NDVI for groups of fields, with a single observation per field. Based on this approach, the relationship between opium yield indicators and NDVI was inves-tigated by Taylor et al. (2010) as part of wider research into improving opium production estimates using remote sensing. Field trials conducted in the UK showed a high correlation between NDVI and measurements of mature capsule volume (R^2 = 0.70) across multiple fields and three growing seasons (Waine et al., 2014).

Investigations using 2011 yield and VHR image data from the UNODC's annual survey in-dicated the potential for operational use but there were too few ground observations per image to validate the methodology. The following conditions were recommended by Waine et al. (2014) for field measurements in support of the bias-correction approach: (1) accurately geo-referenced ground data; (2) samples should be distributed across the range of crop variation with respect to NDVI; (3) ground measurements of poppy crop parameters must be accurately co-registered with ortho-rectified imagery; and (4) imagery used to derive NDVI should be targeted for collection around the flowering growth stage to maximise the correlation between yield indicators and NDVI. This conference paper presents investigations into a bias-correction methodology using ground observations and image data from the UNODC's 2013 and 2014 annual opium surveys.

2. Data and methodology

2.1. Yield datasets

Field observations from the annual opium survey in 2013 and 2014 were supplied by the UN-ODC for sample sites with coincident VHR satellite images collected for poppy interpretation. This data included quadrat level measurements of the number of capsules/flowers and mature capsule vol-ume together with ground photography and GPS data. The UNODC also supplied interpretations of poppy fields as digital boundary files for each image. Quadrat level data was used to calculate the mean volume of mature capsules per unit area (cm^3 m^{-2}) for each sampled field. Confidence inter-vals (95%) for the mature capsule volume (field average) for each image were calculated using the formula:

$$\mathrm{CI} = \bar{y} \pm \left(\frac{s}{\sqrt{n}} \cdot 1.96\right) \quad (2)$$

where $\bar{y}$ is the mean mature capsule volume for the image,

$$s = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(y_i - \bar{y})^2}, \quad (3)$$

y_i is a sample observation (field average) and n is the number of sample observations.

2.2. Image data

Multispectral QuickBird (QB) and WordView2 (WV2) satellite image scenes were supplied by the UNDOC. The image data had a spatial resolution of 3.6 m (QB) and 2 m (WV2), spectral resolutions of 630–690 nm (QB and WV2) in the red and 760–900 nm (QB) and 772–890 nm (WV2) in the near-infrared. The timing of each VHR image in relation to crop growth-stage was assessed using high-frequency satellite imagery from the Moderate Resolution Imaging Spectroradiometer (MODIS) (Simms et al., 2014). Timing of growth-stage was found to be similar within individual scenes. Table 1 shows a summary of the yield datasets for 2013 and 2014. Hilmand 2013 (held8) was not considered for further analysis as the satellite imagery was collected too late in the growing cycle. The Uruzgan images in 2014 (uruz-erad1 & uruz4) were collected on the same orbital pass and treated as a single image scene. Each image was corrected to top-of-atmosphere reflectance to minimise spectral differences between the WorldView 2 and QuickBird sensors (Pacifici et al., 2014). The images were then or-thorectified to reduce geometric distortion and

NDVI calculated as (ρNIR −ρR)/(ρNIR +ρR), where ρNIR is near-infrared and ρR is the ref reflectance.

2.3. Mature capsule volume and NDVI

Within each selected image the location of the sampled fields was identified using a combination of GPS coordinates, geo-tagged ground photography and visual interpretation of pan-sharpened VHR imagery. The field-average NDVI was then extracted for each sample field as the mean of the image pixels intersecting the field polygon. For each image the empirical relationship between mature capsule volume and NDVI was de-termined using linear regression of the form y = a(NDVI) + b, where y is the mature capsule volume

Table 1: *Summary of 2013 and 2014 yield datasets provided by UNODC/MCN for this study and multispectral satellites QuickBird (QB), WorldView2 (WV2) at 3.6 and 2 m pixel size respectively. Image held8 excluded as poppy crop was cleared*

Year	Image	Reference	Province	Acquisition	Sensor	Poppy growth stage (image)	Fields analysed	Poppy parcel interpretation
2013	*held8*		Hilmand	22/04/2013	QB	cleared	0/2	yes
	held	HLD	Hilmand	27/04/2013	WV2	sceneced	5/10	no
	kand-cnc p3-4	KDR	Kandahar	14/04/2013	WV2	capsule	6/6	yes
	uruz-target1	URZ	Uruzgan	27/04/2013	QB	capsule	3/9	yes
	farah-erad1	FRH	Farah	13/04/2013	WV2	capsule	12/12	yes
2014	held	HLD	Hilmand	24/04/2014	WV2	sceneced	6/8	yes - part
	uruz-erad1 & uruz4	URZ	Uruzgan	27/04/2014	WV2	capsule	9/9	no
	fara	FRH	Farah	15/04/2014	QB	flowering	12/12	yes
	bada-erad3-p1-2	BKN2	Badakhshan	26/06/2014	WV2	capsule	15/15	yes
	bada-erad1	BKN1	Badakhshan	26/06/2014	WV2	capsule	9/9	yes
	kand	KDR	Kandahar	10/04/2014	WV2	capsule	3/9	no

per unit area, a is the slope and b is the offset. The 95% confidence intervals of the mean expected value of y for a given NDVI (x^*) were constructed using:

$$\hat{y} \pm t_{0.025,n-2} \cdot s_y \cdot \sqrt{\frac{1}{n} + \frac{(x^* - \bar{x})^2}{(n-1) \cdot s_x^2}} \quad (4)$$

where s_y is the standard deviation of the residuals, $t_{0.025,n-2}$ is the student t-value for 95% CI (two tailed), s_x^2 is the variance and $\bar{x}$ is the mean NDVI.

The field delineations of poppy crops supplied by UNODC from their cultivation survey were used to extract the average NDVI for each poppy field in the image. Geometric differences between the field polygons and the orthorectified images were corrected by manually shifting individual polygons to align them with the imagery. A 2 m internal buffer was applied to the field parcels to reduce the edge effects.

The bias-corrected mature capsule volume was calculated by substituting the mean field average NDVI for all poppy fields in an image (population mean, $\bar{x}_{pop}$) into the empirical relationship between mature capsule volume and NDVI from the sampled fields.

3. Results

The linear regression of mature capsule volume and field average NDVI for 2013 and 2014 images are shown in figures 1 and 2 respectively. Image 2014 BKN1 was excluded from the analysis as there was no relationship between the mature capsule volume and NDVI from the image. Bias correction using the linear regression models above is summarised in table 2 for six of the nine images from the 2013 and 2014 data. There were no poppy field interpretations for HLD 2013, URZ 2014 and KDR 2014 as either the image was too late, the R^2 was low or there were too few field observations to warrant image interpretation. The correlation between mature capsule volume and NDVI is highly variable between images, with R^2 ranging from 0.08 to 0.42 for images with more than three fields. Images FRH 2014 and BKN2 2014 have an R^2 value greater than 0.4 and yield figure corrections of -17% and 17% respectively, with improved or similar confidence intervals compared to the sample data alone. KDR 2013 and HLD 2014 have low R^2 values indicating high variance in the relationship between mature capsule volume and NDVI. This is shown in the increased CI of the bias corrected mature capsule volume. The bias-corrected yield for FRH 2013 is within 1% of the sample yield despite a very low R^2 of 0.14.

Figure 1 - Field average NDVI plotted against mature capsule volume per unit area for individual image sites in 2013. Dashed lines show 95% confidence interval for the regression line

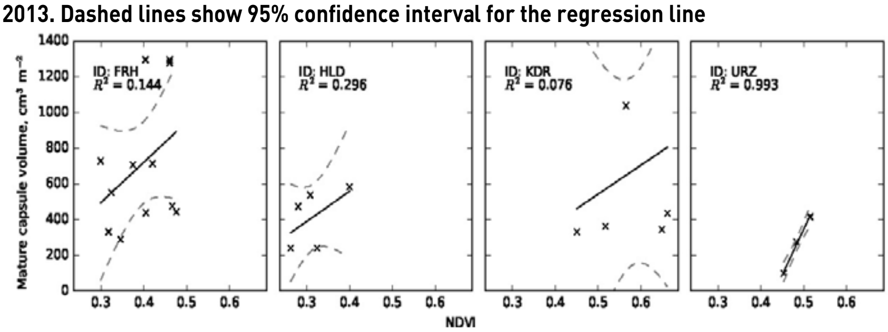
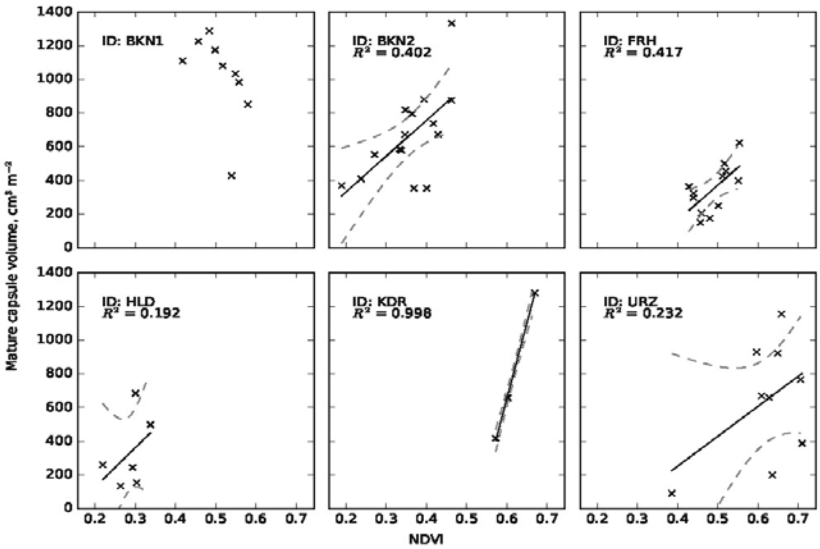


Figure 2 - Field average NDVI plotted against mature capsule volume per unit area for individual image sites in 2014. Dashed lines show 95% confidence interval for the regression line. BKN1 shows no relationship.



4. Discussion and recommendations

The empirical relationships between field average NDVI and mature capsule volume for the Afghanistan data (figures 1 and 2) are poor compared with the data from the UK (R^2 >0.7 at flower-ing). The potential reasons for the discrepancy are the differences in agricultural practices and poppy varieties, the differences in the methodology between the UK field trials and the Afghanistan data collection, and the quality of the yield observations.

The manual cultivation methods used in Afghanistan are likely to result in greater variation in the quality of crops than the standardised mechanised practices used in the UK. In the UK field trials, sample locations were co-located with pixel level accuracy (<1 m) across the range of NDVI variability. In Afghanistan accurate co-location of the quadrat locations (<1 m) is not possible using the current GPS units so the field-averaged yield and NDVI are used instead. Detailed examination of the Afghanistan field data and ground photography suggests that the average of the quadrat level data may not be representative of individual fields. Many of the quardats are located along field boundaries, which may introduce sample bias if these areas are consistently higher or lower yielding than the rest of the field.

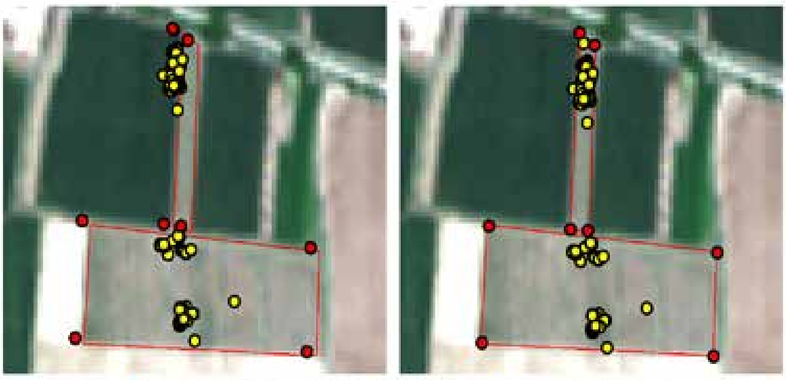
Table 2 - Results of bias correction methodology applied to 2013 and 2014 image data. NDVId is the difference between the mean NDVI of the sample fields and the mean NDVI of all poppy fields in the image. CIsamp is the 95% confidence interval of the sample yield estimate and the CIcorr is the 95%confidence interval of the regression model yield estimate.

Year	ID	No. fields	Yield sample mean (cm^3 m^{-2})	$\pm CI_{samp}$ (%)	Yield bias corrected (cm^3 m^{-2})	$\pm CI_{corr}$ (%)	R^2	NDVI range all fields	NDVI range sam-pled	Yield differ-ence (%)	$NDVI_d$
2013	URZ	3	262	69	395	13	0.99	0.439	0.062	51	0.026
2013	FRH	12	712	30	721	32	0.14	0.401	0.177	1	0.004
2013	KDR	6	669	59	577	114	0.08	0.659	0.211	-14	-0.057
2014	FRH	12	347	23	288	30	0.42	0.215	0.125	-17	-0.028
2014	HLD	6	329	53	428	77	0.19	0.192	0.119	30	0.042
2014	BKN2	15	666	20	778	18	0.40	0.496	0.273	17	0.053

There is also the potential for increased NDVI values relating to the presence of weeds where the density of opium cropping is low. Visual inspection of the quadrat photographs for KDR 2013 showed inconsistencies between capsule counts and the recoded data. There was also ambiguity in the labelling of sampled fields and data points. There is potential for error in matching the NDVI values with the correct field data as the plot photo-locations are used for linking the fields in the database with the image interpreted field parcels.

A better correlation of NDVI with mature capsule volume could be obtained by accurately co-locating individual quadrat measurements with the image pixels. The GPS coordinates and image ortho-rectification are not sufficiently accurate to ensure pixel level geo-location. However, by col-lecting the corner positions of the sampled fields the sample data can be shifted to better align with the image data (see figure 3).

Figure 3 - Suggested additional GPS point locations at field corners allow improved placement of yield points with imagery. GPS points shifted to image (right) using field corners.



The range of NDVI values from all poppy fields in the image is much greater than the range of NDVI for the sampled fields (table 2). This suggests the current approach of sampling the range of yield by subjective assessment of crop quality is not capturing the true variability.

Some of the errors in field data collection and the placement of sample quadrats are related to the security conditions faced by the field survey teams. Taking field measurements and photographs exposes surveyors to personal risk, which is reduced by taking measurement at the corner of fields or behind compound walls. An advantage of using an imagery based approach is that NDVI data can be used to preselect fields to sample. A range of field sites representing the range of NDVI could be pre-sented to the survey teams provided that images are collected around the crop flowering period. Once in the area of the image, a sub-selection could then be made based on an in-field risk assessment. This would also improve the field selection process compared to the current subjective assessment of a low, medium or high yielding crop. Implementing this approach would require improved communication with the field survey teams. Images would need to be processed and visually interpreted for opium poppy fields in the 2-3 weeks between image collection and capsule maturity when yield observations are made in the field.

Imagery that coincides with the 3–4 week period around poppy flowering has the the highest R^2 and greatest stability of the relationship between NDVI and capsule volume in UK data (Waine et al., 2014). The timing of the UNODC imagery from both years is towards the end of the growth cycle and close to crop senescence, where the relationship between potential yield and NDVI breaks down.

The remote sensing approach aims to relax the requirement for a random distribution of sample points and to reduce the number of samples required to make a yield estimate. It does not correct for error in the yield observations, which was found to vary between the images locations. Data recording errors and mislabelling that result in outliers in the regression of mature capsule volume and NDVI will have a significant effect on the results. The suitability of the imagery also varies according to its timing in relation to the crop growth stage. Imagery collected late in the growing season will have a shorter range in NDVI and less stable relationship with potential yield resulting from a reduction in photosynthesis as the crop senesces. As such the approach could not be used for all of the 2013 and 2014 images. However, the potential of the approach can be seen in the improved yield estimates for FRH 2014 and BKN2 2014. These image sites had more than 6 field locations, imagery at flowering or capsule stage and $R^2 > 0.4$.

A small targeted yield sample remains the best approach to improve the accuracy of yield ob-servations of mature capsule volume. However, field data quality is likely to remain highly variable given the unpredictable security conditions in which surveyors work. It is recommended to apply the following criteria for each image before applying a bias-correction: (1) suitable image timing (ide-ally 2–4 week period around poppy flowering); (2) ground locations of measured fields accurately determined in imagery; (3) minimum of six ground data points, positive correlation and $R^2 > 0.4$; and (4) image mean NDVI of poppy fields within the bounds of the model. The value of R^2 suggested is supported by findings in Taylor et al. (1997), where an $R^2 > 0.3$ was recommended for application of a regression estimator in cultivation surveys.

5. Conclusions

A bias-correction methodology using VHR satellite imagery was applied to the yield data of the UNODCs annual opium survey from 2013 and 2014. The aim of the approach is to reduce bias caused by the non-random distribution of the sample and reduce the number of samples required to make an estimate. Of the 12 VHR images, 6 were bias corrected with 2 resulting in an improved yield estimate. The remaining images had a low R^2 for the empirical relationship between mature capsule volume and NDVI, which was attributed to the quality of the yield observations and the accuracy of field-averaged yield data calculated from three quadrat locations in heterogeneous fields. Improvements to the survey methodology were recommended to improve the empirical rela-tionships between NDVI and capsule volumes. These were to optimise the timing of VHR imagery collection to coincide with poppy flowering, improve the relative alignment of quadrat GPS locations using field corners, and using the stratified NDVI image to target field locations to sample. Criteria for applying the bias correction methodology for operational use were also suggested. The authors acknowledge that the recommendations and quality criteria cannot currently be met in all cases given the complex logistical and security situation in Afghanistan. The UNODC seeks continuing improvement in the quality of ground data collection through improved surveyor training and concentrating its effort on a small and targeted yield sample. In this context the approach should be tested further for operational use in bias correction of yield estimates going forward.

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B09

Survey methods for the Enumeration of Nomadic and Semi-Nomadic (Transhumant) Livestock

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ABSTRACT

Despite the growing importance and contribution of the livestock sector to the economy of many countries, statistical data on the sector remains weak and surrounded with large uncertainties. Even the total number of pastoralists in the world is not known within any degree of confidence. Data on nomadic and semi nomadic livestock is even less reliable given the specific challenges related to collecting data on this type of livestock since standard survey methods cannot be easily applied. Nomadic and transhumant pastoralists move their animals according to the availability of fodder resources and tend to inhabit relatively remote and inaccessible areas, which are major constraints on the conduct of conventional field surveys. Special attention is therefore required to devise appropriate methods for enumerating nomadic and transhumant livestock.

FAO's previous guidelines on collecting livestock data (FAO, 1992) included a review of methods for enumeration of nomadic livestock, but this was published over twenty years ago. Since then, new methods of assessing livestock resources and production parameters have been developed and new tools have become available for geo-referencing, recording and analyzing data as well as computer software programmes for data capture, checking, analysis and display have also greatly improved.

In light of the importance of nomadic livestock for many countries, the lack of a document synthesizing the existing approaches and in order to reflect new methods and tools, the FAO Global Strategy to Improve Agricultural and Rural Statistics has developed new guidelines on collecting statistics on nomadic and transhumant livestock. The guidelines address the methodological and operational challenges to enumerating nomadic and semi-nomadic livestock (GSARS, 2016). This paper draws on findings and guidance provided in these guidelines.

Keywords: Nomadic and transhumant livestock, ground and aerial survey, agricultural census

PAPER

1. Introduction

In many developing countries, livestock production is one of the fastest growing components of agriculture and, as economic development progresses, is expected to become the largest contributor to the sector. Information on livestock producers and their animals is thus essential to the design, implementation, monitoring and evaluation of socially desirable interventions in the sector, including selective breeding, animal health, improved feeding, processing and marketing policies and investments.

The total number of pastoralists in the world is not known within any degree of confidence, because of inconsistencies in definitions and uncertain figures, but has been variously estimated at 20 million pastoral households (de Haan et al., 1997; referred to in Blench, 2001); 180.7 million individuals - pastoralists (Thornton et. al., 2002); and 200 million individuals - pastoralists (Rota and Sperandini, 2009). Estimating the number of nomads has been even less certain, with a commonly quoted figure about 30-40 million individuals. This figure seems to come from an estimate made at the latest in 1995 and numbers are likely to have fallen since then. ("Nomads: the facts". New Internationalist. Oxford, UK. 5 April 1995. Available at: http://newint.org/features/1995/04/05/facts/).

1. Issues to be addressed for enumerating nomadic and semi-nomadic livestock

Where agricultural households are settled and farm specific areas of land, the locations of towns, villages and farms are known and mapped. In these areas, the implementation of agricultural censuses or surveys – including on livestock – is a relatively straightforward process of organisation of statistical survey. Where livestock producers are transient pastoralists, standard survey methods of agricultural enumeration cannot be easily applied. Nomadic and transhumant pastoralists move their animals according to the availability of fodder resources and tend to inhabit relatively remote and inaccessible areas, which are major constraints on the conduct of conventional field surveys. Special attention is therefore required to devise appropriate methods for enumerating nomadic and transhumant livestock,.

FAO's previous guidelines on collecting livestock data (FAO, 1992) which included a review of methods for enumeration of nomadic livestock, were published over twenty years ago. Since then, new methods of assessing livestock resources and production parameters have been developed; and new tools have become available for geo-referencing, recording and analysing data. Computer software programmes for entering, checking, analysing and displaying data have also greatly improved. A review of existing literature shows that the enumeration of nomadic and semi-nomadic population or livestock is discussed in several documents and research papers. However, there is no single document holistically synthesising the existing approaches. In light of its importance for countries, and in order to reflect new methods and tools, the FAO Global Strategy to Improve Agricultural and Rural Statistics has included the development of new guidelines on collecting statistics on nomadic and transhumant livestock as a priority topic in its research programme, addressing the methodological and operational challenges to enumerating nomadic and semi-nomadic livestock (GSARS, 2016).This paper draws on findings and guidance provided in these guidelines.

2. Types of surveys[1]

In general, two types of surveys (or combination of the two types) can be used to enumerate nomadic and transhumance livestock: (i) ground surveys and (ii) aerial/satellite surveys. Each method has prerequisites, advantages and disadvantages that are summarised in Table 1.

Ground surveys methods are mainly derived from techniques of enumerating nomadic people as used in population censuses. In fact, collecting data on nomadic and transhumant livestock needs a good knowledge of the population who raise that category of livestock. Ground surveys are implemented through two main ways:

- First, animals can be counted on **enumeration points** which are sites where animals congregate. There are several types of enumeration points commonly used, such as watering points, vaccination points, dip tanks and spray races, temporary seasonal camps, stock routes and livestock markets. It is also possible in some situations to create specific enumeration points for the purpose of the survey. Often different type of enumeration points are used for the enumeration of pure nomadic livestock and of transhumant livestock. In the case of livestock census of Niger 2004/5, the watering points were used as enumeration points for nomadic (?) and internal transhumant livestock, and stock routes (transhumance corridors) were observed for the external transhumant livestock.

- Secondly, as in some countries nomadism and transhumance are practiced by some specific **ethnics groups or clans**, livestock enumeration can be done with the support of ethnic group/clan leaders and family networks to locate livestock by identifying and locating temporary seasonal camps of group members. The enumeration is then organised by visiting these camps. The basic conditions for using this approach are given in Table 1.

Aerial surveys are more suitable and effective for large survey areas and in areas that are difficult to access, including desert environments. Most of the aerial survey methods used for enumeration of nomadic livestock are derived from the techniques used by wildlife biologists to estimate population size of wild animals. A large number of publications can be found in the literature on the use of these methods. ILCA (1981) discusses these methods and their application to livestock, wildlife and land-use surveys.

Aerial surveys can be implemented in various ways:

- Low level aerial surveys, which are usually done from aircraft flown at between 300-1,000 feet (100-300 meters) above the ground, are ideally suited for coverage of extensive, remote areas, which are inaccessible by other means.

- Drones, which are relatively cheap and lightweight, are starting to be used for data collection in relatively remote areas. They can be fitted with video or still cameras for livestock enumeration purposes. The major limiting factor at present is flight duration which is very short now.

- An additional method of survey is reliance upon satellite imagery. Today, this is widely available and, in the absence of reliable maps, can be an effective substitute in planning and implementing field data collection for livestock enumeration. Satellite imagery provides a broad overview of the landscape and land cover, and can be useful in locating tracks, settlements and water sources, as well as updating existing maps. For the time being, such imagery is limited in terms of enabling animals to be counted.

[1] An indicative decision tree is provided in annex

Combining aerial and ground surveys

Generally, when implementing aerial surveys, it is necessary to conduct complementary ground surveys to address some of the disadvantages of aerial survey methods such as impossible distinction between sheeps and goats, which can only be recorded as small ruminants; as well as between donkeys, mules and horses, all recorded as equines. Cattle can only be distinguished by colour type. A ground survey is necessary to assess breeds, and herd age and sex structure (Ethiopia, nomadic livestock survey in Somali Region, 2004).

3. Census or sample survey?

In case of ground surveys, the first step is to establish a complete listing of all enumeration points for the selected type and/or ethnic groups or clan to build a reliable national sampling frame for data collection. The second step is to decide between implementing a complete enumeration census or a sample survey. Where possible the complete enumeration for nomadic and especially for cross-border transhumant livestock is preferred.

In case sampling is necessary, e.g. because of operational, financial or timing constraints, a stratification would be useful, depending on the availability of additional information. The stratification would reduce statistical variation and improve the precision of estimates. The strata may be the different categories of enumeration points in the selected type or administrative areas. Some strata may be completely surveyed and a sample of enumeration points may be selected for others.

4. Sampling design

4.1 Ground surveys

Sampling enumeration points for transhumant and nomadic livestock is quite challenging because of the mobility of animals. The calculation of the probabilities of selection (used for weight estimation) may be complex and the information needed for the calculus may be difficult to collect in the field. In most countries, a stratified simple random sampling may be suitable when it is necessary to sample enumeration points. Depending on the number of enumeration points and their geographical dispersion, a multi- stage sampling may be used to reduce the cost of the survey. Here the estimation of the probability of selection of each animal is complex. More details sampling and estimation issues are available in (GSARS, 2016).

4.2 Aerial surveys

There are two main methods of assessing livestock populations from the air: total aerial counts and sample counts. A total aerial count of animals in an area can be obtained by flying a series of closely spaced, parallel flight lines with overlapping observation strips, or by a circular "cork-screw" flight path of decreasing radius over the area of interest (see Figure 1). This flight pattern should cover the whole area with no gaps between the flown patterns.

Four main methods of sampling livestock populations from the air are used Systematic Reconnaissance Flights (SRF), Stratified Random Aerial Transects (SRAT), Aerial Quadrat Sampling (AQS) and Aerial Block Sampling (ABS);. For more information on these methods, refer to (GSARS, 2016). The total number of animals is calculated by estimating the density of animals in the sampled area and then the total number of animals is calculated by multiplying this density with the total area of the survey.

The most common aerial sampling method applied for enumerating nomadic livestock is the Systematic Reconnaissance Flight (SRF). The Central Statistical Agency of Ethiopia used the SRF in 2003 to conduct a livestock aerial survey (Central Statistical Agency, 2004). In SRF surveys, a series of parallel flight lines are flown at equal distance from each other across the designated area (Norton-Griffiths, 1978; ILCA, 1981; Clarke, 1986). Each flight line is divided in sectors equal in ength to the flight line spacing to create a grid over the entire area (see Figure 1). Within each strip flown, only a part of the area is counted.

Figure 1 - Total Aerial Count Patterns; SRF Sample Coverage

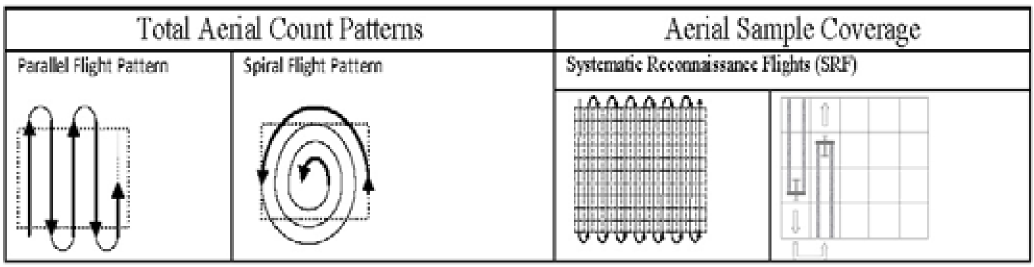

Table 1 - Prerequisites, Advantages and Disadvantages of Survey Methods

Prerequisites	Advantages	Disadvantages
Ground Survey - Water Points, Vaccination Points, Dipping/spraying points		**Example: Mali Survey 2001**
Requires complete list and map of all water or vaccination or dipping/spraying points in enumeration area.	• Animals can be easily seen and counted when coming to water or vaccination or dipping/spraying points where enumerators can be located; • Logistically simple and easy to organise.	• Frequencies vary with species and location; • Animals brought not necessarily nomadic/ transhumant; • In some situations can be difficult to avoid double counting; • Young stock may be excluded; • Additional information/surveys required to determine watering frequencies/ to assess proportions vaccinated / determine proportion dipped/sprayed and proportion of nomadic/ transhumant animals to estimate population size.
Ground Survey - Ethnic Groups/Clans		**Example: Ethiopian Afar Region Survey 2004**
Prior agreement and full cooperation of all group members; and list and map of all camp locations in enumeration area.	Involvement of Group/clan leaders in survey planning; in identifying and locating all members facilitates information collection.	• Assumes that clan leadership hierarchy know camp site locations of all members; • Areas may be very large, exact locations may not be known; • Some pastoral areas are shared by more than one group/clan, so more than one set of leaders may need to be involved.
Ground Survey - Stock Routes		**Example: Niger transhumant corridors Survey 2004/5**
Complete list and map of all stock routes in enumeration area; and cooperation of herder to channel animals through check points.	• Can be good indicator of numbers moving from one area to another; • Animals pass along stock route where enumerators can be located.	• May be many routes; • Routes not always well defined; • Often multiple tracks; • May change from year to year; • Not all animals use same route; • Difficult to count large herds of moving animals.
Aerial Survey - Systematic Reconnaissance Flight;		**Ethiopian Somali Region Survey 2004**
Preferably has clearly defined boundaries visible from the air: coastlines; mountain ranges; rivers; roads.	• Good for large, inaccessible areas, with no reliable ground counting frames; • No prior assumption with regard to livestock distribution;	• Cannot distinguish between sheep and goats - recorded as small ruminants ; • Cannot distinguish between donkeys, mules and horses; • Can only distinguish cattle colour types . • Requires ground survey to determine ratio/ herd age and sex structure
Aerial Survey – Stratified Random Aerial Transects		
Has clearly defined boundaries visible from the air.	• Good for large, inaccessible areas, with no reliable ground counting frames	• In addition to the above, it assumes that identified strata are relatively homogeneous with regard to livestock distribution is concerned
Aerial Survey-Aerial Quadrat Sampling and Aerial Block Sampling		
Has clearly defined boundaries visible from the air.	• In block and quadrat sampling, the aircraft makes as many passes as are required which can facilitate counting of animals.	• Suffer from boundary effects, (difficult to decide whether an animal is within or outside of the sample unit) particularly for quadrat sampling • Blocks and quadrats tend to accentuate sampling error .

5. What is the most appropriate way of counting animals?

In case of ground surveys, animals can be enumerated by physical inspection in herds and flocks (direct observations), or from the numbers reported by informants (interviews). The first option is the best in order to avoid declaration biases. Enumerators must count animals themselves by using various tools: hand tally or counter (single or multiple counters), photographs, etc. In order to avoid double counting, the counted livestock may be marked and an enumeration certificate may be provided to herders after counting. The second option of enumeration consists in using questionnaires to collect the number of livestock through the herders declaration. Some issues have to be taken into consideration: recall period should be different from large ruminants (12 months) and small ruminants (6 months), the herder is not always the owner, and herders are sometimes reluctant to provide accurate information. These issues may be sources of important declaration biases. It is thus important to select a sample of herds for a supplementary direct counting of livestock in order to correct these biases. In case of aerial survey, animals are counted and recorded during flight. In addition, photographs are taken of larger herds, for subsequent verification and correction of observer bias. Instead of having teams of people in a low flying aircraft, cameras can be installed that take photographs at regular intervals. Aerial photographs may be used to check the visual counts and correct for observer bias.

The information collected during a livestock enumeration depends very much on national and local circumstances and on the purposes of the survey. Potential tools for livestock enumeration, field data collection, analysis and presentation of results have greatly improved in recent years, with the advent of hand-held navigation devices, more powerful computers and general advances in Information Communication Technology (ICT). For example, there is an increasing use of Computer-Assisted Personal Interviewing (CAPI) tools in data collection on livestock that replace the Paper-and-Pen Interview (PAPI). Recording the location can be done manually using either dedicated GPS devices or using an add-on GPS app for smartphone or tablet (when CAPI data collection method is used).

An analysis of field data collection costs considering different methods implemented in tropical and sub-tropical countries shows variations between countries (table 2). The costs have been adjusted for inflation and converted to Purchasing Power Parity (PPP) values. The highest cost per animal counted was in Jordan at USD 0.74, which may be due to the building of specific facilities at which the animals were counted. The next highest was the aerial survey in Ethiopia at USD 0.47 and this is undoubtedly because of the use of aircrafts which require specialised equipment and highly trained staff. The remaining enumerations for which costs are available display a cost per animal counted that is much lower than registered in Jordan or for the aerial survey, in the order of 10 per cent per animal. The cost per animal counted ranges from US$ 0.06 to US$ 0.02. However, these figures, can only be considered as indicative.

Table 2 - Comparison of the costs of enumeration of nomadic/transhumance livestock

Country	Year	Method	Total cost (USD)	Total nomadic / transhumance animals counted	Estimated total nomadic / transhumance population	Cost per animal counted (USD)	Cost per animal in the estimated population (USD)
Afghanistan	2002	Census: village visits	No cost given	Unclear as many may be sedentary			
Ethiopia-Afar	2004	Stratified sample: household visits	312,416	Not clear	9,014,365	Cannot calculate	0.03
Ethiopia-Somali	2004	Aerial: 3.5% Systematic sample	223,453	477,684	13,648,408	0.47	0.02
Jordan	1991	Census: Constructed locations	2,476,616	3,346,000	3,346,000	0.74	0.74
Mali	2001	Census: water points	241,535	4,193,848	4,193,848	0.06	0.06
Mongolia	2012	Ground: 33% stratified sample	277,976	13,640,000	40,920,000	0.02	0.01
Niger	2004-5	Stratified sample: water points and transhumance routes	No cost given	Not given	10,644,899		
Nigeria	1992	Aerial: 5% systematic sample	No cost given				

6. Conclusions

The challenges to obtaining reliable information about nomadic livestock can be addressed using various approaches according to local circumstances and requirements. Also the advent of hand-held navigation devices, more powerful computers and general advances in Information Communication Technology (ICT) in recent years have greatly improved tools for livestock enumeration, field data collection, analysis and presentation of results. Different country experiences show that a careful analysis of country s conditions can allow the selection of the most suitable method for generating data on nomadic and semi nomadic livestock. Ground surveys have been used in Mali and Niger (ground surveys using water points and transhumance routes), Mongolia (stratified sample survey), Jordan (complete enumeration of designated concentration areas) and Bolivia (stock routes). Aerial surveys have been used in Ethiopia and Nigeria (aerial survey complemented by ground survey).

The main conclusion is that there is no universally applicable method of enumeration of nomadic and transhumant livestock in all country conditions. The available methods should be carefully analysed in the light of the country peculiarities, resource and time constraints in order to choose the optimal approach.

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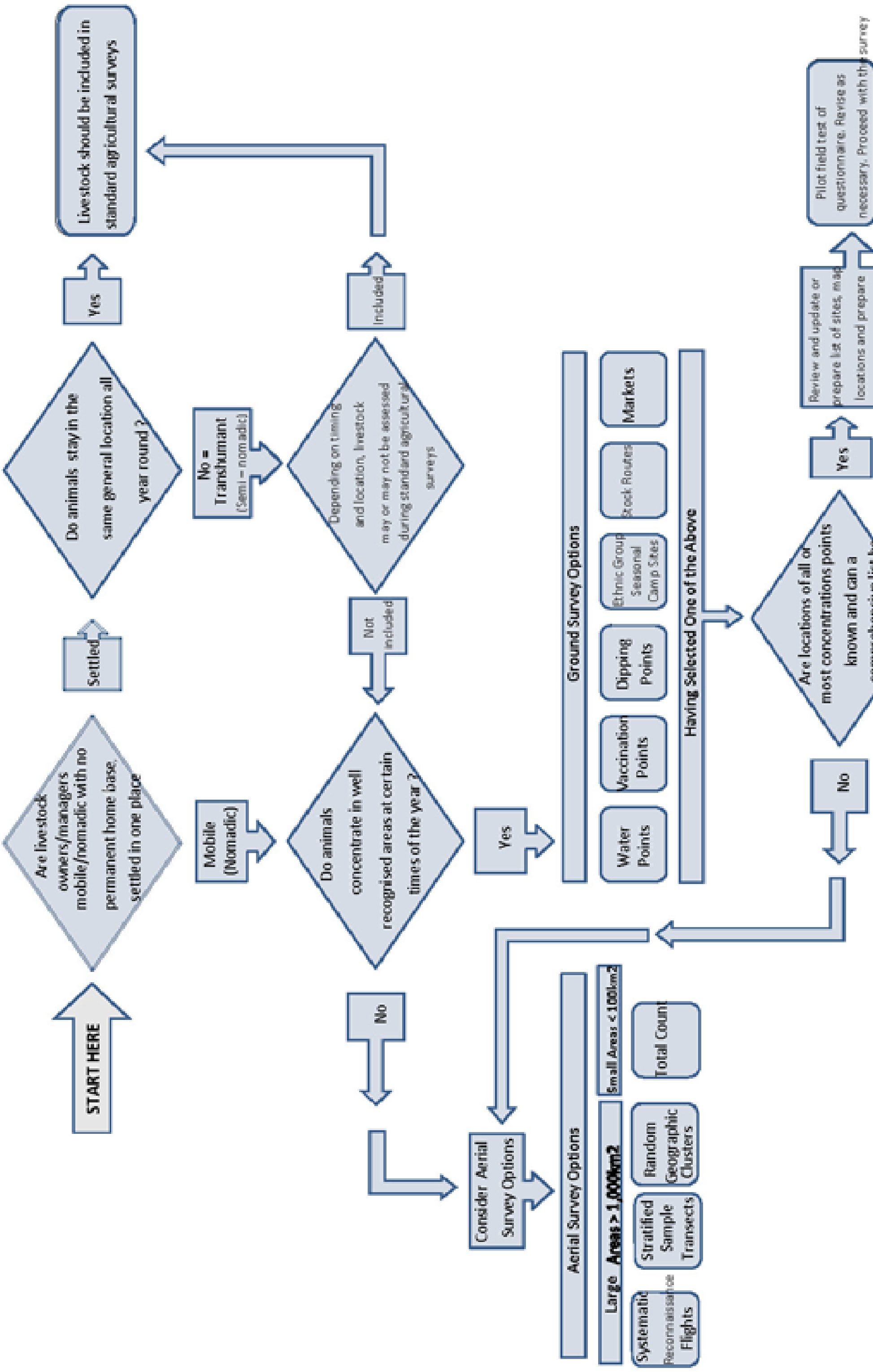
Annex - Indicative decision tree



THEMATIC SET

B10

FOOD SECURITY MEASUREMENT: METHODS AND APPLICATION

Session Organizer
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LIST OF PAPERS

How undernourished are Indians really? A critical assessment of indicators and scope for improvement

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Md Z. Siddiqui | Crawford School of Public Policy Australian National University | Canberra, | Australia
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DOI: 10.1481/icasVII.2016.b10

Children Effect on Household Food Insecurity: An application of the Classical Rasch Model to Household Survey in Uganda

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R. Wesonga | Makerere University, School of School of Statistics and Planning (SSP) | Kampala | Uganda
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DOI: 10.1481/icasVII.2016.b10b

Estimating Comparable Prevalence Rates of Food Insecurity through the application of the Food Insecurity Experience Scale

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DOI: 10.1481/icasVII.2016.b10c

Food counts - Measuring food consumption and expenditures in household surveys

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B10

How undernourished are Indians really? A critical assessment of indicators and scope for improvement

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DOI: 10.1481/icasVII.2016.b10

ABSTRACT

Food and nutritional security re-emerged as a major challenge facing developing countries since the global food, fuel and financial crises in 2008. A wide variety of approaches are used to gauge the status of food insecurity at global, national, household and individual levels. However different indicators often provide a diverseset of estimates and a contrasting picture owing to the nebulous concept of what constitutes food insecurity and the differences in measurement approaches adopted. In this paper, we briefly review the most commonly-adopted approaches used by researchers for assessing food and nutritional insecurity. These include FAO's prevalence of undernutrition indicator, household-based consumer expenditure surveys (CESs), and anthropometric measures used in evidence-based and policy-oriented research.

We also assess the prevalence of nutritional deficiency in India in terms of the macronutrients at the national levelusing the latest CES data (2011-12). We complement our analysis with anthropometric measures to assess the link between food intakes and nutritional outcomes. Finally,we conduct the multivariate analysis using a multilevel modelling framework to examine the relative importance of particular covariates and geographical contextual factors in determining the different measures of food and nutritional security. We highlight that applying uniform norms for a geographically and ethnically diverse country like India is inappropriate. We conclude there are serious limitations to measuring undernutrition solely through calorie intake; and argue that a multi-dimensional approach incorporating anthropometric measures and a multilevel modelling framework is required to better measure and understand the underlying causes of undernutrition.

Keywords: Undernutrition, Food security, Multilevel modelling

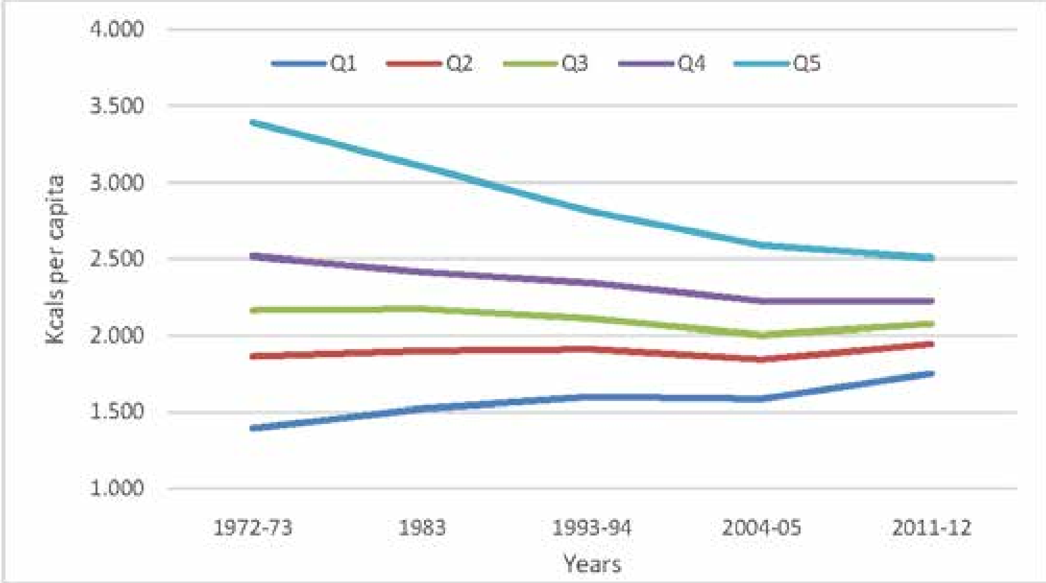
PAPER

1. Introduction

India is home to nearly 25% of the undernourished population in the developing world, and consequently, global undernutritionis highly sensitive to the prevalent situation in that country. Interestingly, total per capita calorie consumption in India has declined over the past three decades despite rising incomes over the same period. However, within income classes, our analysis (using various rounds of the National Sample Survey (NSS) data shown in Figure 1 belowreveals that overtime caloric intakes of poor Indians (two lowest quintile economic groups) has grown, albeit slowly,and for the rich (higher quintile groups) it has declined progressively since1972-73.

In this paper, we analyse alternative measures of undernutrition in India and undertake our own modelling of caloric intakes using multilevel analysis. The paper is organized as follows. The next section critically reviews the most commonly-adopted approaches used for assessing food and nutritional insecurity. Section 3 provides a comparison between calorie intakes and anthropometric outcomes in India using the most recently available survey data. Section 4 presents the multilevel modelling analysis of caloric intakes, wherein weexamine the relative importance of particular covariates and regional contextual factors. The last section summarizes the key findings of the study highlightingthe key policy implications.

Figure 1 - Trends in per capita calorie consumption across economic classes (quintiles) in rural India



Source:Authors' own estimation using NSS data.

2. Review of the existing approaches

A number of coexisting indicators are being used to infer on the state of food security and undernutrition at global, national, household and individual levels. Unfortunately, these different indicators tend to be used independently of each other and usually are seen as alternatives by the end-user. We briefly discuss below the main attributes of these indicators.

FAO's prevalence of undernutrition (PoU) indicator is the most widely-acknowledged indicator used in food security debates. It is based on three critical parameters: mean quantity of calories available in a country for human consumption, inequality in access to those calorie intakes and mean minimum age-sex specific calorie requirements of that population. FAO has been publishing this indicator annually as a 3-year average in its State of Food Insecurity in the World (SOFI) publications.The method has been widely criticised in policy circles as it measures food availability rather than food consumed. Notwithstanding recent improvements, FAO'sestimation method still suffers from some key non-remediable problems in the accurate assessment of food security. These include itsconsideration of being based on minimum activity levels whichistoo simplistic an assumption for developing countries where majority of the workforce is involvedin heavy manual labour. It is incapable of capturing the impact of short-term price and economic shocks whose frequencies have been increasing in the recent past. Also, as an aggregate measure,it is still unable to assess the nutritional status of households/ individuals and identify them.

Another commonly used approach is that of nationally representative household-level CES which contain a detailed component on food quantities consumed at the household level. The quantities consumed are converted to obtain estimates of nutrient consumption which can then be compared with the age-sex-activity specific requirement cut-offs to identify the households with undernourished individuals. The use of a non-parametric household survey approach is considered to be an improvement over FAO's aggregate measure as it helps to undertake multilevel targeting and monitoring within countries as it captures the demographic structure of the household population itself; and also has the ability to evaluate the dietary diversity and macronutrient status*. However, a problematic issue is that it does not capture the intra-household allocation of commodities. Also, data surveys are not undertaken on a regular basis and are computationally intensive and expensive both in terms of financial and technical resources. In addition, food eaten away from home, wastage, losses and non-food use within the households are not adequately captured across these surveys. Further, survey measures suffer from non-sampling errors due to misreporting, incomplete questionnaire forms and issues of telescoping and recall bias.

While the previous two indicators focus on macro level, another widely-acknowledged approach to measure food insecurity is the use of anthropometric indicators such as wasting (low weight for height), stunting (low height for age) and underweight (low weight for age; Body Mass Index (BMI) less than 18.5 for adults). This approach measures nutritional outcomes at the individual level. A key positive feature of anthropometric indicators is that they are simple, accurate and relatively cheaper to compute. They evaluate the nutritional outcomes at the individual level and thus can be used to determine intra-household allocation, for targeting interventions and monitoring them across age and gender traits in a population. These indicators directly connect to the development status of a population (Pelletier 1994; Deaton and Dreze 2009). However, the methods for measurement of nutritional outcomes in the adult population can be problematical due to the lack of consensus on the global reference standard for such population. Anthropometric failures might occur due to reasons such as manifestation of diseases, prolonged illness etc. that are completely uncorrelated with food insecurity. Also, such an approach does not identify the nutrients causing poor anthropometric status.

Given the merits and demerits of each of the approaches, one can conclude that there is no picture-perfect yardstick to measure undernourishmentas each method contributesas different pieces of the broader food insecurity puzzle. Accordingly,we argue it is time to link the household survey approach with the anthropometric surveys such that the outcomes of both approachescan be used in a mutually-reinforcing and complementary manner to provide a multi-dimensional insight into undernutrition issues. For instance, if the overall vital health indicators are weakening while that of anthropometric status are improving then it is suggestive of the fact that the available resources should be directed towards primary health care, disease prevention and other social support facilities rather than boosting up food supplies. Here, adopting a multi-dimensional approach becomes critically important for policymakers in assessing country-level food security and hunger and poverty-related issues. Attention in the following sections turns to these issues.

3. Calculation and comparison between prevalence of undernutrition and prevalence of underweight in India

In this section we compare and contrast PoU measures of undernutrition with anthropometric measures of underweight using the most recently available datasets in order to highlight differences between these two approaches and its implications for policy. We estimate prevalence of undernutrition (PoU) using the unit-level NSS data from 61st Round (NSS-61) for the period 2004-05 covering 1,24,680 households and the 68th round (NSS-68) for the period 2011-12covering 1,01,662 households. The nutrient intake of an individual is calculated using the quantity of each food item consumed by each household which is converted into its nutrient equivalent content of calories. We calculate PoU on the basis of the recommended dietary allowances (RDAs) as given by the Indian Council of Medical Research-National Institute of Nutrition (ICMR-NIN). A household was considered to be calorie deficient if its actual total calorie consumption was less than the calorie required for that household given the age, sex, activity status of household members as per RDAs (Chand and Jumrani, 2013).This computation uses the RDA levels for moderate activity in rural areas and assumes sedentary lifestyles in urban areas. PoU is estimated as proportion of people living in households that are not consuming threshold energy intakes. We present PoUfor major states in Table 1 below. We also present the prevalence of underweight by utilising the National Family Health Survey 2004-05(NFHS-3); a household survey which provides information on health-related matters. The survey covers 1,24,384 females (aged 15-49 years) and 74,369 males (aged 15-54 years) across 29 states. NFHS-3 collected information on height and weight of women and men which is then used to calculate BMI - calculated as weight in kilograms divided by height in meters squared (kg/m2). The WHO classification of underweight for adults is defined as the cut-off point where BMI ↓ 18.5; and used to define thinness or acute undernutrition. We also present preliminary results for a limited number of statesreleased thus far from the most recent NFHS-4 survey (2015-16). The prevalence of underweight among major statesis also presented in Table 1.

Although NFHS and NSS surveys are not strictly comparable owing to the different time periods,Table 1 servesto demonstrate the considerable differences that exist between PoU and BMI measuresof malnourishment when data is disaggregated at the regional level.These most striking differences are in the rural settingwhere states such as Kerala and Tamil Nadu have a PoU of 78% and 84%, respectivelyin 2004-05and are well above the all-India average; compared with a prevalence of underweight (using BMI measure)of 21% and 32% (for 2005-06) respectively, which sits below the all-India average. By the same token, states such as Bihar and Uttar Pradesh have PoU in the rural areas well below the all-India average for 2004-05, whilst in terms of BMI measures, those two states have prevalence rates of underweight (for 2005-06) well above the all-India average. Of particular concern here is insignificant correlation between the rank ordering of states ranked by BMI and those ranked by PoU. Moreover, whilst underweight prevalencehas fallen considerably between 2004-05 to 2015-16, based on preliminary NFHS-4 survey results, this has not been reflected in any significant reduction in PoU over the periods 2004-05 and 2011-12indicating that the differences between the two measures are widening overtime.

To have a state such as Kerala with human development index approaching that of a developed country status having one of the highest PoU in India questions the validity in the uniform application of calorific thresholds in India. India is a subcontinent withconsiderable ethno-physiological differences in its population across regions; differences in public health infrastructure and other social determinants impacting on health (inequalities) such that in some regions people can survive more effectively on lower calories; and differences in climatic and topographical conditions requiring differing calorie expenditure. In light of the above, there is an important role for multilevel analysis of caloric intake to play in setting the minimum calorie norms for different regions or states of India. We now explore this issue.

*In this study, we have analysed all the macronutrients but only the results for calories have been presented due to the word limit.

Table1: *Prevalence of underweight (BMI) and prevalence of undernutrition (PoU) in India by major states for rural and urban areas*

	Proportion of BMI<18.5 (NFHS-3; 2005-06) (15-49 years)		Proportion of BMI<18.5 (NFHS-4; 2015-16 (Recent preliminary data)						PoU (NSS-61) 2004-05		PoU (NSS-68) 2011-12	
			Women (15-49 years)			Men (15-49 years)						
State	Rural	Urban	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Rural	Urban
JAK	29.03	19.01							52.57	31.05	49.12	31.33
HMP	30.92	19.74							52.07	32.89	37.96	37.21
PUN	20.34	18.46							58.78	48.5	53.67	46.84
UTC	32.80	19.45	20.0	15.5	18.4	18.5	12.5	16.1	58.18	36.93	35.67	34.11
HAR	34.23	22.85	18.2	12.2	15.8	12.9	9.0	11.3	55.53	53.91	61.11	51.63
RAJ	41.78	30.57							54.90	50.79	51.66	46.88
UTP	39.41	28.86							53.92	49.62	60.25	61.45
BIH	40.59	31.9	31.8	22.2	30.4	26.9	18.9	25.4	58.31	43.17	63.13	46.84
ASM	37.31	29.32							69.72	51.74	77.55	60.68
WBG	43.11	23.30	24.6	14.0	21.3	20.3	19.0	19.9	69.11	62.41	69.53	63.88
JHK	44.36	29.98							67.62	36.13	62.78	53.47
ORS	40.52	27.45							69.51	51.19	66.99	54.51
CHG	43.99	28.72							74.64	53.03	73.34	53.32
MAP	44.61	32.27	31.8	20.6	28.3	31.1	22.5	28.4	76.15	60.05	63.20	59.84
GUJ	42.65	27.18							77.89	59.91	81.67	55.76
MHR	42.06	27.05	30.0	16.8	23.5	23.7	14.5	33.5	80.51	74.44	68.90	62.00
ANP	37.00	22.08	20.3	11.5	17.6	16.5	11.5	14.8	76.93	62.14	64.85	50.37
KAR	40.12	25.43	24.3	16.2	20.7	18.4	14.2	16.5	85.59	65.24	77.03	67.13
KER	21.15	16.50							77.99	64.07	79.92	67.03
TAN	32.17	22.74	18.5	10.9	14.6	14.3	10.7	12.4	84.02	67.19	81.05	64.77
All-India	**34.62**	**23.40**							**68.03**	**59.35**	**66.08**	**58.71**

Source: Authors' own calculations utilising NFHS-3 unit-level data, Census of India data and NFHS-4 state level fact sheets for proportion of underweight for 15-49 age group; NSS-61 and NSS-68 surveys.

4. Multi-level modelling of calorie consumption

4.1 Data and methods

We now turn our attention to investigating the differing characteristics governing calorie consumption itself and use multi-level modelling to explore regional differences. We utilise the most recent NSS-68 (2011-12) CES to establish our mode1 (see earlier). We use the natural logarithm of total caloric intake as the dependent variable and incorporate a number of individual-level variables into the modelling framework. These include: monthly per capita expenditure (MPCE) as a proxy measure of economic status; MPCE2; household size; household employment activity (self-employed as reference); ration card (no card as reference); maximum education of household head (illiterate as reference); interaction effect between education*MPCE; socio-religious (Hindu-general as reference); quintiles (hectares) of land possession (first quintile as reference); sex of household head (male as reference). A multi-level regression model was used to estimate the impact of various factors affecting nutrient (i.e. calories) intakes. The model is written as follows:

$$Y_{ijk} = \alpha + \sum_m \beta^m X_{ijk}^m + u_k + v_{jk} + e_{ijk} \quad (1)$$

- Y_{ijk} – log per capita calorie intake of household i nested in j^{th} neighbourhood/first stage unit(FSU) and k^{th}state
- X_{ijk}^m –fixed component – where superscript m represents number of covariates
- u_k – intercept effect of k^{th}state
- v_{jk} – intercept effect of j^{th} neighbourhood (FSU) nested in k^{th}state

... e_{ijk} – residual error of householdi nested in j^{th} FSU nested in k^{th} state

The model shown in equation 1 contains a fixed component which has a separate intercept (x) and a slope parameter (b^m) estimating the effects of a one unit change in the covariates on y_{ijk}. The remaining terms in right hand side (random components) in equation 1 capture the independent effect of geographical space as an independent explanatory factor - in terms of the impact of the state, and the neighbourhood nested within the state. The advantage of multi-level modelling approach is that it allows the intercepts to vary with respect to states and FSUs to account for the macro-level unobserved contextual factors at the stateand neighbourhood level, beyond household-level attributes. Thus the intercept for a given state and neighbourhood can be expressed as x + u_k and x + u_k + v_{jk} respectively. We generate two regression models – both for rural and urban areas. All econometric analyses were conducted using Stata 13.

4.2. Results

Table 2 below presents the results of regression model for both rural and urban settings. As expected, we observe there is a highly significant and positive relationship between calorie intake and MPCE in both rural and urban settings; and this positive relationshipappears to be non-linear and diminishing in nature as evidenced by the negative coefficients for $MPCE^2$.

Table 2 - Multilevel model for calorific intakes in India, 2011-12, using NSS-68 survey

Parameters	**Rural (R)**		**Urban (U)**	
	Coefficients	**CI (at 95%)**	**Coefficient**	**CI (at 95%)**
Logarithm of MPCE	1.135***	(1.071;1.199)	1.094***	(1.013;1.175)
Logarithm of MPCE^2	-0.033***	(-0.36;-0.031)	-0.030***	(-0.033;0.027)
Household (HH) size	-0.018***	(-0.019; -0.017)	-0.026***	(-0.027;-0.025)
HH activity type:reference- self employed				
Non-agriculture(R); Regular wage/salary earning (U)	-0.192***	(-0.024; -0.014)	-0.001	(-0.005; 0.004)
Regular wage/salary earning (R); Casual labour (U)	-0.029***	(-0.034; -0.023)	0.015***	(0.008; 0.022)
Casual labour in agric. (R)	0.006**	(-0.002; 0.0127)	NA.	NA
Casual labour in non-agric. (R)	-0.009***	(-0.015;-0.002)	NA	NA
Others (R&U)		(-0.037; 0.020)	0.000	(0.008;0.008)
Ration card type: reference - no card)				
Antyodaya	0.103***	(0.094;0.113)	0.104***	(0.089;0.120)
BPL	0.079***	(0.073;0.085)	0.079***	(0.072;0.086)
Others	0.052***	(0.046;0.057)	0.039***	(0.033;0.045)
Maximum education HH head: reference - illiterate				
Literate	0.170*	(-0.001;0.341)	0.605***	(0.344;0.867)
Primary-Middle	0.277***	(0.154;0.400)	0.670***	(0.476;0.863)
Secondary plus	0.439***	(0.318;0.560)	0.890***	(0.707;1.074)
12+ years of education and above	0.373***	(0.233;0.512)	1.060***	(0.861;1.250)
*Interaction effect – education*log MPCE*				
Literate*logarithm of MPCE	-.016**	(0.030;-0.001)	-0.053***	(-0.075; -0.030)
Primary-middle*logarithm of MPCE	-.026***	(-0.037; -0.016)	-0.060***	(-0.076; -0.043)
Secondary plus*logarithm of MPCE	-.041***	(-0.052; -0.031)	-0.080***	(-0.095; -0.064)
12+ years of educ. and above*logarithm of MPCE	-.038***	(-0.049; -0.025)	-0.110***	(-0.110; -0.778)
Social status: reference- Hindu (general)				
Muslim	-0.013***	(-0.019; -0.006)	0.004	(-0.003;0.012)
Christianity	-0.003	(-0.016;0.009)	-0.002	(-0.017;0.012)
Sikh	0.024	(0.005;0.042)	0.008	(-0.010;0.026)
Hindu (SCs)	-0.001	(-0.006;0.036)	0.006*	(-0.000;0.014)
Hindu (STs)	0.007*	(-0.001;0.014)	0.17**	(0.004;0.030)
Others	0.005	(-0.016;0.026)	-0.017*	(-0.035;0.001)
Land-ownership (in hectares): reference - first quintile				
Second quintile	0.002	(-0.005;0.007)	NA	NA
Third quintile	0.016***	(0.010;0.022)	NA	NA
Fourth quintile	0.034***	(0.028;0.041)	NA	NA
Fifth quintile	0.043***	(0.36;0.050)	NA	NA
Sex of HH Head: reference - male				
Female	0.016***	(0.011;0.22)	0.018***	(0.012;0.025)
Constant	-0.990***	(-1.38; -0.600)	-1.001***	(-1.510; -0.502
Random Effects				
State Level - ICC	0.147	(0.842;0.243)	0.107***	
State/FSU - ICC	0.328	(0.270;0.393)	0.299***	

***, ** and * refer to 1%, 5% and 10% significance levels, respectively
ICC – Intra-class correlation; NA- not applicable

Consistent with the empirical literature, our model results reveal a negative relationship between household size and calorie intake reflecting possible scale economies in food preparation.Education on its own has a positive effect on caloric intake in both the settings. Interestingly,the interaction effect Education*log MPCE shows that its impact gets smaller with improvements in the economic status of Indian households. Of significance, at very high levels of MPCE, education actually starts showing a negative effect on caloric intake; a phenomenon that is particularly pronounced in urban areas.

As expected, people who possess any kind of ration card were likely to have a higher caloric intakecompared to the non-cardholder reference category; and those with a greater subsidy entitlement were more likely to have higher consumption of calories. Landholding size is positively associated with caloriewith this variable not being applicable in urban areas. With regards to socio-cultural characteristics, with only a few exceptions, there was little statistical variation across groups in calorie intake. Our estimation results also show that in comparison to the male-headed households, female-headed households are likely to have higher intakes of calorie in both rural and urban settings. With regardsto occupational categories in the rural areas, most households'occupational activitieshave a lower propensity to consume calories compared to the reference category of households who wereself-employed in agriculture, reflecting differences in physical activity across occupations. In the urban setting, casual labourers had higher propensity to consume calories relative to self-employed.

Of particular interest is the random component of our multilevel modelling for examining independent effect of region on calorie intakes. We find that in rural settings, about 33% of the total unexplained variation in log of per capita calorie intakes is explained by our random components - 15% by states and 18% by neighbourhoods (measured by the intra-class correlation, ICC). In case of urban settings, states explain around 11% of the total residual variance and neighbourhood around 20%. In Figures 2 and 3 below, states are ranked in terms of the impact of state-level unobserved factors influencing calorie consumption. We confine our discussion to the 20 major states of India which are modelled as intercept shifts in the propensity of calorie intakes along with their confidence intervals (95%) and are shown in the figures below as caterpillar plots. In rural areas, after allowing for individual household covariates, households belonging to states such as Kerala, Tamil Nadu, Karnataka, Andhra Pradesh, and Gujarat lie below the Indian average in calorie consumption. In contrast states such as Bihar, Jharkhand, Uttar Pradesh, and Orissa as well as mountainous states such as Uttaranchal, Himachal Pradesh and Jammu and Kashmir all laywell above the Indian average in calorie consumption. A similar pattern of regional differences also exists in the urban settings (Figure 3). The important issue here is that,besides household-level characteristics, unobserved contextual factors at the regional level play a significant role in determining calorie intakes across India. In this context, it becomes important to disentangle these regional-level effects in order to more appropriately inform policy matters relating to undernutritional issues.

Figure 2 - State level random effects in calorie intakes: rural areas

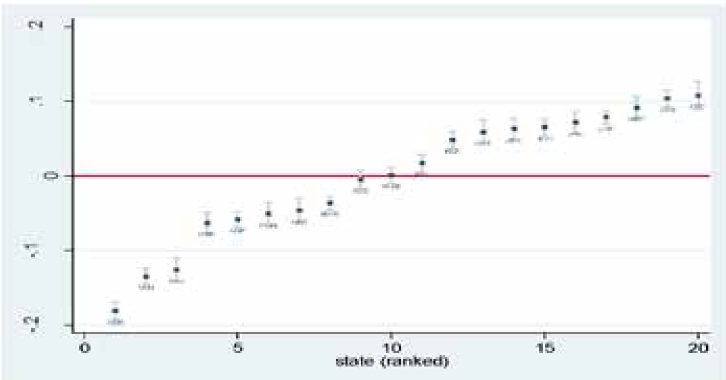
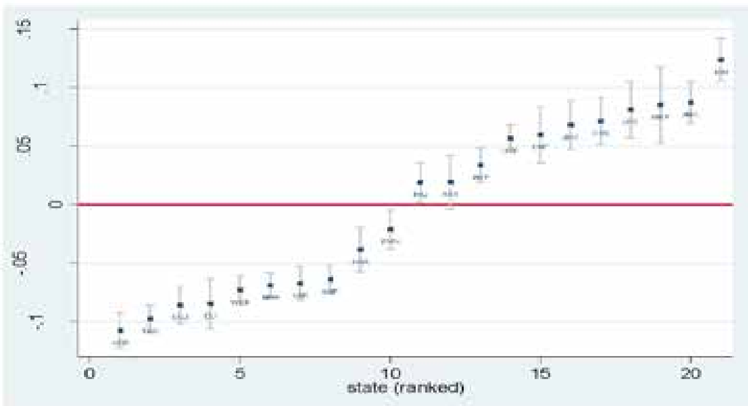


Figure 3 - State level random effects in calorie intakes: urban areas



5. Conclusion

Using the most recently available surveys on calorie consumption and BMI, this paper shows there is considerable divergence between PoU and anthropometric methodsand consequently there is the need to adopt a multi-dimensional approach tomeasuring food and nutritional insecurity in order to inform policy in India. In recognition of this, we undertook multilevel analysis to model caloric intakes. Our results show that in addition to household level characteristics, unobserved contextual factors at the regional level play a significant role in determining calorie intakes across India. The extent to which these regional differences are due to factors such as, physiological differences reflecting different ethnicities across regions, differences in climatic/topographical conditions and consequent differing physical activities and calorie requirements, or differences in public health infrastructure and other social support and consequent differing calorie requirements to maintain minimal health, is unclear. What is clear, is that imposing a uniform calorie threshold across all of India, irrespective of region, in order to measure prevalence of undernutrition is inappropriate and leads to misinformed policy. As an imperative, more research is required into understanding contextual factors contributing to spatial differences in minimum calorie requirements necessary for maintaining good health. This paper makes an initial contribution to understanding these issues.

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Children Effect on Household Food Insecurity: An application of the Classical Rasch Model to Household Survey in Uganda

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ABSTRACT

Food security has been a phenomenon of interest worldwide because population groups in several parts of practically all continents are said to experience some form of food insecurity, hunger or related phenomena. Ability to measure the extent or magnitude and severity of food insecurity makes it possible to come up with more realistic, adequate and robust ways of solving the problem. This study applied the Rasch model to measure food insecurity in Uganda. The dataset used was generated using the 18 USDA food security assessment questions. Model Testing was done using the Infit and the outfit test statistics with the range 0.7 to 1.3 considered acceptable.

An algorithm for the Rasch model was developed and run using the R-programming software which also generated the Infit/Outfit statistics, Beta coefficients and probabilities. The households were then classified into three categories; food insecure (0.0 to 0.49, moderately food insecure (0.5 to 0.79) and food secure (0.8 to 1.0). Most households (46.6%) were found to be moderately food insecure and one third (33.5%) were found to be food insecure.Children 5 to 17 years have a significant influence on the food insecurity status of a household.

Keywords: Household Food Insecurity, Infit/outfit, Household Classification, Rasch Model

PAPER

1. Introduction

Food security has been a phenomenon of interest worldwide because population groups in various continents are said to experience some form of food insecurity. The challenge has been how to measure it. Ability to measure the extent or magnitude and severity of food insecurity makes it possible to come up with more realistic, adequate and robust ways of solving the problem. Correct measurement of food insecurity is hinged on a clear understanding of its multi-faceted nature. Years of research and discussion led scientists to generally agree that food insecurity is constituted by four major components namely food availability, food access, food utilization and food stability. It has also been shown that macro level analysis results in outcomes that may reflect a large community as food secure when pockets of communities or individual community members are food insecure. One of the best ways of analyzing food insecurity is therefore the household as it is representative of community characteristics at micro level.

The household is the best unit to measure food insecurity due to the following reasons: Food security dynamics are at play at all levels from global community to individuals. Measurement at higher levels has led to wrong conclusions as many communities said to be food secure would still have many individuals or households in dire need of food. Whereas the ideal would be analysis at individual level, it is very cumbersome and expensive. The household has a good mix of individuals including infants, children, adults, males and females, young and old. It therefore provides a good representation of social economic and cultural characteristics of community. Household food security status can be aggregated to obtain food security status of bigger entities like villages, districts, nations, regions up to global level. According to Jones, Ngure and Young (2013), the food acquisition behaviors of households are important for translating physical and economic access to food into food security. All food security components namely food availability, access, utilization and stability as well as coping strategies are best assessed at household level. *It can be considered the best micro-level reflection of the global community.*

When the Rasch Model was introduced as an approach for measuring food insecurity by the United States Department of Agriculture (USDA), it attracted a lot of interest and has since been used in a number of countries to measure food insecurity. The 18 USDA food security questions include the 10 questions for adults and 8 questions for households with children. In West Africa, Obayelu (2012) disaggregated the 18items into 10 adult-referenced items and 8 child-referenced items (children were those less than 15 years) and found that household food security status with respect to adults and children showed a differential pattern. For instance, in Kogi rural, a lower proportion of adults (25.8%) were food secure compared to the children (40.6%). The pattern is similar for the urban with 24.4 per cent of the adults food secure compared to 29.9 percent of children. This is contrary to the findings of Esturk and Oren (2014) who in their study in Adana region in Turkey found that food insecurity was higher for households with children (69%) compared to households without children (39.6%). Lori Reid (1997) in the USA found that Prevalence of food insecurity among children zero to 12 years of age was not significantly different from that of households in general. The three studies resulted in differing outcomes. Could it be the consideration of which ages the children are that affected level of food security arrived at (One considered 15 years and below,This study considered adults and children below 18 years as they constitute a big proportion of Uganda's population. The 2012 Uganda's population report showed that over half of Uganda's population, (56.1%) are children (↓18 years). Unemployment rate for Uganda's youth aged 15–24 is very high, reported by World Bank (2008) to be 83%. This makes them vulnerable to food insecurity given that income is a decisive variable for household food security (Esturk and Oren, 2014). Other youth challenges are lack skills and market access for income generation to maintain food security.

The analysis involved determination of food security status using the 18 items and the 8 children-referenced items (Table 1). The dataset is from two Ugandan districts involved in fishing, livestock and crop farming for their livelihoods. The study also analysed the relationship between food security and three age categories – children below five years, five to below 18 years and adults (18 yearsand above).

Table 1 - Food Coping Questions: Variable Description

E1	Worried whether food would run out before getting money to buy more.
E2	Food harvested or bought just didn't last, and we didn't have money to get more.
E3	Couldn't afford to eat balanced meals.
E4	*Relied on only a few kinds of low-cost food to feed our child/children because we were running out of food and money to buy food.*
E5.	*Couldn't feed our children a balanced meal, because we couldn't afford.*
E6.	*Our children were not eating enough because we just couldn't afford enough food.*
E7	Did you/or other adults in your household ever cut the size of your meals or skipmeals because there wasn't enough food or money for food?
E8.	If Yes to E7, how often did this happen?
E9.	Ever eaten less than you felt you should because there wasn't enough money to buy food?
E10.	Were you ever hungry but didn't eat because you couldn't afford enough food?
E11.	Did you lose weight because you didn't have enough money for food?
E12	Did you(or other adults in your household) ever not eat for a whole day because there wasn't enough food or money for food?
E13.	If Yes to E12, how often?
E14	*Ever cut the size of (any of your children's) meals because there wasn't enough food or money for food?*
E15	*Did any of the children ever skip meals because there wasn't enough food or money for food?*
E16	*If yes to E15, howoften did it happen?*
E17	*Were your children ever hungry but you just couldn't afford more food?*
E18.	*Did any of your children ever not eat for a whole day because there wasn't enough money for food?*

2. Methodology

Food insecurity analysis was done using the Rasch Model. The Rasch model is capable of simultaneously measuring individuals' ability to respond to a set of score items, while also assessing difficulty levels of the score items.It is the only IRT model in which total score across items characterizes a person totally. The sum of all these item scores gives each individual a total score (summary of all item responses) which is used for comparison. The person with a higher total score is said to possess more of the variable being assessed. The summing of item scores to get a single score implies that it is intended to measure a single/unidimentional variable. The Rasch model is named after George Raschwho made a case for models based on the principle of invariant comparison. The principle of invariant comparison states that, "The comparison between two stimuli should be independent of which particular individuals were instrumental for the comparison; and it should also be independent of which other stimuli within the considered class were or might also have been compared"(Rasch, 1961).Since formulation of the model by Rasch in 1960, various generalizations have been developed (Mair and Hatzinger, 2007). In food security assessment for example, two households assessed by two researchers should be independent of the researchers (http://www.rasch-analysis.com/rasch-model-specification.htm).

2.1 Model Testing

The Rasch model analysis generates 2 model fit sets of statistics, the infit and outfit. The weighted Infit and/or outfit statistics represent difference between item performance as expected by model under the model assumptions and observed household responses. They are used to assess extent to which items conform to the Rasch model specifications. They are based on the conventional sum of squared standardized residuals and is given as:

$$\frac{z^2}{N} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where: $z^2 = \frac{(X-E)^2}{\sigma^2}$ is the squared standardized residual

N is the number of observations summed

X is an observation

E is expected value based on Rasch parameter estimates

σ^2 is the modeled variance of X about its expectation.

The Infit/Outfit good range is 0.8 – 1.2 but values 0.7 – 1.3 are considered acceptable. When an item fits the model perfectly, the Infit/Outfit value equals one. Infit value above 1.0 indicates that the item discriminates less sharply than the average of all items in the scale while Outfit value above 1.0 indicates a weaker than average association of the items with the underlying conditions. The item Outfit is an outlier-sensitive fit statistic which like Infit compares the observed household responses with responses expected under the assumptions of the Rasch Model (Obayelu, 2012). Hackett et al (2008) in their gender respondent effects on Brazilian food security scale used weighted item infitvalues, arguing that infit values were most commonly used in food security scale assessment. They did not use the outfit statistics because they were heavily influenced by extreme responses. Obayelu (2012) in his comparative analysis of householdfood security status in Kwara and Kogi states in Nigeriahad both Outfit and Infitstatistics that were within the range of 0.8 and 1.2. According to him and other scholars, values higher than 1.2 indicate questions that are not consistently understood and should be removed or omitted. Values lower than 0.8 are more closely associated with the underlying condition and are undervalued in an equal weighted scale.Connel, Nord, Lofton and Yadrick (2004) in their Rasch model analysis to determine the food security status of older children in schools also reported Infit/Outfit statisticsof between 0.86 and 1.11 except one question whose outfit and infit statistics exceeded the range but they included it in their analysis. This study assessed both infit and outfit statistics and considered the range 0.7 to 1.3 as acceptable. Yong quoted Wang and Chen (2005) as recommending a plot of the mean squares on a graph, checking them visually to identify a misfit (Chong Ho Yu, 2010).This study also used a Rasch model graphical check.

2.2 Rasch Model Analysis using R Programming

The extended Rasch model in R statistical package was used to analyse the 18 items responded to by 577 households in Tororo and 598 households in Busia. The probability of a household's reaction to a stimulus was a function characterizing the household's food insecurity level as a latent trait. The log odds of a household i correctly responding to an item j was a function of ability (β_i) and the item's difficulty (δ_j). The location of a household on the Rasch scale was determined using the IRT indicator distribution I_{ij} with

$$\Pr(I_{ij}=1 \mid \beta_i \delta_j) = \frac{\exp(\beta_i - \delta_j)}{1+\exp(\beta_i - \delta_j)} \quad \ldots\ldots\ldots\ldots \quad (2)$$

Where I_{ij} is a dichotomous random variable representing response of household i to item j

i = 1, 2, ……., n are the households ($n_{Tororo} = 577, n_{Busia} = 598$)

j = 1, 2, ……., m (m=18) are the items

β_i = i^{th} household's ability parameter for i = 1, … n

This is also referred to as the severity of household food insecurity

δ_j = j^{th} item's difficulty parameter

Responses to the 18 Rasch Model questions were coded into binary codes. For the often/sometimes/never responses, "often" or "sometimes" were coded as affirmative (value = 1), and "never" was coded as negative (value = 0). For yes/no responses, "yes" was coded as 1 and "no" as 0. For "how often?" responses, "almost every month" and "some months" were coded as 1 and "only 1 or 2 months" and never were coded as 0. Thus, the data structure looked like Figure 1;

respondent	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	.	.	.
1	1	1	1	1	1	1	0	0	1	1			
2	1	1	1	0	1	1	0	0	1	1			
3	1	1	0	0	0	0	0	0	0	0			
4	1	0	1	1	1	0	1	0	1	0			
5	0	1	0	1	1	0	0	0	0	0			
6	1	1	1	1	1	1	1	0	1	1			
7	1	1	1	1	1	1	1	0	1	1			
8	1	1	1	1	1	1	1	0	1	1			
9	1	1	0	1	0	0	0	0	1	1			
10	1	1	1	1	1	1	0	0	1	1			
.	1	0	1	1	1	1	1	1	1	1			
.	0	0	0	0	0	0	0	0	0	0			
.	1	1	1	1	1	1	1	0	1	1			

Figure 1: Modified Data Structure

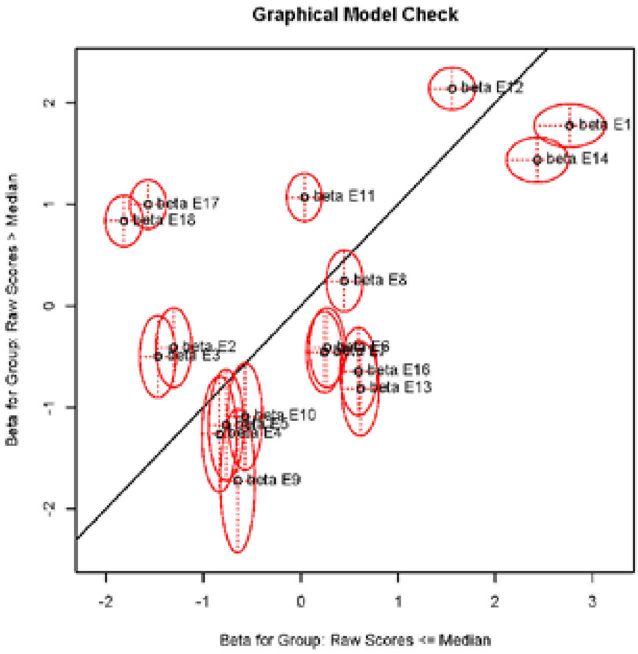
An algorithm for the Rasch model was developed and run using the R-programming software which also generated the Infit/Outfit statistics, Beta coefficients and probabilities for Busia and Tororo datasets.

The households were then classified using thresholds:Food Insecure (0.00-0.49); Moderately Food Insecure (0.50-0.79); Food Secure (0.80-1.00).

3. Results and Discussion

The graphical model check in Figure 2shows E9 and E13 to E18 to be outliers/misfits.Table 2 shows their outfit MSQs to be outside the acceptable range. However, their infit MSQ statistics except for E17 (infit MSQ 2.007) and E18 (infit MSQ 1.995) are within or close to acceptable range of 0.7 to 1.3.Therefore, given the infit statistics of E2 to E16 being within acceptable range, for the Rasch analysis we consider the 16 items E1 to E16. For Infit statistics for E17 and E18 (Table 2) are above 1.0 implying the item discriminate less sharply than the average of all items in the scale. Outfit statistics forE2, E3, E17 and E18 are above 1.0 indicating their weaker than average association with the underlying conditions.

Figure 2a - Graphical Rasch Model Check for all 18 Items



Generally, values higher than 1.2 indicate questions that are not consistently understood and should be removed or omitted. These include E2, E3, E17 and E18 that were earlier identified with outfit MSQ greater than 1. Values lower than 0.8 are more closely associated with the underlying condition and are undervalued in an equal weighted scale. These include E4 to E7, E9, E13 to E16 (see outfit MSQ, Table 2).

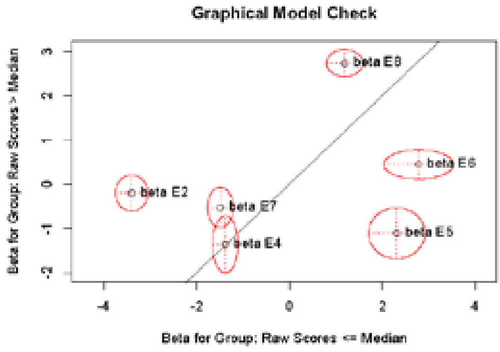
Considering the proposed interpretation of the infit/outfit ranges for parameter level mean square fit statistics by the website http://www.rasch-analysis.com/rasch-model-specification.htm, we have the following: Table 2showsvariables E17 and E18 with outfit MSQ↑2.0 implying theywould distort the measurements. Variable E3 has value between 1.5 and 2.0 and is therefore unproductive for construction of measurement. Most of the variables E2, E4 to E12, E15 and E16 have values between **0.5 and 1.5** and are therefore **good for productive measurement**. Variables E13 and E14 have values below 0.5 and are considered less productive for measurement, but not degrading and may produce misleadingly good reliabilities and separations. When we consider the infit MSQ, the variables all fit within the range 0.5 and 1.5 with the exception of E17 and E18. They can therefore be used for productive measurement.

Table 2 - Infit/Outfit Test Results for the 18 Items

	Chisq	df	p-value	Outfit MSQ	Infit MSQ	Outfit t	Infit t
E2	1286.13	1008	0	1.275	0.893	2.04	-2.32
E3	1530.81	1008	0	1.517	0.989	3.3	-0.21
E4	641.791	1008	1	0.636	0.726	-3.82	-6.63
E5	693.454	1008	1	0.687	0.824	-3.31	-4.11
E6	756.669	1008	1	0.75	0.754	-3.65	-6.36
E7	646.423	1008	1	0.641	0.833	-5.49	-4.17
E8	816.519	1008	1	0.809	0.924	-2.8	-1.86
E9	585.344	1008	1	0.58	0.689	-4.84	-7.75
E10	770.023	1008	1	0.763	0.78	-2.63	-5.32
E11	1265.53	1008	0	1.254	1.212	3.28	4.77
E12	1217.26	1008	0	1.206	1.187	1.67	4.37
E13	486.701	1008	1	0.482	0.618	-8.88	-10.59
E14	501.747	1008	1	0.497	0.685	-5.67	-8.87
E15	504.175	1008	1	0.5	0.71	-4.91	-7.92
E16	564.924	1008	1	0.56	0.67	-7.24	-8.94
E17	3125.6	1008	0	3.098	1.995	12.37	16.91
E18	3399.51	1008	0	3.369	2.007	11.72	16.53

Figure 2b shows that only two variables E4 (outfit MSQ 0.6, infit MSQ 0.7); and E7 (outfit MSQ 0.7, infit MSQ 0.7) were close to the line of model fit and would be considered to be within acceptable range as confirmed by their outfit MSQ/infit MSQ given in Table 3.

Figure 2b - Graphical Rasch Model Check for Children Items



Their values are within the productive measurement range of 0.5 to 1.5 when one considered both infit and outfit MSQs. Variable E6 infit MSQ of 0.5 also puts it within the productive measurement range. The other variables are misfits. Therefore, considering only the children factors for the Rasch analysis, variables E4, E6 and E7 can be used for food security analysis for household with children.

Table 3 - Outfit Infit Analysis for Households with children

Question	Chisq	df	p-value	Outfit MSQ	Infit MSQ	Outfit t	Infit t
E5	2501.445	614	0.000	4.067	1.178	5.49	2.42
E14	**339.406**	**614**	**1.000**	**0.552**	**0.659**	**-3.45**	**-6.9**
E15	191.457	614	1.000	0.311	0.41	-8.57	-12.18
E16	**247.383**	**614**	**1.000**	**0.402**	**0.531**	**-5.69**	**-8.94**
E17	**451.067**	**614**	**1.000**	**0.733**	**0.725**	**-1.87**	**-5.41**
E18	2161.368	614	0.000	3.514	1.142	5.25	2.46

3.1 Household Food Classification Using the Rasch Model

The probability of a household being food secure was derived from the Rasch Model with household food security status computed based on the following food security classification; Food Insecure (0.00-0.49); Moderately Food Insecure (0.50-0.79); Food Secure (0.80-1.00).

Table 5 - Household food insecurity status and the effect of number of household members by age category (<5 years; 5 to <18 years and 18 years and above)

Food Security Status/Characteristics	Insecure	Moderate	Secure	Total
Food Insecurity Distribution (%)	33.45	46.64	19.91	**1175**
HH average number of children <5 years old	1.61	1.64	1.74	**1.65**
HH average number of children 5 to <18 years old	2.7	2.47	2.45	**2.54**
HH average number with adults >18 years old	2.73	2.44	2.46	**2.54**

Table 5 shows that the largest percentage (46.6%) of households was moderately food insecure while one third (33.5%) were food insecure and only one fifth (19.9%) were classified as food secure. According to the analysis, food insecurity is more prevalent to households with more children aged 5 to 17 years, as it is with households having more adults compared to those with few children (5-17 years) and adult (18 years and above) household members. Children aged 5 through 17 years are classified as the most active whose bodies undergo various biological and physiological changes besides the intellectual growth (Kaiser et al., 2003). All these processes they undergo require a lot of energy as they form what type of adults they intend to be. Although, some of them may contribute to the household food production, their contribution is far less than their consumption since at most times, they are at school or involved in other activities that do not necessary contribute to the household food basket(Jyoti, Frongillo, & Jones, 2005).

Table 6 - Effect of Number of Children (less than 5 years and Less than 18 years) on Food Security Status in Uganda

Food Security Classification	Households with <5 year-old Children Status				Households with 5 to <18 year-old children status				Total
	With less than 5 year olds		Without less than 5 year-olds		With 5 to less than 18 year-olds		Without 5 to less than 18 year-olds		
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	
Food Insecure	102	25.95	291	74.05	59	15.01	334	84.99	393
Moderate	137	25.00	411	75.00	119	21.72	429	78.28	548
Food Secure	57	24.36	177	75.64	47	20.09	187	79.91	234
Overall Total	**296**	**25.19**	**879**	**74.81**	**225**	**19.15**	**950**	**80.85**	**1,175**
	Pearson chi2 (2) = 0.2180 p= 0.897				Pearson chi2 (2) = 6.8066 p = 0.033				

When analyzed by age category of the children (Table 10), there is no significant difference in food security status for households with children under 5 years of age compared with those without this category of children (˙ 0.2180 2 Pearson s , p 0.897). However, a significant difference in food security status was found between households with children aged 5 to ↓18 years and households without this category of children (˙ 6.8066 2 Pearson s , p 0.033). It is possible that mothers tend to pay special attention to their very young children, providing for them required meals. When children grow older, they are expected to fend for themselves and may at times not be present for all the meals at home.When food is scarce, priority may be given to the younger children.

4.0 Conclusion

The effect of number of children in a household was studied(Owino, Wesonga, & Nabugoomu, 2014). Two main categories of children were thus hypothesized, those below five years and the 5 to 17 year olds with average household composition of 1.61 and 2.7 respectively for the sample of 1175 mainly rural-based households in the Eastern region of Uganda. Children 5 years to less than 18 years have a significant influence on the food insecurity status of a household. Attention needs to be given to understanding the food security situation of households with this category of children in order to plan for interventions.

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B10

Estimating Comparable Prevalence Rates of Food Insecurity through the application of the Food Insecurity Experience Scale

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ABSTRACT

This paper presents the methods for estimating comparable food insecurity prevalence rates across countries and time using the Food Insecurity Experience based Scale (FIES) or other similar food insecurity scales. Data are collected though the Gallup World Poll (GWP); however when data collected in national surveys using similar tools is available, those data are used to compute comparable prevalence rates. Results are provided regionally for 2014 and 2015.

Keywords: Food insecurity experience based scales, Rasch model, Voices of the Hungry project, global monitoring

PAPER

Introduction

The FAO Voices of the Hungry (VoH) project has developed methods to measure the access dimension of household or individual food insecurity based on the Food Insecurity Experience Scale (FIES), an 8-item questionnaire that elicits information on individuals' experiences and behaviours resulting from inadequate access to food (see World Summit (2009) for an official definition of this concept and United Nations (2015) to frame the project in the context of the post 2015 Sustainable Development Goals agenda).

The questionnaire was administered in 2014 and 2015 through the Gallup World Poll (GWP) in 147 and 140 countries, respectively. The GWP vehicle ensures continuous global monitoring; current plans are to continue including the FIES survey module (FIES-SM) in the GWP until at least 2018. The FIES-SM was translated into all major languages in each country where it was administered. The samples represent the adult population (15+ years) in each country, and sample sizes vary from 1000 up to 5000 individuals.

In parallel, several independent national surveys have fielded the FIES-SM or other similar food insecurity scales to monitor the food insecurity situation in the country. The samples collected in national surveys are representative at sub-national level, and sample sizes are much wider than in the GWP; therefore, when available, these data are used to calculate the prevalence of food insecurity in the country. The VoH methodology is based on the idea that it is possible to measure the severity of constraints on food access (an unobservable, or latent trait) based on people´s self-reported experiences. This is accomplished through the use of statistical techniques borrowed from Item Response Theory (IRT), commonly used in the educational and psychological testing fields, and in particular the Rasch Model (see Fisher & Molenaar, 1995 and Rasch, 1960). The model assumes that all questions refer to the same latent trait and form a scale of severity on which items (questions) and individuals (respondents) can be mapped. VoH developed a methodological extension of this model to ensure comparability among countries, surveys and from year to year. An R package to implement these methods can be downloaded from the FAO webpage.

The paper is structured as follows. Section 2 describes the FIES questionnaire and its rationale. Section 3 explains the methods to evaluate data quality, comparability across countries and time and scale stability across time. Sections 4 and 5 present some relevant results. Finally, Section 6 draws the main conclusions.

2. The Food Insecurity Experience Scale Survey Module (FIES-SM)

The FIES Survey Module (FIES-SM) is composed of eight questions1 with simple dichotomous responses ("yes"/"no"). Respondents are asked whether, at anytime during a certain reference period, they have worried about their ability to obtain enough food, their household has run out of food, or if they have been forced to compromise the quality or quantity of the food they ate due to limited availability of money or other resources to obtain food. (see FAO, 2013 for a description of the development of the FIES module).

In the version that has been applied globally through the GWP, questions are framed with reference to individuals and have a reference period of 12 months (Table 2-1). This is because the GWP is conducted in different months in different countries and a shorter recall period might result in lack of comparability across surveyed countries due to the possible seasonality of food insecurity.

Table

Questions in the Food Insecurity Experience Scale Survey Module for Individuals (FIES SM-I) as fielded in the 2014 GWP		
	Now I would like to ask you some questions about food. During the last 12 MONTHS, was there a time when… :	(label)
(Q1)	… you were worried you would not have enough food to eat because of a lack of money or other resources?	(WORRIED)
(Q2)	… you were unable to eat healthy and nutritious food because of a lack of money or other resources?	(HEALTHY)
(Q3)	… you ate only a few kinds of foods because of a lack of money or other resources?	(FEWFOODS)
(Q4)	… you had to skip a meal because there was not enough money or other resources to get food?	(SKIPPED)
(Q5)	… you ate less than you thought you should because of a lack of money or other resources?	(ATELESS)
(Q6)	… your household ran out of food because of a lack of money or other resources?	(RANOUT)
(Q7)	… you were hungry but did not eat because there was not enough money or other resources for food?	(HUNGRY)
(Q8)	… you went without eating for a whole day because of a lack of money or other resources?	(WHLDAY)

3. Data and methods

As outlined in Section 1, data analysed by the FAO VoH project are obtained through the GWP vehicle, with some exceptions where national data are available (USA, Mexico, Brazil and Guatemala). These national data were collected using tools that are similar to the FIES (see for instance Coleman-Jensen et al, 2015; IBGE, 2014; Tarasuk et al, 2014; Villagómez-Ornelas et al, 2014) and through equating procedure, it is possible to produce results that are comparable to the GWP results. In this section, we describe methods to test data quality, scale stability between years and comparability across countries and time. The data frame of reference is the GWP data, as national data require case-by-case considerations, and will not be described here.

3.1 Quality of Gallup World Poll FIES data

This section describes the methods to assess the quality of the FIES data. Data are analysed using the one-parameter logistic model (or Rasch model) which is used to estimate item (question) and respondent severity parameters along the same latent trait. This paper will not present a detailed description of the modeling framework applied to the FIES data, but further details can be found in FAO (2016), Section 4. Quality assessment statistics derived by the application of the Rasch model are briefly described below:

- **Missing responses** refer to cases where a respondent has stated that they do not know or have altogether refused to answer any of the FIES questions. Such cases are not considered in the analysis, but distribution of missing responses is reported as a general data quality indicator.

- **Item *Infit* and *Outfit* Statistics**: the FIES-SM was administered in close to 200 languages, in various countries throughout the world. Therefore, properly assessing the fit of all the items to the measurement model is crucial. The *infit* and *outfit* statistics assess the performance of the items included in the scale; that is the strength and consistency of the association of each item with the underlying latent trait. One of the Rasch model assumptions is that all items discriminate equally. Thus, ideally, all *infit* statistics should be 1.0;however, infit values in the range of 0.7 to 1.3 are considered acceptable. Similar standards may be applied to item *outfit* statistics. *Outfits* greater than 2.0 should be flagged for further assessment since outfit statistics are sensitive to even a few cases with highly improbable response patterns.

- **Rasch Reliability**: the standard Rasch reliability statistic is the proportion of total variance of severity of food insecurity in the non-extreme sample (omitting extreme raw scores 0 and 8) that is explained by the measure. A modified version of Rasch reliability that weights each raw score equally (rather than by the proportion of the sample in each raw score) is highly correlated with overall model fit across surveys using the same scale. This "Rasch reliability (equally weighted)" statistic is used as a proxy for model fit by VoH (see Nord, 2014).

▪ **Conditional Independence of items**: the Rasch model assumes that responses to any two items are correlated only because of their mutual association with the underlying latent trait. This means that we do not want two questions that ask about essentially the same behavior or condition caused by food insecurity (Nord, 2014). In general, conditional correlations greater than 0.30 between more than two pairs of items are flagged to identify the presence of a second dimensions in the data.

3.2 The updated global standard: how to ensure comparability across countries and time

Two potentially competing objectives of the Voices of the Hungry (VoH) project are to calculate prevalence rates of food insecurity that are comparable across countries and, for each country, comparable over time. The VoH report on the 2014 data (FAO, 2016) described the procedure for estimating prevalence rates that are comparable across countries. In order to calculate prevalence rates of food insecurity that are comparable over time in each country, it is desirable to have a fixed global standard scale and a fixed national scale for each country. Otherwise, if either of these changed over time, it would be difficult to distinguish real changes in national prevalence rates from changes due to random fluctuations in either the global standard or the country scale. Moreover, it is desirable that the global standard and national scales be quite precise. However single-year sample sizes of non-extreme cases (i.e., omitting cases that denied all items or affirmed all items) in the GWP are too small in most countries to provide sufficiently precise parameter estimates (cases with extreme responses are omitted when estimating the Rasch model through conditional maximum likelihood, as per Fisher and Molenaar, 1995). To overcome the small sample-size problem, three years of data will be used to calculate the final global standard and the final scale for each country. Thus, from year 3 onward, for each country, the national scales will be fixed. Prevalence rates will change only as the proportions in each raw score change. For 2014 and 2015, provisional national prevalence estimates will be based on a provisional global reference scale and provisional national scales. This will necessitate revising each country's prevalence estimates for 2014 in 2015, and for both 2014 and 2015 in 2016. Operationalizing this plan is straightforward. In the present paper, each country's scale is calculated based on aggregated data from 2014 and 2015 (when available, as a few countries did not have data collected in both years). Therefore, the calculation of country-specific item and raw score parameters, the global standard and thresholds on each country's scale are calculated using the pooled 2014-2015 data. Prevalence rates for each year are calculated by applying the same proportions-by-raw-score to each year's distribution of respondents across raw scores. From here on, we will refer to the country-data obtained by pooling data from 2014 and 2015 as "*pooled data*".

3.3 Scale stability between 2014 and 2015

The stability of the scale within the same country over time indicates that the meaning of the questions has been perceived in the same way by respondents over time. To test the stability of the scale we compare item severity parameters estimated for each country between 2014 and 2015. If, for one country, the difference between item parameter estimates is large enough and significant, we define the corresponding items as "unique". This implies that for that country those items have functioned differently between the two years. This may be due to the sampling framework, to a different interpretation of the items due to language adaptation or to poor fit of the Rasch model in one of the two years. If stability of the scale is observed in the large majority of countries, the VoH strategy is to consider the severity of the items estimated for the pooled data to calculate the global standard, estimate person parameters, measurement error and prevalence rates, and therefore to produce comparable results across countries and over time. The VoH approach to assess year-to-year stability of the scale considers three factors: absolute difference in item parameters, margin of error of item parameters, and the possibility that one or two items are unique but the rest are good.

4. Results

4.1 Quality of Gallup World Poll FIES data

In this section, we describe the results on the performance of the FIES in the 2015 round of the GWP, and in the pooled 2014-2015 data. A brief comparison with 2014 results is also included, but not described in detail (as already done in FAO, 2016). The **percentage of cases with any missing responses** is relatively low in the 2015 and pooled data. This percentage is higher than 5% for 13% of countries in 2014, 18% for 2015 and 14% of countries in the pooled data (results not shown). Table 1 includes a **summary of item infit statistics** for the 2015 and the pooled GWP samples. It can be noted that the infits improve considerably using the pooled data compared to 2015 and 2014 (this latter comparison is not shown). This result supports the use of pooled data to estimate item and person parameters rather than a single-year.

Table 1. *Summary of item infit statistics*												
	2015	*Pooled*	*2015*	*Pooled*	*2015*	*Pooled*	*2015*	*Pooled*	*2015*	*Pooled*
Item	Infit 0.8 to 1.2 (% of cases)	Infit 0.8 to 1.2 (% of cases)	Infit 0.7 to 1.3 (% of cases)	Infit 0.7 to 1.3 (% of cases)	Mean infit	Mean infit	Minimum infit	Minimum infit	Maximum infit	Maximum infit
WORRIED	74.2	83.7	89.1	95.2	1.101	1.112	0.6	0.824	1.549	1.549
HEALTHY	90.6	93.2	94.5	98.6	1.003	1.01	0.647	0.651	1.525	1.327
FEWFOODS	89.1	93.2	97.7	97.3	0.977	0.971	0.733	0.688	1.528	1.344
SKIPPED	88.3	92.5	95.3	99.3	0.932	0.923	0.523	0.614	1.257	1.639
ATELESS	78.9	86.4	93.8	98.6	0.904	0.893	0.608	0.6	1.344	1.086
RANOUT	75.8	87.8	92.2	100	0.905	0.915	0.595	0.72	1.414	1.244
HUNGRY	50.8	61.2	75	93.2	0.797	0.834	0.4	0.435	1.263	1.266
WHLDAY	66.4	66.7	83.6	89.1	1.182	1.171	0.836	0.957	2.199	1.855

Regarding the **outfit statistics**, the comparison between the single-year results and those based on the pooled data leads to less discrepant values (not shown). This is in line with the idea that possible anomalous response patterns need to be detected using single-year data. Mean **conditional correlation** is very low considering both the pooled and the year-by-year data (results not shown). Maximum conditional correlation instead improves considerably using the pooled data (Table 2 shows a comparison with 2015).

The mean **reliability** (equally weighted across raw scores) for the pooled data is 0.74 and ranges between 0.68 and 0.83. This result is consistent with the year-by-year analyses. In summary, the pooled data leads to improved item performance (and therefore the estimation of person parameters and prevalence rates) in terms of infits and residual correlation. This ensures that prevalence rates calculated according to parameters estimated on the pooled data are not only comparable, but also more reliable than those obtained using year-by-year parameters.

Table 2. *Maximum residual correlation (numbers in red refer to the 2015 samples while numbers in black refer to the pooled data)*

	WORRIED	HEALTHY	FEWFOOD	SKIPPED	ATELESS	RUNOUT	HUNGRY	WHLDAY
WORRIED		0.47	0.3	0.35	0.3	0.86	0.67	0.2
HEALTHY	0.31		0.61	0.33	0.54	0.21	0.26	0.18
FEWFOOD	0.25	0.57		0.28	0.36	0.28	0.21	0.08
SKIPPED	0.2	0.15	0.25		0.67	0.41	0.48	0.5
ATELESS	0.22	0.26	0.29	0.44		0.45	0.56	0.14
RUNOUT	0.19	0.16	0.18	0.35	0.33		0.72	0.33
HUNGRY	0.18	0.17	0.2	0.46	0.38	0.54		0.71
WHLDAY	0.06	0.13	0.04	0.18	0.14	0.25	0.42	

4.2 Comparability across countries and time

The updated global standard based on the pooled data (not shown) is only slightly different from the one calculated using 2014 data only (see FAO, 2016). The provisional thresholds for moderate or severe, and severe food insecurity considering the updated global standard change as follows: the threshold for the moderate or severe level is less severe (-0.29 versus -0.25 using the 2014 data only) while the threshold for the severe level is more severe (1.85 versus 1.83 using the 2014 data only). Items are considered common when their severity in a country differs from the one on the global standard by less than 0.35 units on the global reference scale. In 93 percent of the countries, a set of at least 5 common items was identified, thus allowing a robust equating procedure to be carried out. This result is in line with results of equating based on the 2014 data only.

4.3 Scale stability between 2014 and 2015

The stability of the scale between 2014 and 2015 was analyzed for countries where FIES data in the GWP were available for both years. Of 136 countries considered in the analysis, 99 (73.9%) have all common items between 2014 and 2015, 26 (19.4%) have only one unique item, 7 have two unique items and 2 have three unique items. No country has more than 3 uncommon items. The stability of the scale can be considered, overall, very good. It is worth noting that the instability observed in the GWP may be mostly due to differences in samples (possibly primarily different languages), and may reinforce the VoH plan to base the global reference scale on three years of data and revise prevalence estimates accordingly. A threee-year GWP sample is likely to be more representative of the population of interest.

5. Prevalence rates at country and regional level

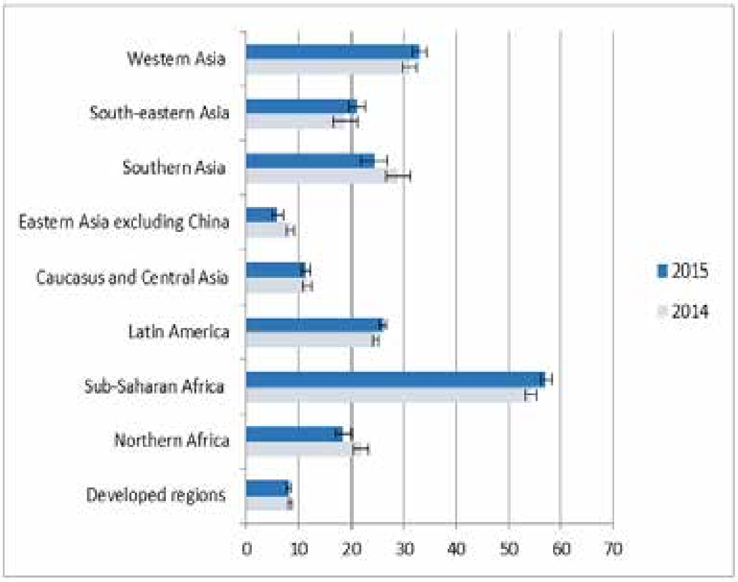
Table 3 shows the distribution of countries for different classes of food insecurity at moderate or severe and severe levels for 2014 and 2015. This distribution does not show particular changes in the two years, neither for the moderate or severe level nor for the severe level. Figure 2 represents the food insecurity prevalence rates calculated at moderate and severe level for the FAO regions, comparing 2014 and 2015. Margins of error are also included. It can be observed that the majority of the regions do not show a significant change infood insecurity prevalence rate over time.

Table 3. *Distribution of countries for different classes of food insecurity*

	Moderate or severe		Severe	
Range (%)	% of cases 2014*	% of cases 2015*	% of cases 2014	% of cases 2015
<5	8.2	8.6	17.0	15.7
5-14.99	32.7	35	33.3	32.9
15-24.99	17.7	12.1	14.3	15
25-50	21.8	22.9	16.3	17.9
>50	19.7	21.4	19.0	18.6

* Prevalence rates for 2014 and 2015 are calculated using the equating with the updated 2014-2015 global standard.

Figure 2 - Prevalence of food insecurity (moderate+severe) by FAO region, 2014 and 2015



6. Conclusions

The FIES provides a quick and reliable tool to estimate the prevalence of food insecurity at different levels of severity. The application of the FIES-SM in the GWP data in 2014 and 2015 has shown how comparability of the results is reached not only between countries, but also over time (using the pooled data approach). By pooling the data from 2014 and 2015 to estimate the Rasch model parameters corresponding to which prevalence rates are calculated, the reliability of the measure is increased. A three-year based analysis (using the 2016 GWP data) will provide a robust global standard for monitoring the evolution of food insecurity worldwide.

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Food counts - Measuring food consumption and expenditures in household surveys

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ABSTRACT

The objective of this paper is to summarize a set of state-of-the art analyses of the key issues involved in the measurement of food consumption in national household surveys. Food consumption data from household surveys are possibly the single most important source of information on poverty, food security, and nutrition outcomes at national, sub-national and household level, and contribute major building blocks to global efforts to monitor progress towardsthe major international development goals. This objective is achieved through a series of case studies from a diverse set of countries--including developing countries, the OECD, Canada and the U.S.--addressing the main outstanding research issues as identified by a recent assessment of 100 existing surveys (Smith et al., 2013). The individual research papers examine, both theoretically and empirically, how survey design options affect the quality of the data collected and, in turn, the implications of those options for statistical inference and policy analysis.

Keywords: Food Consumption; Household Surveys: Survey Methods

PAPER

1. Background and justification

Food constitutes a core component of a number of fundamental, broad-based welfare indicators, such as food security, nutrition, health, and poverty. It makes up the largest share of total household expenditure in low-income countries, on average accounting for about 50% of the household budget (USDA, 2011). Low levels of access to food was an important factor contributing to the estimated 850 million individuals who were chronically undernourished in 2012-14 (FAO, 2014). Proper measurement of food consumption is therefore central to the assessment and monitoring of the well-being of any population, and therefore is of interest to multiple international, national, and local agencies, and to several development domains – social, economic, and human. Data on food consumption are needed, for example, to monitor the achievement of the United Nations' First Millennium Development Goal, to eradicate extreme poverty and hunger, and may play an even greater role in monitoring the ambitious post-2015 sustainable development agenda. Similarly, its measurement is crucial to assess and guide FAO's mandate to eradicate hunger, food insecurity and malnutrition, as well as the World Bank's twin goals of eliminating extreme poverty and boosting shared prosperity. Sound food consumption data is also required by national and local governments, as well as non-governmental organizations, to guide their local and regional analysis, programming and policymaking. The lack of food consumption data or its mis-measurement may result in the mis-allocation of funding and may compromise the design, monitoring and evaluation of programs or policies.

The last two decades has witnessed unprecedented progress in the production and dissemination of household consumption and expenditure data across the developing world. In 1990, the World Development Report published by the World Bank was based on data from only 22 countries, and no country had more than one survey. Today there are 125 countries with consumption or expenditure information, and many of them have multiple surveys, adding to a total of more than 850 surveys (Ravallion and Chen, 2011). The number of countries with no poverty data over a 10 year period declined from 33 percent to 19 percent since the 1990s, whereas the share of countries with 3 or more data points over a 10 year period increased from 27 to 41 percent over the same period (Serajuddin et al., 2015).

Depending on their primary objective, the surveys collecting information on household consumption or expenditure take different forms, including Household Budget Surveys (HBS), Income and Expenditure Surveys (IES), or ‗multi-purpose' or ‗integrated' household surveys, like the Living Standards Measurement Study surveys. We refer to this family of surveys, which are usually nationally and sub-nationally representative, as Household Consumption and Expenditure Surveys (HCES).

While the variety of HCES purposes naturally translates into different designs, the dramatic increase in the number of household surveys in developing countries has been associated with a proliferation of approaches and methods used in the collection of food data that is not only due to their different purposes or country-specific considerations. While there exist international guidelines and recommendations for the design and implementation of each of the distinct types of HCES surveys, they are specific to each type of survey, are generally not prescriptive, lack coherency and usually leave much flexibility to national survey statisticians. Consequently, we observe heterogeneity in methods, even within the same type of survey, both across countries, as well as within countries over time.

The notion that survey design matters is not new, as the work of Mahalanobis and Sen (1954) and Neter and Waksberg (1964) more than half a century ago testifies. Despite the fact that consumer spending plays a central role shaping a variety of key economic behaviors—savings, earning processes, insurance, responding to shocks and tax policies among others (Browning et al. 2014)- the issue has traditionally been largely neglected by economists. The longstanding relative neglect of food consumption metrics has also contributed to the lack of guidelines and has been another source of the proliferation of variability in HCES questionnaire design, data collection methods and data processing practices. The lack of coherence is the outcome of limited and inadequate guidance, the lack of a body of conceptual, theoretical and empirical literature, including the lack of empirical examples of the tradeoffs involved in alternative available survey design options. In combination with the low level of funding that most low- and middle-income countries' national statistical organizations—which are the HCES implementing agencies of—have experienced over the past two decades, this confluence of factors has trapped many countries in a vicious cycle of statistical underdevelopment and underperformance which manifest themselves in many ways (Kiregyera 2014: 2). This situation is not unique to HCES: it is part of a broader, national statistics for development problem that has attracted increasing attention in recent years (Jerven 2013), and has spawned growing recognition of the need for a global strategy for improving statistics. This is encouraging. It makes for a more enabling environment for introducing change, suggesting the timing is good and the prospects for addressing common roots of these problems are promising. To date, much of the focus has been on agricultural and rural statistics (FAO 2010; World Bank, et al., 2011). While it is clear that there is a great deal of overlap between food and agriculture issues (Carletto et al., 2015), there remains a longstanding past due and increasingly urgent need to more directly address food consumption issues per se (Herforth & Hoberg 2014, Fiedler et al., 2012).

In recent years there has been a surge of interest in the measurement of household expenditure. Most of this interest has been generated by two factors: a) increasing evidence that changes in survey instruments over space and time compromise our ability to draw inferences and conduct trend analysis, and b) the persistent fall in the quality of Consumer Expenditure Surveys; particularly that related to under-reporting in developed countries. These concerns prompted two recent assessments of the current state of measurement of household expenditures. . One, initiated by the U.S. Bureau of Labor Statistics with the aim of producing recommendations for re-designing the U.S. Consumer Expenditure Survey, was undertaken by an expert panel formed by the National Research Council's Committee on National Statistics (Natl. Res. Counc., 2013). The second was the 2011 Conference on Research in Income and Wealth sponsored by the National Bureau of Economic Research, which focused on improving the measurement of consumer expenditures (Carroll et al, 2014). However, these initiatives were restricted to developed countries, only focus on total household expenditure - as opposed to food expenditure, and focus primarily on one particular type of survey - HBSs. Nevertheless, they provided useful lessons for all countries: they further demonstrated the enormous heterogeneity in methods and the growing urgency of a strategy, or at minimum criteria, for guiding countries through the diverse, oftentimes conflictive available possible approaches, while calling attention to the limited consensus as to how best to collect these data, and renewing the call for more research in these areas.

With respect to evidence from developing countries, Deaton and Grosh (2000) provided a comprehensive review of the issues and data needs for the measurement of consumption in household surveys, drawing on the lessons derived from LSMS surveys. The bulk of that work is now more than 20 years old. Since then a few other papers have analyzed the implications of particular aspects of survey design on total expenditures, poverty and inequality measures. For example, Jolliffe (2001) and Pradhan (2001) evaluate the impact of varying the length of the consumption list in El Salvador and Indonesia respectively; Gibson et al (2003) look at the effect of changing the length of the data collection period for the case of China; Beegle et al (2012) compare results from 8 questionnaire designs which include variations in methods of data capture, level of respondent, length of reference period, number of items in the recall list, and the nature of the cognitive task required of the respondent; and Backiny-Yetna et al (2014) compare different data collection methods, which include 7-day recall period, a 7-day diary, and a usual month'.

There is arguably a need for more systematic research on some topics before a general consensus about best practices on the collection of food consumption or expenditure data in household surveys can be derived. While the lack of broadly accepted practices affects all aspects of household consumption or expenditures, it is particularly pronounced in the case of food consumption: not only because there exist few papers that focus explicitly on food (e.g. the work by Backiny-Yetna et al, 2014), but also because the research has almost exclusively looked at only mean expenditures, and poverty or inequality measures.

The impact of survey design on other moments of the distribution is less-well understood., and as mentioned before, with increasing interest in using the data to analyze other dimensions of well-being, such as food security, health, diet quality, nutrition and the agriculture-nutrition nexus, which has given rise to the need for additional, more detailed information, The increased availability of HCES has sparked the use of these surveys in ways not conceived of when they were first designed. While some HCES—such as LSMS—were originally designed to be multi-purpose, others, such as HBSs, were originally more narrowly focused. HBS, for instance, originally had the clear goal of collecting the data necessary to (1) define and update the basket of commodities for the Consumer Price Index (CPI), (2) measure household consumption for the System of National Accounts (SNA), and, in some cases, (3) define the country's poverty line in order to track the living standards of the population, study the determinants of poverty and of other dimensions and dynamics of well-being, and to better understand public program coverage, participation and impacts. As they and other HCES have morphed into or become more multi-topic surveys, they have collected additional data. In some cases they have been modified to provide a more comprehensive picture of the household and, in some cases, of the individual household members' characteristics While still collecting the consumption data required to comply with their original mandate to measure economic conditions, poverty and inequality, they have come to collect more information on a wider array of topics, such as housing conditions, education, health, assets/wealth, employment, and income, among others. Moreover, as the data are being increasingly re-purposed by new stakeholders with altogether new interests, they have brought with them demands for altogether new types of data and new approaches to the surveys. HCES are now being used to for a host of new food consumption and nutrition-related analyses, which they were never intended to support. Among these new applications are the use of HCES to conduct subnational food security analysis, compile subnational food balance sheets; assess diet quality and dietary change (Monteiro et al., 1994; Nascimento et al., 2011; Levy et al., 2012, Coates 2013); analyze the relationship between household food expenditure and malnutrition (Campbell et al., 2010); estimate sodium intakes (Sarno et al., 2009); identify and monitor overweight and obesity (Kolodinsky & Goldstein 2011; Lobato 2009); to measure nutrient availability or proxy nutrient intakes (Pérez-Cueto et al., 2006; Bermudez et al., 2012; Fiedler & Helleranta 2010; Fiedler et al., 2012; Fiedler et al., 2013a; Fiedler et al., 2013b; Fiedler et al., 2013c; Fiedler et al., 2014a; Fiedler et al., 2014b; Fiedler & Lividini, 2014; Fiedler 2014); assess the adequacy of availability of fruits and vegetables to meet global health needs (Siegel et al., 2014); identify the most common food sources of specific nutrients (Bermudez et al., 2012; Fiedler et al., 2013a); to identify the number, percentage and location of households that acquire fortified or fortifiable foods, and model the impact of fortification programs (Fiedler & Afidra 2010; Nascimento et al, 2011; Marchioni et al, 2011; Claro & Monteiro 2010; Levy et al. 2012; Levy et al, 2009 Bermudez et al., 2012; Fiedler & Helleranta 2010; Fiedler et al., 2012; Fiedler et al., 2013a; Fiedler et al., 2013b; Fiedler et al., 2013c; Fiedler et al., 2014a; Fiedler et al., 2014b; Fiedler & Lividini, 2014; Fiedler 2014; Ricciuto et al., 2007; Beatty 2008; Kirckpatrick & Tarasuk 2008; Monteiro et al., 2000; Mondini & Monteiro 1994); to model the impact of biofortification programs (Fiedler et al., 2013; Fiedler & Lividini 2014; Lividini & Fiedler 2015; Fiedler & Lividini 2015), as well as to conduct feasibility and cost-benefit analyses of individual fortification, biofortification and supplementation programs, as well as of portfolios of combinations of programs (Fiedler et al., 2013; Fiedler & Lividini 2014).

This blossoming of the use of HCES to address food and nutrition issues reflects the intersection of three sets of events: (1) the growth in evidence-based policy, (2) the fact that food and nutrition issues have been at center-stage in international development for the past decade, and (3) the fact that there has long been a dearth of nationally representative dietary assessment studies which has severely constrained the nutrition evidence base and has throttled global progress in improving nutrition. Despite various shortcomings, household consumption and expenditures surveys (HCES) are increasingly being used to address the food and nutrition information gap because they contain a wealth of information about food acquisition and consumption; are being done with increasing frequency in an increasing number of countries (Serajuddin, 2015); have large samples; are statistically representative at subnational levels; and are much less costly than other dietary assessment data sources because these multi-purpose surveys are already being conducted and paid for by other government agencies (Fiedler 2013).

While there has been a surge of interest and HCES analyses of nutrition and food security issues, the potential of this particular type of repurposing of HCES has yet to be realized for several reasons. First, there is a lack of awareness of public nutritionists and food policy analysts about what these data contain. Second, there is a need for further research and action to improve the quality and utility of these data. To date, the nutrition community's HCES-related role has been overwhelmingly that of a passive user of HCES data from surveys that have already been conducted. Many HCES shortcomings, however, stem from design and implementation issues. If the nutrition community—with its unique skills and experiences—were to get more proactively involved in the design, implementation and analyses of HCES, they could be strengthened substantially as a tool for evidence-based food and nutrition programming and policymaking. At the heart of this Special Issue of Food Policy is the distillation of what we currently know about household survey design, the identification of better practices, the presentation of original, state-of-the-art research addressing the key methodological agenda items involved in strengthening HCES, which were recently identified in a review of 100 HCES (Smith et al., 2013). These are essential next steps to build global momentum and global consensus to enable exploiting this unique, shared, golden opportunity to re-purpose HCES and enable their better fulfilling this role, while at the same time making public nutritionists and food policy analysts more aware of what HCES have to offer.

A majority of the papers to be included in this Special Issue were initially prepared for a workshop jointly organized by FAO and the World Bank in Rome in November, 2014. They reflect a diversity of disciplinary approaches (statistics, economics, nutrition, food security analysis), and broad geographical coverage (with studies from African, Asian, Latina American and OECD countries – EC, US, Canada).

The main commonality linking the studies in the Special Issue is that they look at alternative or new methods from existing datasets, sometimes purposely collected for methodological studies, in order to identify the implication of survey design for measurement and analysis, and to translate those into recommendations for scalable approaches for future survey design.

The start of this work program was preceded and to some extent sparked by a desk review of the reliability and relevance of the food data collected in national household consumption and expenditure surveys, which was jointly leaded by the International Household Survey Network (IHSN), FAO and the World Bank (Smith et al, 2013). That assessment identified the multiple purposes these household surveys serve, proposed a method to assess the reliability and relevance of survey questions, and applied the method to 100 household surveys from low- and middle-income countries, a sample that resulted from selecting the most recent nationally representative household survey from each developing country, with the only condition of having enough documentation. The assessment points to many areas where survey design and questionnaires can be significantly improved, among which five were selected as key themes for the Rome workshop and this Special Issue. They are the following:

• Measuring food acquisition versus measuring food consumption. The term food consumption is interpreted in many ways. For the economists it is the amount of money spent to acquire food; for the food security analysts, it is the amount of food available for consumption; while for the nutritionists it is the amount of food actually eaten. Food data were initially collected in HCES simply to construct the consumer price indices or to inform national accounts. Therefore, the food data collected referred primarily to items acquired through purchase by the household during the reference period. Over the years, food items procured through own-production, barter, gifts and payment-in-kind were introduced into these surveys to better apprehend food acquisition in rural areas. These surveys aimed at capturing food that was acquired by the household in order to be consumed. However, with time, surveys have been also focusing on food items actually consumed by the household and the various sources from which food was acquired (purchases, own-production or gifts). Papers in the volume will address issues related to the differences between food data collected in acquisition type versus consumption type surveys and the use of these data to conduct specific analysis on consumer behavior.

• Measuring Individual vs Household Consumption. The food consumption/expenditure modules of household consumption and expenditure surveys (HCES) capture household, but not individual, level information. Yet, food and nutrition policies and programs often require information about which foods and nutrients are consumed by which groups of individuals, and in what quantity. While individual dietary intake data are often more appropriate for meeting these information needs, HCES are more widely available and conducted more regularly than individual-level dietary assessments. Furthermore, most dietary surveys do not assess the intake of all household members, making it difficult to plan programs, such as fortification programs, that are intended to benefit more than just one type of target individual. Until individual-level dietary data collection becomes routinely available, understanding whether and how household-level data can be used to approximate actual individual food and nutrient consumption is a worthwhile undertaking. Some of the papers in the volume will assess methodologies for deriving individual level estimates form household data.

• Recall and reference periods: benefits of bounding recall, and impact of length of recall periods on recall quality and telescoping. Nutritionists favor shorter recall periods (e.g. 24-hour recall) whereas expenditure surveys commonly use recall of 1 week or more. The impacts of recall period decisions on the quality of the data for different uses are far from being fully understood, and some of the papers in the volume will address some of the questions related to that. To assess usual consumption, how many times should data be collected from households and for what observation or reference period? What difference will extending reference periods and conducting repeat visits actually make to estimates of poverty and nutrient insufficiencies?

• Food consumed away from home (FAFH) and cooked/packaged meals. FAFH and prepared foods represent an increasing share of food consumption, and will continue to do so as GDP per person grows, and food systems evolve. This is an area where many surveys could improve, but where evidence on the robustness of alternative methods is weakest. A sub-set of the papers in this volume will look at the implication and methods for capturing FAFH, whether eaten in commercial or public establishments (e.g. restaurant, schools).

• Length and specificity of survey food lists. For many analytical purposes survey food lists need to be sufficiently detailed to accurately capture consumption of all major food groups making up the human diet. There are trade-offs in the decisions involved with coming up with a survey food lists of the 'optimal' length and specificity, that re not well understood. Some of the papers in the volume will attempt to provide evidence to help survey design practitioners and analysts address those concerns, and highlight the implications for policy analysis.

2. Research findings

The key aspects of the special issue are as follows:

1. The special issue brings together a collection of empirical studies on the implications of different survey design options for the measurement and estimation of different indicators and parameters of crucial importance to several development domains. The data used in these studies include nationally-representative data and detailed case studies across a range of countries from several of the main developing regions, as well as from developed countries. The results of the study will therefore be of interest to a global audience.

2. The special issue confronts the issue of survey design prioritized by a major international review, thus responding to the research needs and priorities reflecting the shared concerns of the main international experts on the topic. In addressing those concerns, the special issue will draw on expertise from a range of disciplines and institutional backgrounds, mirroring the diverse readership of Food Policy.

3. All the papers in the special issue have now been received and the findings will be summarized in the final version of this papers when it is submitted by the deadline of July 15.

Table 1 - List of papers

Lead author and paper	Country
1. Jed Friedman (World Bank): *The nature of food consumption reporting error in survey: evidence from a randomized experiment in Tanzania*	Tanzania
2. Celeste Sununtnasuk (IFPRI), *Assessing the adequacy of the Adult Male Equivalent in estimating the intrahousehold distribution of energy and nutrients: Evidence from the 2011-2012 Bangladesh Integrated Household Survey*	Bangladesh
3. Reina Engle-Stone (UC Davis): *Investigating the Significance of the Recall Period of Household Consumption and Expenditures Surveys for Food and Nutrition Policymaking*	Bangladesh
4. Nathalie Troubat (FAO): *Impact of survey design in the estimation of habitual food consumption of Mongolian urban households*	Mongolia
5. Mark Denbaly (USDA-ERS): *Lessons Learned from the National Household Food Purchase and Acquisition Survey (FoodAPS)*	USA
6. Renos Vakis (World Bank): *What's in the Meal? Improving Measurement of Food Away from Home and Poverty in Peru*	Peru
7. Carlo Cafiero (FAO): *National food security assessment through the analysis of household surveys food consumption data: the case of Brazil's Pesquisa de Orçamento Familiares 2008/09*	Brazil
8. Jennifer Coates (Tufts) - *Estimating Individual Consumption from Household Consumption and Expenditure Survey Data for Nutrition Programming Decisions*	Ethiopia and Bangladesh
9. Thomas Crossley (University of Essex and Institute of Fiscal Studies, UK): *A Comparison of Recall and Diary Food Expenditure Data*	Canada
10. Maria Laura Louzada (University of Sao Paulo): *Assessing the consumption of ultra-processed foods through household food acquisition and individual food intake data: evidence from Brazil*	Brazil
11. Jack Fiedler (IFPRI): *Developing the Agenda for Strengthening Household Consumption and Expenditure Surveys: How Important are Meals Away from Home and Numbers of Partakers?*	India, Nigeria, Bangladesh
12. Prospere Backiny-Yetna (World Bank): *The Impact of Household Food Consumption Data Collection Methods on Poverty and Inequality Measures in Niger*	Niger

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(all Caps, character 14 pt, bold, adjust Left) 2 lines space 12 pt between last session and references The second line of a reference has 0,5 cm indent.

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THEMATIC SET

B11 FOOD AND NUTRITION SECURITY STATISTICS: METHODS AND APPLICATION

Session Organizer
C. Cafiero | | FAO | Rome | Italy

ABSTRACT

Food security at household and individual level is widely understood as the ability to access, on a continued basis, adequate amounts of food of the right quality in ways that do not otherwise compromise the overall welfare. Measures of household or individual access to food can then be used to inform indicators of access to food at local, national and global level to be used in monitoring progress towards the objective to ensure food security for all. How to measure food access though has been a long debated issue. Several methods have been proposed, ranging from the analysis of food expenditure data collected through household budget surveys to the analysis of quantitative food consumption data collected over short reference periods, that of individual dietary intake and nutritional status data, and including the analysis of experience-based food insecurity scales that look at the ability to access food as an individual or household latent trait. This session aims at tacking stock of existing methods to measure households and individuals' ability to access adequate amounts of food, and to discuss how such data can be used to inform food security assessments at local, nationaland global levels. Submission of papers that discuss methods for collection and analysis of data on food expenditure, food acquisition, food consumption, dietary intake, dietary quality, experience-based food insecurity scales, nutritional status, and welfare losses due to inadequate access to food is encouraged. We particularly encourage submission of papers discussing the statistical properties of the various indicators, and presenting methodological advances in the development of valid indicators of inadequate access to food, with reference to cost effectiveness, reliability, and the possibility to compare classifications at various degrees of severity of the inability to access food.

LIST OF PAPERS

Food Insecurity in Rural Households of Cameroon: Factors Associated and Implications for National Policiest

B. Tanankem Voufo | Ministry of Economy, Planning and Regional Development, Department of Analysis and Economic Policies | Yaoundé | Cameroon

A. H. Fotio | Sub regional Institute of Statistics and Applied Economics | Yaoundé | Cameroon

DOI: 10.1481/icasVII.2016.b11

Do Boys Eat Better than Girls In India? Longitudinal Evidence on Dietary Diversity and Food Consumption Disparities among Children and Adolescents

E. Aurino | School of Public Health, Imperial College London | London | United Kingdom

DOI: 10.1481/icasVII.2016.b11b

Assessing Vulnerability to Food Insecurity in Mountain Areas of Ecuador: the Composite Vulnerability Indicator (CVI)

A. Borlizzi | FAO, Forestry Department | Rome | Italy

DOI: 10.1481/icasVII.2016.b11c

Determinants of dietary Diversity in Namibian Children: Evidence from 2013 DHS

L. Pazvakawambwa | University of Namibia, Department of Statistics and Population Studies | Windhoek | Namibia

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ABSTRACT

Using data from the third Cameroonian Household Consumption Survey conducted in 2007 by the National Institute of Statistics, this paper aims to estimate the food security status and identify the factors associated to food insecurity in rural households of Cameroon. It is found that the incidence of food insecurity in rural area is about 33.8% using the household caloric acquisition method of estimating food security status. Further analysis using the bivariate logistic regression method identified region of residence, landless status, and household-head's age as important determinants of food insecurity. Far-north's households are at least 1.5 times more exposed to food insecurity than other households of the country. Moreover, households who are sharecropper have 1.7 times more chance to experience food insecurity than those who are landowners. In addition, having a household head aged 40-49 and 50-59 increases the risk to be in food insecurity by 1.5 and 1.3 respectively, compared to households that head's age is less than 30. The region of the Far North should be preferred for eventual policies of fighting against food insecurity. Also, rural households that the head's age is high must have priorities, and resident rural population should be encouraged and helped to own land.

Keywords: Food Insecurity, Calorific contribution, Cameroon.

PAPER

1. Introduction

Due to its agro-ecological diversity[1], Cameroon shows great potentialities for agricultural production and livestock. Up till the late 1980s, the country was considered self-sufficient in agricultural production and played a role of food garret for its neighbouring countries (Gabon, Central African Republic, Chad, etc.). In the early 1990s, the country began importing massive quantities of cereals and other foodstuffs. This situation leads the Government and International Organisations to pay more attention to food security questions in the country.

In 2007 and 2011, the World Food Programme (WFP) conducted a Comprehensive Food Security and Vulnerability Analysis (CFSVA) in Cameroon in order to provide an understanding of food security and vulnerability situation of rural households. The results of these studies indicate that the particular case of rural households in Cameroon is not rejoicing. This situation is particularly weakened due to the level of poverty in rural area. Indeed, according to the results of the third Cameroonian Household Consumption Survey conducted in 2007 by the National Institute of Statistics, the rate of poverty in rural area was 54.5% against 11.9% in urban area.

It is then imperious to know for rural households, what are the socioeconomic and demographic factors that influence their food security situation. Accordingly, this paper aims to estimate the food security status and identify the factors associated to food insecurity in rural households of Cameroon.

The rest of the paper is organized as follows. Materials and methods are presented in section 2, results are presented and discussed in section 3 and section 4 concludes the paper.

2. Material and Methods

In this section, we give the definition of food security, and present the methodology that is used to measure it. We also describe the methodology that is used to identify the key determinants of food security status.

[1] The country is divided into five agro-ecological zones, with each of them suitable for specific agricultural production and livestock.

2.1. The food security concept

The standard definition of food security in use is that adopted during the World Food Summit held in 1996. According to this definition, "*food security exists when all people, at all times, have physical, social, and economic access to the sufficient food which meets their dietary needs and food preferences for an active and healthy life*" (FAO, 1996). This definition points out four distinct but interrelated elements of food security, which are essential to achieve food security: *food availability*, *accessibility*, *utilization*, and *sustainability of access*.

2.2. Instruments of measuring food security

In this paper, we use an indicator related to the calorific contribution approach of measuring food insecurity (see Kidane et al., 2005, and Muhoyi et al., 2014). The quantities of food consumed by households or individuals, recorded during a survey, are converted into calories using calories tables. The Household Calories Availability per adult equivalent (HCAeq) is then computed for each household as follows:

$$HCA_{eq} = \frac{\sum_{j=1}^{m} Q_j A_j}{\sum_{i=1}^{k} u_i}$$

Here, u_i is the number of adult equivalent of the household i, Q_j is the quantity of the product j (food) acquired by the household, and A_j is the quantity of calories contained in 100 grams of product j. Calories consumption per "adult equivalent" is needed to take into account the variation of individual dietary energy needs by age and sex and the difference between households in their demographic composition.

We now need a threshold to decide, given the value of the HCAeq, if a given household is food-secure or not. In this regard, we calculate the daily required calories for each household's member depending upon the recommended (FAO, 1996) caloric requirement for a person, considering its age and sex, and sum it up for each household. The household calories availability per adult equivalent is used to compute calorific indicator of food insecurity similar to a monetary poverty indicator:

$$P_\alpha = \frac{1}{N} \sum_{i=1}^{q} \frac{(Z - D_i)^\alpha}{Z}$$

Here, D_i is the threshold of calories consumption. When $\alpha = 0$, P_0 defines the food insecurity rate (headcount); when $\alpha = 1$, P_1 defines the food insecurity gap (depth); and when $\alpha = 2$, P_2 defines the squared food insecurity gap (severity).

2.3. Data

The Data used in this study are from the Third Cameroonian Household Consumption Survey (ECAM3) conducted from September to December 2007 by the National Institute of Statistic (NIS) of Cameroon. The survey, which main focus has been on measuring household"s living standards, concerned about twelve thousands households. With respect specifically to food, data are collected on all foods acquired by households, including their food purchases, foods consumed from their own farms or garden and food received in kind. The survey collected detailed information on daily expenditures of households in food consumption for two weeks. Our sample consists of 3,800 rural households.

The major difficulty encountered in calculating calorific contribution is the fact that in most cases, food items acquired by households was measured using Local Unit of Measure (LUM). The main operation done in data set has consisted to transform household"s food acquisitions in standard units (Kilogram) by using appropriate coefficients of conversion.

2.4. Determinants of food security

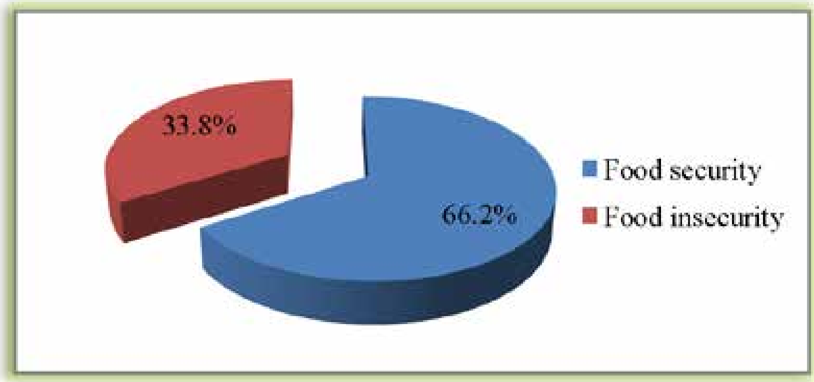
In order to quantify the probability of risk to food insecurity according to socioeconomic factors, we perform a logistic model. The binary form of the dependent variable i.e. „0" for food secure and „1" for food insecure, guided us to use this model (see for example Feleke et al., 2005; Babatunde et al., 2007 and Bashir et al., 2012). The explanatory variables in our model are: household head age, gender of household head, education of household head, household size, farmland size, region of residence, distance between households and the nearest market, household-head's socioeconomic group and diversification of household-head's activities.

3. Results and discussions

3.1. Descriptive statistics on food insecurity

Here, we present the mains results obtained from the computation of the proxy indicator of food insecurity. It is important to recall that threshold of food insecurity using calorific approach is variable[2] (see the section on materials and methods); that is two different households can have different thresholds according to their composition. For comparison, we also provide results obtained using a fixed threshold of 2,400 KCAL per person per day.

Figure 1 - Situation of food insecurity of Cameroonian's rural households



Source: Authors' calculations using CHCS 2007

From the Figure 1, we see that the incidence of food insecurity in rural area is about 33.8%, showing that more than one-third of rural households were subsisting on less than daily per capita calorie requirement during the survey period in 2007. This rate is not very far from the one that was found by the WFP during his Comprehensive Food Security Household Survey, using the Food Consumption Score to analyze food insecurity.

The results of the test performed to compare food insecurity incidences obtained using variable and fixed threshold respectively are reported in the last column of Table 1. They reveal at p↓5% that the two food insecurity incidences are significantly different for all regions. We also note a strong variation in the incidence of food insecurity across regions.

This can be explained by differences in eating habits from one region to another or by inequalities between regions in term of food accessibility.

Table 1 - Incidence and depth of food insecurity

Region	Variable threshold		Fixed threshold		p-value (test for comparison of incidences)
	Incidence	Severity	Incidence	Severity	
Adamawa	0.374	0.048	0.484	0.054	0.000
Centre	0.247	0.011	0.291	0.012	0.000
East	0.295	0.017	0.344	0.022	0.000
Far-north	0.512	0.036	0.642	0.044	0.000
Littoral	0.210	0.009	0.229	0.007	0.000
Nord	0.386	0.031	0.475	0.036	0.000
North-west	0.236	0.020	0.277	0.025	0.000
West	0.289	0.008	0.399	0.010	0.000
South	0.325	0.021	0.389	0.025	0.000
South-west	0.270	0.030	0.319	0.031	0.000
Total	**0.338**	**0.025**	0.418	0.029	0.000

Source: *Authors' calculations using CHCS 2007*

At the level of the different regions of Cameroon, it is evident that, the North and the Adamawa regions are the most exposed to food insecurity. The incidence of food insecurity in these regions is respectively 38.6% and 37.4%. This is expected considering that the northern part of Cameroon is confronted with harsh climatic conditions.

To know how far the food insecure households are below the recommended daily caloric requirement, food insecurity gap was calculated. Food insecurity gap provides the possibility to estimate resources required to eliminate food insecurity through proper targeting. Te calculated value of this indicator were found to be 2.25% (see Table 2) using variable threshold and 2.9% using fixed threshold. The gap is higher in the northern part of the country (4.8% and 3.6% for the Adamawa and Far-north regions respectively).

[2] Some studies often use a standard threshold of 2,400 kcal/capita/day.

3.2. Determinants of household food insecurity

The results of the binary logistic regression are presented in Table 2. Model evaluation is done by looking at Likelihood Ratio Test. The LR chi2 value is 318.09 with p-value of 0.00, so the model is fit and there is at least one variable that can describe household food security status. The coefficients are interpreted at 1%, 5% and 10% significance level.

The fact that household head has a secondary job or practices hunting, is not related to the food security status of the household. Nevertheless, practice of agriculture is related to food security status of the household. The fact for a household head to practice agricultural activities as sharecropper positively affects food insecurity of the household. The odd ratio in favour of food insecurity is increased by 1.70 as the household head is sharecropper as compared to the situation where he is land owner. This result can be due to the fact that farmers who are sharecroppers have to sell or offer part of their production to fulfil the land's rights of exploitation, which can limit their food supply.

Table 2 - Results of the logistic regression

Variables	Odds ratio	P|>z
Level of education of the household's head (Ref: No education)		
Primary	-0.83	0.10
Secondary1	1.03	0.84
Secondary2	1.70	0.03**
University	-0.44	0.21
Household-head's gender (Ref: male)		
Female	-0.57	0.0***
Household size (Ref: 1 person)		
2-3 persons	-0.65	0.00***
4-5 persons	-0.34	0.00***
6-7 persons	-0.25	0.00***
8 persons and +	-0.21	0.00***
Household-head's socioeconomic group (Ref: senior executive in public private)		
Farmer	-0.86	0.56
Own behalf	-0.94	0.81
Region (Ref: Adamawa)		
Centre	-0.36	0.00***
East	-0.58	0.04**
Far-north	1.54	0.02**
Littoral	-0.26	0.00***
North	-0.85	0.47
North-west	-0.47	0.00***
West	-0.71	0.12
South	-0.49	0.06**
South-west	-0.55	0.02**
Hunting (Ref: yes)		
No	1.09	0.57
Household-head's age (Ref: less than 30 years)		
30-39 years	-0.79	0.11
40-49 years	1.52	0.01***
50-59 years	1.35	0.06*
60 years and +	-0.90	0.53
Practice agricultural activities (Ref: yes, owner)		
Yes, sharecropper	1.70	0.04**
Yes, free exploitation	-0.80	0.51
Secondary job (Ref: yes)		
No	-0.87	0.18
Distance between household and the nearest market (Ref: less than one kilometer)		
1-2 kilometers	1.02	0.86
3-4 kilometers	0.97	0.84
5 kilometers and +	1.23	0.11
Quantitative variables		
Area of land cultivated	-0.99	0.86
Constant	-	-
Summary statistics of the model		
LR chi2(17) = 318.09	Prob>chi2 = 0.00	
Log likelihood = 1,634.15	Pseudo R2 = 0.09	
Number of observations = 2,826	Corrected Classification Rate (CCR) = 0.64	

Source: *Authors' calculations using CHCS 2007*

*** Significant at 1%, ** significant at 5%, * significant at 10%.

The farmland size appears not to be related to the food security status of the household. This result is similar to that obtained by Babatunde (2007), in his study on the food security of rural households in northern Nigeria. In that study, as it is the case with this one, the unit of cultivated surface is hectare, which can be considered as huge for household for which access to land is not easy.

Our results highlight a link between region of residence and food insecurity. Except North and West regions, the effect of other regions on food security is significant at 5%. In light with our descriptive statistics, the sign (positive) of the coefficient related to the Far north region means that as compared to a household living in Adamawa, the risk for a household living in Far north to be food insecure is 1.54 times higher. In addition, this risk is 0.58, 0.55, 0.47, 0.36 and 0.26 times lower for the Littoral, Centre, North-west, South-west and East regions respectively. The order of vulnerability to food insecurity by region can be established as follows: Far north, Adamawa, Littoral, Centre, North-west, South, South-west and East.

Household size has a positive and significant relationship with the probability of being food secure. The magnitude of the effect decreases with the size of the household, ranging from 0.65 for households having 2-3 persons to 0.21 for those having more than 8 persons. Here, we can consider the size of the household as a factor of diversification of agricultural labor force and source of income at the household level.

Households headed by females have a higher probability of being food secured than their male counterparts. Indeed, the risk for a rural household headed by a woman to be food insecure is 0.57 times less than that of a household headed by a man. This result was not unexpected since most women are more adept than men in issues involving expenditure and calorie. There is another argument that food activities (purchasing, preparation, etc.) is most of time concerned with the female, so a household having female household head is more independent in these spending on food as compared to household headed by males.

The age of the household"s head seems to negatively influence the household food security situation. Two of the categories of this variable are significant (this is 40-49, and 50-59). Having household head aged 40-49 and 50-59, the chances of the household of being food insecure are 1.52 and 1.35 times respectively higher as compared to a household whose head is less than 30 years. The younger people are stronger than the elders and can perform tougher jobs in field. Moreover, households with older heads are the multigenerational households having more retired and/or older persons to feed. This may explain the negative effect of this variable on household food security. On the other hand, there is equal possibility that the older household heads have low tendency of adopting improved technology in agriculture and also economically not much active compared to younger one. In a related study, Bashir et al. (2012) found that an increase of one year in the age of household head decreases the chances of the household to become food secure by 3%. Similar relationship was observed by Titus and Adetokundo (2007) for Nigeria.

Summing up our results, the key determinants of rural household"s food insecurity, according to CHCS 2007, are the region of residence, mode of farmland ownership, household size, household head"s age and household head"s gender.

4. Conclusion and policy implications

This study has two main objectives: determine the food security status of rural households in Cameroon and identify the main determinants of household"s food insecurity. We used the household caloric acquisition method of estimating food security status. We also performed a bivariate logistic regression to identify key determinants of food insecurity.

The results reveal that 34% of the rural households were not able to meet the daily recommended caloric requirement. Concerning descriptive analysis, we noticed a considerable disparity of food insecurity distribution across regions. The northern part of the country is more vulnerable to food insecurity.

Further, the study has shown that the major factors affecting food security of rural households are: region of residence, mode of farmland ownership, household size, household head"s age and household head"s gender. More specifically, compared to a household living in Adamawa, the risk for a household living in Far north to be food insecure is 1.54 times higher. The econometric analysis allowed us to establish an order of vulnerability per region. It also allowed us to have some socioeconomic and demographics factors of food insecurity.

In the light of these results, we can make recommendations concerning policy of fighting against food insecurity, and give some orientations for future researches. The region of the Far North should be preferred for eventual policies of fighting against food insecurity. Rural households that the head"s age is high must have priority, and resident rural population should be encourage and help to own land. It is also suggested that income generating opportunities need to be created along with improvements in secondary and technical education systems.

Finally, we recommend that further studies should be conducted in the area of food insecurity by considering detail and accurate information on various variables including political, climatic and weather (rainfall and temperature), topology, natural disasters, ecological conditions and other factors that affect food insecurity.

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Do Boys Eat Better than Girls In India? Longitudinal Evidence on Dietary Diversity and Food Consumption Disparities among Children and Adolescents

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ABSTRACT

This paper examines the dynamics of gender-based disparities in the intra-household allocation of foodduringchildhood and adolescence in India by using three rounds of longitudinal data from two cohorts. While no gender-based disparities in dietary diversity occur at 5, 8 and 12 years old, a marked pro-boy gap emerges at 15 years old. Specifically, mid-adolescent girls tend to consume fewerprotein- and vitamin-rich foods such as eggs, legumes, root vegetables,fruit and meat.This result is robust to gender differences between adolescents in terms of puberty onset, time use and dietary behaviours. Finally, gender disparitiesin dietary diversityinmid-adolescence do not vary by maternal education, poverty or place of residence, whilst they are moderated by levels ofthe caregiver's educational aspirations. Specifically, the pro-boy bias is particularly marked amongst adolescents with 'academically aspiring' caregivers.

Keywords: Gender; Dietary diversity; India; Intra-household dynamics; Adolescents

Classification codes: J130; J160; I140; I132

PAPER

1. Introduction

In India,undernutrition and micronutrient deficiencies are widespread, despite rapid economic growth (Deaton andDrèze 2009). Analysis of the latest national-level data available (from 2005)shows no significant differences in stunting between boys and girls under the age of 5 years (Tarozzi 2012;Corsiet al. 2015).Employing the same data, Tarozzi (2012) documents a gender-neutral situationin terms of anaemia for children under5 years old. The evidence on gender-based discrimination in feedingpractices, conversely, is mixed: while infantgirls appear to be systematically breastfed for shorter periodsthan boys (JayachandranandKuziemko 2012; Barcelloset al. 2014; Fledderjohann et al. 2014),there is no conclusive indication of a female disadvantage with regard to the intra-household allocation of foodin the case ofpre-schooland school-age children. For instance, Borooah (2004) demonstratesa pro-boy bias in dietary diversity only in the case of children aged up to 24 months born to illiterate mothers, whileDasGupta (1987) reportsthat infant girls and boys receive similar caloric intakes, although girls tend to be fed with more cereals while boys are given more milk and fats. In a more recent paper, Fledderjohann et al (2014) also report higher chances of milk consumption for under-5 boys as compared to their peers.Further, Kehoe et al. (2014) report no gender differentials in the dietary patterns of 10-year-olds in South India.

The absence of evidence related to gender-based gaps in anthropometric indicators[1] and the relativelynuanced picture with regard to feeding practicescontrasts to a wide literature documenting stark pro-boy biases in other dimensions of child development in India. Girls' disadvantage is systematically reflected in higher selective abortions and under-5 mortality rates (Jha et al. 2011; Tarozzi 2012), as well as in lower levels of immunisation (Prustyand Kumar 2014),worse educational outcomes (Derconand Singh 2013; Woodhead et al. 2013) and lower aspirations (Derconand Singh 2013; Beamanet al.2012).These pro-boy biases appearto start early – often even before children are born – and tend to increase as children are reaching adolescence (Pells 2011; Derconand Singh 2013).

In contrast to the evidence for young children, the 2005 nationally representative data revealsizeablegender inequalities in diets and nutrition indicators in the case of adults.

[1] Possible explanations for the absence of gender gaps in nutrition can relate to the mixed evidence on dietary practices or, as suggested by Marcoux (2002), to the higher biological resilience of girls.

Compared to males, Indian femalesaged 15–49 years old appear to be systematically consuming nutrient-rich foods less frequently and to be twice aslikely asmen to suffer fromanaemia,anon-communicable condition often caused by nutritionally inadequate diets (IIPS 2007; Arnold et al. 2009). The question of when such gender differentials in dietary and health outcomes emerge is, as yet, open, owingmostlyto adearth of large-scale surveys for groups other than pre-schoolers and adults (Kehoe et al. 2014). Longitudinal data are particularly scarce. In turn, the lack of systematic evidence on nutritional indicatorsdisaggregated by age and genderstands as a critical knowledge gap for the optimal design of policies that targetgroups at particular risk,such as adolescent girls and pre-pregnant women (Haddad et al. 1997; Coffey 2015).

This paper attempts to address this question for the first time by employingrich, longitudinaldata from Young Lives.Specifically, by using three rounds of survey data collected in 2006, 2009 and 2013 on two cohorts of children in Andhra Pradesh and Telangana, which together account for the fifth-largest population in any state in India[2], to document the associations between dietary diversity and gender at 5, 8, 12 and 15 years old, after controlling for a large set of child and household characteristics.

Individual dietary diversity is a synthetic measure of dietary quality(Ruel 2002). The indicator is associated with intakes of macro- and micronutrients, as well as with anthropometrics and health outcomes (Arimond and Ruel 2004). A diet that includes a balanced mix of foods rich in protein and vitamins – from items such as dairy products, eggs, meat and fish, and fruits and vegetables – is fundamental for the proper physical and cognitive development of children and adolescents, who are particularly vulnerable to malnutrition owing to their higher nutrient requirements and vulnerability to infectious diseases (Steyn et al. 2006). Qualitative evidence shows that both children and parents in theYoung Lives India sample attach intrinsic value to a varied and good-quality diet, beyond its role in promoting health outcomes (Aurino and Morrow 2015).

The analysis presented in this paper shows that while no gender disparities in dietary diversity existed at 5, 8 or 12 years old, or only slight ones, a pro-boy gap of almost half of a food group emergedat 15 years. Boys' advantage in dietary quality is mostly driven by the consumption of protein- and vitamin-rich foods, such as eggs, legumes, root vegetables, meat and fruit. The result is robust to the inclusion of indicators related to puberty, time use and dietary behaviours. Moderation analysis explores furtherwhether the pro-boy advantage during mid-adolescence varies by levels of maternal education, poverty, place of residence, orcaregiver'seducation aspirations as a proxy measure for parental attitudes towards the adolescent.

While no differences are detected along the maternal education, poverty orplace of residence axes,the treatment of adolescent boys and girls in respect of receiving a nutritious diet varied according to the levels of caregivers'aspirations.Specifically,the pro-boy gap is particularly marked amongst adolescents with 'academically aspiring'caregivers.Although the framework employed in this paper only allows for descriptive evidence and not full causal analysis, this result is suggestive that parental attitudes and aspirations towards the adolescent may constitute an exacerbating factor for gender differentials in diet during mid-adolescence. This evidenceis particularly relevant to the Indian context, for several reasons. First, the country is home tothe highest population of 10-to24-year-olds in the world (UNFPA 2014). Adolescent health, particularly that ofgirls, has been madea key policy priority in order to enable the country to benefit from the demographic dividend, as underscored by the 2014 National Youth Policy (Government of India 2014). Secondly, India bears one of the highest burdens of malnutrition globally, both for children and women (Coffey 2015). As child-bearing is concentrated in the age range in which Indian women are most likely to be underweight, improving dietary habits for adolescent girls and pre-pregnant women, beyond representing a development objective per se, can helpto break the transmission of malnutrition from one generation to the next (Black et al. 2013; Coffey 2015).

This analysis contributes to the literature in various ways. First, it adds to previous economicsresearch on gender-based inequalities in children's dietary practices in India (Borooah 2004; JayachandranandKuziemko 2012; Barcelloset al. 2014; Fledderjohann et al. 2014). In contrast to these studies, which focus on children under5 years of age (usually with cross-sectional data), this paper focuses on school-age children and adolescents, and presents adynamic picture of gender differentials in dietary qualityas children grow up and transition to adolescence.Further, by providing evidence from a large sample, it complements two strands of literature: on the one hand, it adds to the knowledge base on children and adolescents' dietary diversityin low-resource settings, which is still quite limited, and usually relies on rather small and cross-sectional samples (Kehoe et al. 2014).[3] On the other, it complements previous anthropological and demographicevidence that documents gender-based variation in the intra-household allocation of food to children ofdifferent ages in India and South Asia (Gittelsohn 1991; Dasgupta 1987, 1997;Palriwala 1993;Harriss 1991; Messer 1997; Mondal 2009).

The paper proceeds in the following way: Section 2 introduces the data, while Sections 3 and 4 respectively present the basic results and some possible explanations for the emergence of the gap during mid-adolescence. Section 5 explores the role of potential moderating factors in exacerbating or moderating gender differentials during mid-adolescence. Section 6 concludes.

[2] Thesestateswereuniteduntil June 2014, with a joint population of 84 millionpeople in 2011. Since the data I use werecollectedbefore the division, I will from nowongenericallyrefer to "AndhraPradesh".

[3] An exception is Woldehannaand Behrman (2013) who use data from the Young Lives Younger Cohort children in Ethiopia to analyse dietary diversity for children at 5 and 8 years old.

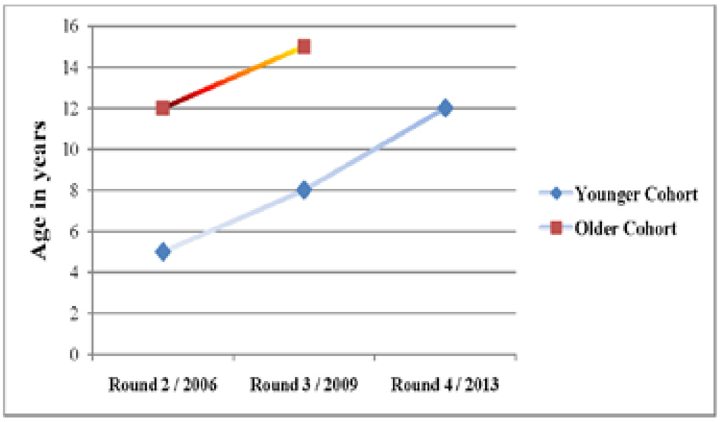
2. Materials and Methods

2.1. Sample

This paper draws on data on two cohorts of children collected by the Young Lives study in the state of Andhra Pradesh, India[4]. The sample was selected through a 'pro-poor' and multi-stage sampling procedure: first, local experts selected 20 'sentinel sites' or clusters per country whileoversampling sites covering more disadvantaged areas. Within each sentinel site, 100 households with a child born in 2001–02 and aged between 6 and 18 months (Younger Cohort) and 50 households with a child born in 1994–5 aged between 7 and 8 years (Older Cohort) were randomly selected (Barnett et al. 2012). For this reason, the sampleis not nationally representative, although careful comparisons with nationally representative surveys show that the variability in the Young Lives sample is comparable to the variabilitythat can be observed in the population as a whole (ibid.).

This analysis draws on data collected in Rounds 2, 3 and 4 of the survey, which took place in 2006, 2009 and 2013 respectively. Younger Cohort children were aged approximately 5, 8 and 12 years old in Rounds 2, 3 and 4, while Older Cohort children were aged 12 and 15 years old in Rounds 2 and 3 (see Figure 1). The first round of survey is not included in this analysis as it didnot includea section on dietary diversity, while the latest round of data for the Older Cohort sample is excluded for two reasons: first, this paper focuses on childhood and adolescence, and second, about half of the Older Cohort sample, at 19 years old,had left their households to get married, which could potentially lead to issues of comparability of dietary patterns with previous rounds. Attrition in the Young Lives sample is extraordinarily low: 95 per cent of the initially surveyed Younger Cohort children were still in the sample in Round 4, and 97 per cent of the Older Cohort sample was tracked until Round 3. Nonetheless, the analytical sample for this analysis was restricted to those children that were present in all the relevant rounds (n=1,915 for the Younger Cohort and n=976 for the Older Cohort) in order to address potential concerns that changes over time may be partially driven by different sample sizes and sample composition.[5]

Figure 1. Data structure, by cohort and round



2.2. Dependent variables

Dietary diversity relates to the number of food groups consumed by an individual in a given reference period (Ruel 2002). The Young Lives study collected data on the child's consumption in the previous 24 hours of 13, 17 and 15 food items in Rounds 2, 3 and 4 respectively[6]. Data werereported by the caregiver in the case of children aged 5 and 8 years old, and by the child in case of 12- and 15-year-olds.

Data on food items were rearranged into seven food groups in order to construct the dietary diversity measure proposed by Swindale and Bilinski (2006):(i) grains, roots or tubers; (ii) fruits and vegetables; (iii) meat, offal and fish,[7] (iv) eggs; (v) pulses and legumes; (vi) milk and dairy products; (vii) food cooked in oil or fat.

[4] Young Livesis an internationalstudy of childhoodpovertythatfollowstwocohorts of children in Ethiopia, India, Peru and Vietnam. More information isavailableat www.younglives.org.uk.

[5] Results are robust to the use of the full sample for each round.

[6] This information does not include quantities of food consumed, which implies that it is not possible to conduct any further analysis beyond consumption of the items.

[7] In Rounds 2 and 3, fieldworkers were instructed to code eggs meat and fish as 'not applicable' if the child was vegetarian. In practice they were however coded as missing values. In order to avoid the loss of information stemming from these missing values, meat and fish were recoded as if they had not been consumed if the following conditions held: (i) both variables simultaneously missing; and (ii) all the remaining questions related to the consumption of the other food items were not missing. The same was done in the cases of children having simultaneous missing values for eggs, meat and fish and all the remaining food groups not missing. This resulted in a recoding of 56and 40 observations in Round 2 and 106 and 54 observations in Round 3 for the Younger Cohort and Older Cohort respectively. A vegetarian variable was created following this recoding and used as a control in the analysis.

The dietary diversity measure accordingly ranges from 0 to 7, which respectively indicates whether the child has consumed any or all of the food groups in the past 24 hours. This index was selected as it is specifically validatedto provide a proxy of nutritional status of children and adolescents in low- and middle-income countries.[8]

In order to allow for an in-depth analysis of which food items would drivethe variation in the aggregate dietary diversity measure, dichotomous variables related to the consumption of the following ten food items were also constructed: (i) cereals, (ii) starchy roots; (iii) legumes; (iv) milk and dairy products; (v) eggs; (vi) meat; (vii) fish; (viii) oil and fats; (ix) fruit; and (x) vegetables.

Descriptive statistics regarding dietary diversity and the consumption of food items ineach round and by each cohort are reported in Table 1.In comparison to other studies conducted in low-resource settings,[9] dietary diversity in this sampleisrelatively low at all ages and for both cohorts, with an average consumption of about four food groups in the previous 24 hours. Most young peopletended to consume cereals, oil and vegetables, with substantial variation with regard to the consumption of animal-source foods or fruits, rootsand legumes.

Table 1 - Descriptive statistics: Dietary diversity and consumption of different food items among children at different ages and in both cohorts (mean withstandard deviation in parentheses)

	Younger Cohort			Older Cohort	
	Age 5	Age 8	Age 12	Age 12	Age 15
Dietary diversity	4.22	4.25	4.16	4.13	4.17
	(0.92)	(0.80)	(0.87)	(0.98)	(0.84)
Cereals	0.99	0.98	0.95	0.99	0.97
	(0.08)	(0.15)	(0.23)	(0.11)	(0.16)
Roots	0.30	0.36	0.41	0.30	0.37
	(0.46)	(0.48)	(0.49)	(0.46)	(0.48)
Legumes	0.45	0.29	0.24	0.39	0.33
	(0.50)	(0.45)	(0.43)	(0.49)	(0.47)
Milk	0.65	0.83	0.74	0.64	0.78
	(0.48)	(0.38)	(0.44)	(0.48)	(0.41)
Eggs	0.18	0.20	0.24	0.19	0.19
	(0.38)	(0.40)	(0.43)	(0.39)	(0.39)
Meat	0.10	0.11	0.14	0.10	0.13
	(0.30)	(0.31)	(0.34)	(0.30)	(0.34)
Fish	0.05	0.02	0.03	0.06	0.02
	(0.21)	(0.15)	(0.18)	(0.25)	(0.16)
Oil	0.96	0.94	0.97	0.92	0.90
	(0.20)	(0.23)	(0.18)	(0.27)	(0.31)
Fruit	0.42	0.31	0.44	0.41	0.34
	(0.49)	(0.46)	(0.50)	(0.49)	(0.47)
Vegetables	0.94	0.97	0.97	0.93	0.97
	(0.24)	(0.16)	(0.18)	(0.26)	(0.18)

[8] In contrast to Swindale and Bilinski, Round 2 data did not allow for the distinction between 'Vitamin A-rich plant foods' and 'Other fruits and vegetables', which resulted in the generation of seven food groups instead of the original eight groups, as it would not have been possible to compare dietary diversity between Round 2 and Rounds 3 and 4.

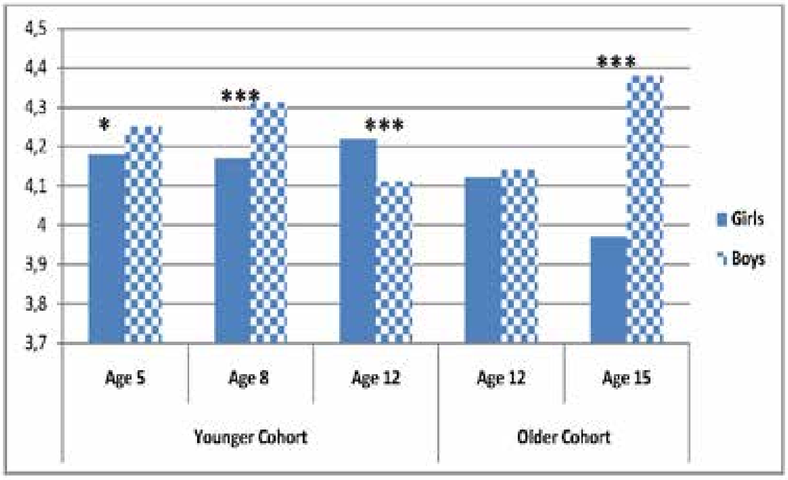
[9] See Steyn et al. (2006) for a review.

3. Results

3.1 Basic result: the emergence of gender-based gaps in dietary diversity during mid-adolescence

Figure 2 presents mean values of the dietary diversity measure disaggregated by child gender and cohort for each round of data.While genderdisparities are statistically significant at all ages except for 12-year-old Older Cohort adolescents, the gap is particularly marked at 15 years old. At this age, the pro-boy difference in dietary diversity accountsfor more than 40 percentage points of a food group.

Figure 2 - Mean of children's dietary diversity by gender, for each cohort and round



**p<0.1, ***p<0.01*

Would the observed gender-based gaps at different ages be significant even after controlling for child- and household-specific factors that are likely to influencedietary quality? To address this question, I rely on a standard multivariate set-up:

$$y_{ij,t} = \beta_0 + \beta_1 M_{ij} + \beta_2 X_{ij,t} + \gamma_j + \varepsilon_{ij,t} (1),$$

where$y_{ij,t}$ relates to dietary diversity of child i, living in cluster[10] $j$and measured at time t;M_{ij} is a dichotomous variable related to child gender, and $X_{ij,t}$relates to contemporaneous observable child, parental and household characteristics. Additionally, γ_j is a vector of time-invariant community characteristics and $\varepsilon_{ij,t}$ is the error term. The vector of child and household covariates$X_{ij,t}$ includesthe following covariates: child caste and birth order; maternal and parental years of schooling;[11]gender of the head of the household; and household's size and the logarithm of consumption per capita in rupees.The set of covariates also includes adichotomous variable related to whether the child wasvegetarian, another to whether an older brother was living in the householdand an interaction term between being a girl and having an older brother. The former controls for the lacto-vegetarian diet pattern, which is common amongst Hindu children (Kehoe et al. 2014), whilethe latter two control for the demographic characteristics of the siblings, which JayachandranandPande

10 Cluster and community are used as synonyms.

11 Religious and adult education were recoded as 0 years of education.

Table 2 - Descriptive statistics:Child and household characteristics, by age and cohort (mean withstandard deviations in parentheses)

Variable	Younger Cohort Age 5	Age 8	Age 12	Older Cohort Age 12	Age 15
Male	0.53	0.53	0.53	0.49	0.49
	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)
Scheduled Caste[a]	0.18	0.18	0.18	0.20	0.20
	(0.39)	(0.39)	(0.39)	(0.40)	(0.40)
Scheduled Tribe	0.13	0.13	0.13	0.10	0.10
	(0.33)	(0.33)	(0.33)	(0.30)	(0.30)
Backward Caste	0.48	0.48	0.48	0.49	0.49
	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)
Other Caste	0.21	0.21	0.21	0.21	0.21
	(0.41)	(0.41)	(0.41)	(0.40)	(0.40)
Child is Hindu	0.91	0.91	0.91	0.92	0.92
	(0.27)	(0.27)	(0.27)	(0.27)	(0.27)
Vegetarian	0.03	0.05	0.13	0.05	0.06
	(0.17)	(0.23)	(0.34)	(0.22)	(0.23)
Child birth order	2.03	2.03	2.03	2.33	2.33
	(1.12)	(1.12)	(1.12)	(1.38)	(1.38)
Child has male older brother	0.32	0.32	0.32	0.41	0.41
	(0.47)	(0.47)	(0.47)	(0.49)	(0.49)
Girl has elder brother	0.15	0.15	0.15	0.21	0.21
	(0.36)	(0.36)	(0.36)	(0.41)	(0.41)
Mother's years of education	3.50	3.51	3.50	2.54	2.54
	(4.39)	(4.39)	(4.39)	(3.96)	(3.96)
Father's years of education	6.24	6.22	6.24	5.30	5.30
	(6.21)	(6.19)	(6.21)	(6.19)	(6.19)
Household head is female	0.01	0.01	0.01	0.08	0.08
	(0.12)	(0.12)	(0.12)	(0.27)	(0.27)
Logarithm consumption expenditure per capita	6.58	6.66	6.73	6.69	6.81
	(0.53)	(0.53)	(0.60)	(0.55)	(0.55)
Household size	6.5	6.82	6.99	5.85	6.13
	(2.74)	(3.01)	(3.12)	(2.31)	(2.64)
Observations	1915	1915	1915	976	976

[a]Caste in India is divided into four official categories. Scheduled Tribes, Scheduled Castes and Backward Classes are recognised in the Constitution of India as historically disadvantaged, while Other Castes are the more privileged and socially and educationally advantaged castes.

Table 3 presents theempirical results based on the specification outlined above, where the relationship between dietary diversity and child genderfor each cohort and age is estimated through ordinary least square (OLS) regressions with community fixed effects.[12] Communityfixed effects are included in order to control for the set of environmental factors ""that are reasonablyconstant over time (e.g. agro-ecological characteristics, cultural preferences around food, etc.), as they may affect the diets of children living in differentcommunities.[13] A potential drawback of the OLS approach is that it may lead to biased estimates of the gender coefficient because ofthe potential correlation between child gender and unobservable child and parental characteristics that may affect the intra-household allocation of good food. While this issue is partially taken into account by the child and household controls included in the model, the present empirical strategy only aims at documenting patterns of associations between child gender, age and diet, and not at claiming causal findings.

[12] The use of the OLS model implies treating the dietary diversity variable as continuous, as in Amugsiet al.(2015) or Jones et al.(2014). This choice was motivated by the ease of the interpretation of the linear model as compared to alternatives such as ordered logistic regression. Sensitivity analysis undertaken through ordered logit models confirms that the choice of the linear model does not distort the findings (results available from the author).

[13] A similar approach is taken by Derconand Sánchez (2013), who use the terms 'community' and 'cluster' synonymously.The use of this technique however inevitably reduces theR-squared of the regression models. I use Round 2 as the reference sentinel site for the community fixed effects.

As compared to the difference-in-means approach presented in Figure 2, the male coefficient now provides a measure of the magnitude and statistical significance of the gender-based gap after controlling for child- and household-specific characteristics and community heterogeneity. With the exception of 12-year-old children in the Younger Cohort, the male coefficient is always positive, which indicates that boys tend to enjoy better diets at different ages. However, the association between gender and diet is only statistically significant at 15 years old, accounting for about half of a food group.

The coefficients of the childand household covariates reveal other interesting patterns. As expected, child dietary diversity is positively associated withincreases in household consumption levels, while the relation between caste and diet variesby age and cohort. Additionally, while at earlier stages of childhood, factors related to socio-economic status such as household consumption levels and caste seem to be driving most of the variation in children's diets, at 15 years old gender appears to be the most critical factor associated withimproved dietary diversity levels. Other potential explanatory factors such as household size and father's years of education do not seem to contribute strongly to children's dietary diversity, while maternal education appears to be weakly associated withbetter diet only at 12 and 15 years old.A similar lack of association between parental education and children's diets in South India is found in Kehoe et al. (2014). This may be explained by the correlation of parental education with household socio-economic status, which is controlled for by consumption levels, and/or by the widespread recognition amongst caregivers of the importance of nutritious diets for child development, irrespective of their education status (Aurino and Morrow2015). In contrast to Jayachandran and Pande (2015), whofind a strong birth order gradient and disadvantage in anthropometric indicators for second-born young girls who donot have elder brothers, no association with dietary quality is found in this sample.

Table 3 - Dietary diversity, by round and cohort (OLS estimates)

	(1) Age 5 (YC– Round 2)	(2) Age 8 (YC– Round 3)	(3) Age 12 (YC– Round 4)	(4) Age 12 (OC– Round 2)	(5) Age 15 (OC– Round 3)
Male	0.101	0.105	-0.090	0.025	0.436***
	(0.068)	(0.061)	(0.062)	(0.122)	(0.099)
Scheduled Caste	-0.168	-0.155**	-0.109	0.026	0.014
	(0.099)	(0.069)	(0.067)	(0.117)	(0.084)
Scheduled Tribe	-0.206**	-0.002	-0.026	-0.072	0.138
	(0.086)	(0.067)	(0.126)	(0.114)	(0.085)
Backward Caste	-0.097	0.010	-0.063	-0.053	0.048
	(0.065)	(0.056)	(0.055)	(0.091)	(0.064)
Child is Hindu	-0.087	-0.072	0.121	0.012	0.145
	(0.099)	(0.050)	(0.072)	(0.108)	(0.130)
Child is vegetarian	0.169	-0.171	-0.207**	0.167	0.059
	(0.115)	(0.100)	(0.076)	(0.112)	(0.085)
Child birth order	0.023	0.005	0.010	-0.018	-0.006
	(0.020)	(0.025)	(0.028)	(0.023)	(0.025)
Child has older brother	-0.024	-0.110**	0.008	0.037	0.046
	(0.058)	(0.040)	(0.061)	(0.097)	(0.101)
Girl has older brother	0.003	0.011	0.025	-0.047	0.002
	(0.075)	(0.060)	(0.066)	(0.106)	(0.100)
Mother's years of education	0.008	0.004	0.012*	0.027***	0.012*
	(0.006)	(0.005)	(0.006)	(0.009)	(0.006)
Father's years of education	0.001	0.005*	-0.000	-0.003	0.003
	(0.005)	(0.003)	(0.002)	(0.004)	(0.004)
Household head is female	-0.059	-0.024	0.096	0.127	-0.023
	(0.181)	(0.140)	(0.120)	(0.116)	(0.104)

Table 3 segue **- Dietary diversity, by round and cohort (OLS estimates)**

Logarithm consumption expenditure per capita	0.446***	0.287***	0.072	0.234***	0.108**
	(0.090)	(0.053)	(0.051)	(0.065)	(0.047)
Household size	0.021***	0.005	-0.002	0.008	0.012
	(0.007)	(0.005)	(0.007)	(0.015)	(0.010)
Constant	1.198*	2.321***	3.637***	2.480***	2.923***
	(0.608)	(0.368)	(0.380)	(0.457)	(0.383)
Observations	1,829	1,829	1,823	941	939
R-squared	0.093	0.063	0.020	0.038	0.085
Communityfixed effects?	YES	YES	YES	YES	YES
Adj. R- squared	0.09	0.06	0.01	0.02	0.07

*Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1*

The results presented so far show the emergence of gender-based gaps in dietary diversity during mid-adolescence. Gender- and age-specific gaps in dietary diversity are explored further by pooling data from the Younger and Older cohorts and treating them as repeated cross-sections. Specifically, I estimate the following model:

$$y_{ij,t} = \beta_0 + \beta_1 M_{ij} + \beta_2 X_{ij,t} + \beta_3 M_{ij} * Age_{ij,t} + \beta_4 Cohort_{ij} + \beta_5 Age_{ij,t} + \gamma_j + \varepsilon_{ij,t} \,(2).$$

Dietary diversity is now a function of the male dummy, the set of child and household characteristics introduced above, male–age interactions, and cohort and age dummies. Male–age interactions are included in order to capture gender-specific gaps in the way parents allocate foods at a given age. Cohort- and age-specific dichotomous variablesrespectively relax the assumptions that the relation between age and diet is the same across different stages of child development, and that structural patterns in diets are invariant across the two cohorts. Column 1 in Table 4 presents results from this pooled model, where only the coefficients related to male and the male–age interactions are displayed, as they constitute the parameters of interest of this model.[14] Estimates have been obtained through OLS,including communityfixed effects. In line with the results presented in Table 3, Column 1 shows that there are no statistically significant differences in thedietary diversity indicatorbetween being a boy at 8 and 12 years old as compared to the baseline category of 5-year-old girls. In contrast, the coefficient associated with15-year-old boys is strong and significant, accounting for about 35 percentage points of the dietary diversity measure, which corroborates the finding related to the emergence of gender differences in dietary quality during mid-adolescence.

With regard to the other controls, the key patterns of association between child and household covariates and dietary diversity do not substantially change from the ones shown in Table 3.[15] Specifically, the negative association with marginalised castes (as compared to the omitted category of Other Caste) and the positive association with household consumption levels become stronger. No statistically significant association between dietary diversity and age or cohort is found.

Which foods are driving the observed gender-based variation in dietary diversity during mid-adolescence? Columns 2–7 in Table 4 address this question, where the outcome variables now relate to the consumption of the differentfood items. Results related to the food itemsthat mostly relate to protein and micronutrient intakes are reported[16]. Estimateswere conducted through the use ofthe linear probability model (LPM) with community fixed effects.[17] At 15 years old, girls are systematically less likely to consume protein-rich foods such as legumes, eggs and meat, and vitamin-rich foods such as fruit and roots as compared to when they were aged 5 years old. At 15 years old, the male–age interaction is also positively associated withthe consumption of milk, although the coefficient is not significant. Additional gender–age gaps emerge from the analysis of the interactions at the other ages considered. Five-year-old boys are more likely to consume milk and vegetables, while at 8 years old boys tend to consume more legumes. In contrast, at 12 years old girls tend to eat more eggs. This last pattern is driven by the Younger Cohort sub-sample.

Notably some of the highlighted gender and age gaps relate particularly to the consumption of some 'unitary' food itemssuch as milk, fruit and eggs. In a context such as India, where meals are usually shared from the same pot, parents may be able to discriminate betweensiblings by providingan egg, a piece of fruit or a glass of milk to the preferred child at a given age.

14 Full results are available upon request.
15 Full results are available upon request.
16 No significant result emerged for cereals and oil.
17 Although the variables related to the consumption of each food group are binary, a linear model was preferred, as in the case of dietary diversity. This choice is due to its easier interpretability as compared to non-linear models, and as it usually provides a good approximation of the response probability for common values of the covariates (Wooldridge 2010).

Table 4 - Dietary diversity and consumption of different food items (pooled data, OLS and LPMestimates, main results)

	(1) Dietary diversity	(2) Roots	(3) Legumes	(4) Milk	(5) Eggs	(6) Meat	(7) Fruit
Male	0.078	−0.000	0.002	0.047*	−0.004	-0.004	−0.003
	(0.059)	(0.023)	(0.032)	(0.027)	(0.016)	(0.010)	(0.021)
Male*8 years old	0.043	0.024	0.080**	0.008	0.018	0.032	0.004
	(0.073)	(0.041)	(0.035)	(0.030)	(0.028)	(0.021)	(0.028)
Male*12 years old	−0.130	−0.021	0.028	−0.042	−0.045**	0.003	0.023
	(0.076)	(0.029)	(0.029)	(0.035)	(0.019)	(0.020)	(0.034)
Male*15 years old	0.359***	0.141***	0.251***	0.025	0.087*	0.045*	0.080**
	(0.091)	(0.039)	(0.058)	(0.045)	(0.045)	(0.026)	(0.037)
Constant	2.389***	−0.136	0.338*	−0.237**	−0.169*	-0.087	- 0.397***
	(0.311)	(0.108)	(0.168)	(0.106)	(0.083)	(0.061)	(0.115)
Observations	7,361	7,360	7,359	7,360	7,361	7,348	7,361
Child and household covariates?	YES	YES	YES	YES	YES	YES	YES
Community fixed effects?	YES	YES	YES	YES	YES	YES	YES
Adj. R-squared	0.04	0.02	0.04	0.08	0.02	0.03	0.04

*Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1*

These findings echo a body of literature in the social sciences that reports gender- and age- based differences in the allocation of higher-quality food in South-Asian households (Gittelsohn 1991; DasGupta 1991; 1997, Harriss 1991; Palriwala 1993). In particular, Harriss (1991) and Gittelsohn (1991), in India and Nepal respectively, report no preferentialtreatment of young children based on gender with regard to nutrition inputs, and the emergence of gender-based disparities during adolescence. This may relate to adolescence being a stage in whichgender norms – including those about food - may become more pronounced. In particular, Gittelsohn's description is rather suggestive:

- While differences were never as severe as for older household women, adolescent girls were disfavored in food allocation. It is at this stage of their lives that they begin to assume many household domestic responsibilities, such as water-fetching, wood collection and food preparation. No longer children, they were served later in the meal, often in the same eating group as the mother. ...On the other hand, adolescent boys were automatically served and frequently offered second helpings ...They were also given moderate-level preference in terms of substitution and channeling, occasionally receiving special foods, and they tended to receive a great amount of food proportionate to body size. (Gittelsohn 1991: 1152)

3.2 Is the gap explained by puberty, time use and dietary behaviours?

The results from the previous section highlighted the emergence of gendergaps in diet during mid-adolescence, after controlling for a variety of observable child- and household-specific characteristics that can influence dietary quality. Nevertheless, mid-adolescent boys and girls may differ systematically insome dimensions, which may represent potential explanations for the emergence of the gap at 15 years old.

Differencesbetweenthe timing of the pubertal growth spurt ofgirls and boys, which under optimal growth conditions usually occurs at 11 years old in girls and 13 years in boys (Rogolet al. 2000), can be one of those factors. Puberty is a phase of radical physical changes, including significant height and weight gain, and increased nutritional requirements. It may therefore beplausible that parents, by witnessing the rapid growth of the adolescent during this stage, would provide him/her with a more varied diet and with foods of higher nutritional quality. Following this line of reasoning, the pro-boy gap at 15years old would arise due to the lateronset of puberty for boys as compared to girls.

Similarly, the gendergap may be driven by systematic differences in time-use patterns between boys and girls that get more pronounced in adolescence, which may in turn influence how parents allocate foods within the household. Time use is highly gendered in India, with girls spending more time on unpaid domestic work and boys being more likely to be engaged in paid work and education (Beamanet al.2012). As genderinequalities in time use tend to widen after puberty (Pells 2011), the emergence of the gap at 15yearsold may be explained by parental bias in the intra-household distribution of food towards the adolescent that contributes most to the family budget through farm or off-farm employment, or that spends more time at school or studying, which in both cases is usually the male (Harriss 1991; Pells 2011; Derconand Singh 2013).

By the same token, adolescent boys and girls may differ significantly with regard to their dietary behaviours, as research from both advanced economies and middle-income countries shows that genderdifferentials along this dimension tend to appear during adolescence. Compared to boys, adolescent girls – even in middle-income countries such India -generally display higher levels of dissatisfaction with regard to their body weight, which in turn is associated withgreater prevalence of restrictive dietary practices among females (CardamoneCusatisand Shannon 1996; Mallicket al. 2014; Stuparet al. 2012). Accordingly, the observed gender-based gap at 15 years old may be the result of adolescent girls' deliberate choicestocontrol their dietary behaviours in order to curb body weight gain, instead of skewed parental allocation of food towards boys of the same age.

The presence of systematic gender differentials between adolescent boys and girls in these three dimensions seems to be corroborated by the data. Table 5 presents gender-based differences between boys and girls in terms of puberty onset, time-use patterns, and dietary behaviours at 15 years old.Puberty is proxied by an indicator of height differences between 15 and 12 years old, as one of the distinguishing features of puberty is the growth spurt, where girls peak height velocity at 12 years and boys two years later (Rogolet al. 2000). On average, Older Cohort boys gained about 15 cm between Rounds 3 and 2, while girls gained 9 cm. As hypothesised, significant gender-based differences can be noted in the time-use indicators. In particular, girls reported that they tended to spend almost twomorehours than boys on household chores or caring for other family members. By contrast, boys tended to spend an additional hour per day in school or studying compared to girls. Surprisingly, there wereno gender differences in the time spent on work on the family farm or for pay.Lastly, gender differences were noticeable with regard to two indicators ofdietary behaviour:(i) number of meals(including snacks) they reported having consumedin the previous day and (ii) days per week in which the adolescent had been engaged in at least one hour of intense physical activity such as running, cycling, etc. The patterns emerging from the data are consistent with the hypothesis that adolescent girls are more likely to adopt weight-control strategies such as skipping meals orundertakingintense physical activitymore frequently than boys (CardamoneCusatisand Shannon 1996; Mallick et al. 2014).

Table 5 - Gender differences in puberty onset, time use and dietary behaviours

	Girls	Boys	Difference (Girls – Boys)
Difference in height (cm), 15–12 years old	8.69	15.20	−6.51***
Hours spent at school or studying	7.92	8.90	−0.98***
Hours spent on leisure activities	3.96	4.26	−0.30**
Hours spent on household care/chores activities	2.47	0.94	1.54***
Hours spent on family farm or business	0.45	0.54	−0.09
Hours spent on work for pay	1.03	1.05	−0.02
Number of meals on the previous day	4.49	4.69	−0.20***
Days featuringintense physical activity over last week	4.18	3.79	0.39**

*** p<0.01, ** p<0.05, * p<0.1

In order to investigate whether these factors explain the emergence of the gap in dietary qualityat mid-adolescence, two different approaches were adopted. With regard to puberty and time use, the basic cross-sectional model of Equation 1 was augmented by the relevantindicators in two separate modelsfor the sample of 15-year-olds. If puberty and/or time use are correlated withthegender-based gap, both a statistically significant association of these indicators withdietary diversity, and a change in the size and statistical significance of the male coefficient would be expected. Column 1 of Table 6presentsthe estimates for the baseline model for the reader's convenience, while Columns 2 and 3 present theresultsof the models that incorporate puberty and time use respectively. F-tests and Chow tests of equality of male coefficients in the different models (as compared to the estimate of the male coefficient from the baseline model) are also presented. Neither the puberty nor the time-use variablesare statistically associated withdietary diversity. Despitethe fact that the size of the male coefficient decreased slightly after the indicator of puberty was included, the Chow testconfirmedthe null hypothesis of the absence of statistical differences between the male coefficient from the augmented model and the baseline model. Similar results emerge when a different indicator of puberty (related to the age at which it occurs) was included, which are not shown here.

With regard to the hypothesis related to systematic gender differences in dietary behaviours, Columns 4 and 5 present the result of two models in which the two indicators of dietary behaviours were used as dependent variables in the multivariate model ofEquation 1. Once child and household characteristics are controlled for, no significant gender-based differences in dietary behaviours arenoticeable. Taken together, these results suggest that potential systematic differences between adolescent boys and girls in terms of pubertal growth spurt, time use and dietary behaviours are not able to explain the emergence of the gender gap in dietary diversity at 15 years old.

Table 6 - Dietary diversity and dietary behaviours among 15-year-olds (OLS estimates, main results)

	(1) Dietary diversity (baseline)	(2) Dietary diversity (puberty)	(3) Dietary diversity (time use)	(4) Number of meals	(5) Physical activity
Male	0.436***	0.374***	0.407***	0.129	−0.656
	(0.099)	(0.103)	(0.105)	(0.111)	(0.527)
Difference in height (cm)		0.009			
		(0.006)			
Hours spent at school or studying			0.006		
			(0.017)		
Hours spent on leisure activities			0.000		
			(0.021)		
Hours spent on household care/chores activities			−0.014		
			(0.026)		
Hours spent on family farm or business			0.017		
			(0.017)		
Hours spent on work for pay			0.004		
			(0.018)		
Constant	2.923***	3.021***	2.903***	2.828***	4.395***
	(0.383)	(0.421)	(0.514)	(0.574)	(1.030)
Observations	939	895	939	940	939
Child and household covariates?	YES	YES	YES	YES	YES
Communityfixed effects?	YES	YES	YES	YES	YES
F-test	0.000	0.000	0.000	0.000	0.000
Chow test (equality male coefficients from baseline and augmented models, p-value)		0.24	0.34		
Adj. R-squared	0.07	0.07	0.07	0.05	0.02

*Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1*

3.3. Extension: is the gap moderated by maternal education, poverty,locationor parental attitudes towards girls?

So far, the appearance ofa pro-boy gap in mid-adolescence has been documented across the whole sample. This section explores whether gender-based differentials in diet would differ across population sub-groups, as the question of whether gender inequalities in diet are exacerbated or mitigated by specific factors, such as maternal education or poverty status, has important policy implications. To this end, the modelling approach allows for gender to vary by maternal education, poverty, place of residence and parental educational aspirations. Following Dercon and Singh (2013), this is achieved in practice by augmenting the basic cross-sectional model usingan interaction variable between the gender dummy and each of those factors. A significance of the interaction term and a change in the gender coefficient would suggest thatthat specific factor magnified or mitigated gender inequalities in diet. Table 6 presentsthe coefficients for childgender and the interactions for the sample of 15-year-olds, after controlling for the set of child and household characteristics,[18] as well as F- and Chow tests. The latter compares the male coefficient from the baseline specification to the augmented models.

This analysis starts by examining the role of maternal education, as this factor emerges as critical in reducing gender inequalities in diet for young children (Borooah2004). This does not seem to be the case for adolescents, where the male coefficient is unchanged and the interaction variable is not significant. The next two models examine whether the gap varies for adolescents in the poorest tercile in terms of consumption per capita (as compared to the second and least-poor terciles)and for those living in urban areas, as povertyandplace of residencehave been shown to exacerbate discriminationagainst girls in India (Pells 2011; Derconand Singh 2013; Mukhopadhyay 2015).The empirical results show that neither financial constraintsnor place of residence contributes tointensifying the gender gap in dietary quality. Similar results are found when there is an interaction with caste is included (not shown here).

Finally, Column 5 reports the results from testing whether parental attitudes and aspirationsfor childrencan constitute a moderating factor for the gender differential in diet.For instance, Derconand Singh (2013) showed that caregivers' educational aspirations predicted both child educational aspirations and cognition, leading to increasing female disadvantage in education during adolescence in India, while Favara (2016) presented similar findings for Ethiopia. In the absence of a specific indicator related to parental attitudes towards the adolescent's health, these are proxied bya measure of the caregiver's aspirations for the adolescent's completed educational level. As in Beamanet al. (2012), the indicator assumes a value of 1 if the caregiver would like the adolescent to at least graduate from secondary school (Grade 12). This indicator is considered a good measure of parentalaspirations for the adolescent, as it is future-oriented and predictive of current behaviour (ibid.). Caregivers' aspirationswere onlyrecorded in Round 2for the Older Cohort, but this should not constitute a concern as parental aspirations and attitudestowards education are usually assumed as relatively time-invariant[19] (Rampinoand Taylor 2013). After the inclusion of the interaction between male and high parental educational aspirations, the advantage in dietary diversityis particularly marked for boys living with 'academically aspiring' parents, as compared to girls whose parents have equally high levels of educational aspirations, while the size and statistical significance of the male coefficient is less pronounced in the case of adolescents with parents with low aspirations. This result persists even after controlling for the adolescent's school enrolment status(Column 5) and time-use indicators (not shown here), as caregivers' preferences for educational achievements may be reflected in differences in those outcomes.

While this empirical framework only provides estimates of associations and not full causality, this evidence can be suggestive that, beyond educational outcomes, caregivers' educational aspirations may exacerbate gender inequalities in other dimensions, such as the intra-household distribution of food.

4. Conclusions

By using three rounds of data from the two cohorts in the Young Lives study, this paper provides original evidence on gender gaps in dietary diversity at different stages of childhood and adolescence in India. The empirical results showthat gender-based differentials in dietary quality are absent at 5, 8 and 12 years old, but that wide pro-boy gaps emerge at 15 years old. Disparities between mid-adolescent boys and girls are driven by the increased likelihood of boys to consume protein- and vitamin-rich foods. This result is robust to genderdifferentials in timing of puberty, in time use and in dietary behaviours. Moderation analysis shows that the magnitude of the gap does not vary by maternal education, poverty or rural/urban location. By contrast, once parental attitudes towards education are interacted with gender, there are smaller differences in dietary quality between boys and girls whose caregivers have low educational aspirations, and the pro-boy bias is mostly manifest amongst adolescents with 'aspirational'caregivers.

The documented variation in the intra-household distribution of highly nutritious (and generally higher-cost) foods underscores the advantages of adopting a longitudinal approach in the analysis of gender inequalities in dietary outcomes.This in turn can enhance the design and targeting of policiesaimed atimproving the nutritional status of groups at particular risk of malnutrition, such as adolescent girls in India.

[18] Full results are available from author.

[19] This is quite a standard hypothesis in the literature, although Beamanet al. (2012) showed that in certain conditions caregivers' aspirations can actually change.

Table 7 - Coefficient on male dummy and interaction of dietary diversity among 15-year-olds with key variables (OLS estimates, main results)

	(1) Dietary diversity (Maternal education)	(2) Dietary diversity (Poverty)	(3) Dietary diversity (Rural/urban location)	(4) Dietary diversity (Caregiver aspirations)	(5) Dietary diversity (Caregiver aspirations + school enrolment)
Male	0.468***	0.491***	0.376***	0.202*	0.201*
	(0.093)	(0.102)	(0.121)	(0.115)	(0.115)
Male* Mother is illiterate	−0.053				
	(0.128)				
Male* Poorest tercile		−0.224			
		(0.141)			
Male * Urban			0.216		
			(0.187)		
Male * High caregiver aspirations				0.300***	0.302***
				(0.104)	(0.103)
Currently enrolled					0.014
					(0.064)
Constant	2.824***	3.219***	2.971***	3.012***	3.006***
	(0.359)	(0.495)	(0.389)	(0.396)	(0.400)
Observations	939	939	939	939	938
Child and household covariates?	YES	YES	YES	YES	YES
Communityfixed effects?	YES	YES	YES	YES	YES
F test	0.000	0.000	0.000	0.000	0.000
Chow test (equality male coefficients from baseline and augmented models, p-value)	0.69	0.14	0.37	0.002	0.002
Adj. R-squared	0.07	0.07	0.07	0.08	0.08

*Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1*

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B11

Assessing Vulnerability to Food Insecurity in Mountain Areas of Ecuador: the Composite Vulnerability Indicator (CVI)

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ABSTRACT

Mountain communities are particularly vulnerable to food insecurity, as they live in isolated areas and fragile ecosystems characterized by poor soil quality and high risk of natural disasters. According to a study by Huddleston et al. (FAO, 2003) almost 250 million people vulnerable to food insecurity were living in mountainous areas of developing countries. A new study, started in 2014 by the Mountain Partnership, aimed to update those results: the present article is part of that study. Household survey data are used to assess the vulnerability to food insecurity of mountain peoples from Ecuador, where mountains cover about the 40% of the national territory and host almost half of the total population.

Using data from the 2011-12 Household Income and Expenditure Survey of Ecuador (ENGHUR) and matching them with the geographic location and elevation of each interviewed household, a profile of mountain peoples of Ecuador is drawn. Vulnerability to food insecurity by elevation class is then analysed through the new "Composite Vulnerability Indicator" (CVI), which takes into account the food security dimensions relevant at the household level. The final figure of people vulnerable to food insecurity is obtained assuming that, if a household is vulnerable under one dimension of food insecurity, it is vulnerable to food insecurity as a whole. Different patterns between urban and rural areas are investigated, in order to distinguish the differential drivers of vulnerability in the two areas, and social safety nets are finally taken into account.

Keywords: Mountain, Vulnerability, Food Security, Sustainable Development Goals

PAPER

1. Vulnerability to Food Insecurity in the frame of the Sustainable Development Goals

Mountain communities are particularly vulnerable to food insecurity, as they live in isolated areas and fragile ecosystems characterized by poor soil quality – shallow soils, steep slopes, moisture and temperature constraints – and high risk of natural disasters such as avalanches, landslides, earthquakes and flash floods. In addition, migrations to major urban centres and lowlands caused over time the erosion of traditional livelihood systems and an increase in food insecurity among those who remained (FAO 2002). At the household level, vulnerability to food insecurity is related to the (in)ability to cope with external shocks that impact food and nutrition security, and to come back to the original conditions once the shock is over.

Vulnerability, on the other hand, can be reduced by building resilience of both people and communities (UNDP 2014) through safety nets that guarantee a minimum acceptable level of household food security over time. They are policy measures adopted to prevent vulnerable people from falling under certain minimum levels of livelihood because of a shock. In the framework of the Sustainable Development Goals[1], targets 1.5[2], target 2.1[3] and target 13.1[4] point to the direction of reducing vulnerability to food insecurity and building the resilience of vulnerable people. Building resilience is also implicitly acknowledged in several other targets (ODI, 2015).

[1] A complete list of the SDGs and their targets is available at: https://sustainabledevelopment.un.org

[2] Target 1.5: "Build the resilience of the poor and those in vulnerable situations, and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters".

[3] Target 2.1: "By 2030 end hunger and ensure access by all people, in particular the poor and people in vulnerable situations including infants, to safe, nutritious and sufficient food all year round".

[4] Target 13.1: "Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries".

According to a study by Huddleston et al. (FAO 2003) almost 250 million people vulnerable to food insecurity were living in mountainous areas of developing countries. The present article is part of a new study started in 2014 by the Mountain Partnership - and presented at COP 21, Paris, in 2015 - aiming to update the results obtained by Huddleston et al. To show the possibilities offered by household surveys in the analysis of vulnerability to food insecurity, household survey data are used to assess the vulnerability to food insecurity of mountain peoples of Ecuador, a country where mountains cover about the 40% of the national territory and host almost half of total population.

In order to estimate the number of mountain people vulnerable to food insecurity in Ecuador, a new "Composite Vulnerability Indicator" (CVI) is derived, which encompasses three food security dimensions relevant at the household level: physical access, economic access, and utilization. The final figure of vulnerable people is then tabulated by elevation class and by urban and rural areas of the country, as well as by ethnic group. Social safety nets are finally taken into account, obtaining the number of vulnerable people not benefiting from any form of aid.

Next sections are as follows: section 2 explains the newly developed methodology of the Composite Vulnerability Indicator; Section 3 describes the main characteristics of Ecuador people by elevation class, based on ENIGHUR 2011/12 data; Section 4 introduces the results of the application of the CVI to the Ecuador case study; Section 5, finally, concludes.

2. A new Methodology: the Composite Vulnerability Indicator (CVI)

Drawing from a global GIS-based analysis of mountain environments and populations, the study of Huddleston et al. (FAO, 2003) estimated that about 40% of mountain people across the world was vulnerable to food insecurity[5].

The 2015 FAO model (FAO, 2015) builds on the 2003 model adding more information to better capture the factors contributing to ensure food security in the specific mountain context[6]. The final figures show that nearly 330 million people, corresponding to 39% of the 2012 mountain population, with higher shares in Africa and Asia compared to Latin America.

To the aims of the present article, a new methodology is proposed which makes use of household survey data in place of spatial data. The unit of analysis is the household, whose vulnerability to food insecurity is analyzed under the lens of three food security dimensions[7]:

1. Physical access to food markets. For isolated households, access to food markets is made difficult by the poor conditions, or even the absence, of transport infrastructure. Consequently, isolated households' food security is more affected by extreme climatic conditions and environmental shocks. Moreover, the opportunities to market their own products are scarce, reducing the potential to improve their livelihoods and their economic access to additional food. Physical access to food is therefore a crucial issue for mountain population that has to be taken into account into the building of a composite vulnerability indicator. The present study considers access to improved ways of transportation like paved or cobbled roads as an indicator for the physical access dimension.

2. Economic access to food. Inadequate purchasing power is generally viewed as the main cause of food insecurity at the household level. As per survey data, the most reported causes of reductions in food expenditure were related with lack of good job opportunities and of health/job assistance: this combination is therefore used to identify vulnerable households under the perspective of the economic access dimension, along with the national poverty line[8]. In rural areas, on the other hand, land ownership is used as an indicator of household resilience[9]. Additional details are provided in paragraph 4.

3. Utilization. Sufficient energy and nutrient intake is the result of good care and feeding practices, food preparation, dietary diversity and intra-household distribution of food. When combined with good biological utilization of food consumed, this determines the nutritional status of individuals.

5 People were considered vulnerable in rural areas characterized by: cereal production less than 200 kg per person; low to medium bovine density index; closed forests and protected areas. 15% of urban mountain people was also considered vulnerable.

6 Yields were taken into account not only for the main cereal crops, but also for beans, cassava and potatoes. FAO Global Land Cover map was used to identify cultivated areas, while the Spatial Production Allocation Model (SPAM) provided information on the yield of the selected crops. Yields were then converted to calories available per hectare using the nutrient values adopted by the FAO Nutrition Division. A threshold of 1,370 calories and of 14 g of protein per person per day was taken as a threshold for vulnerability. For proteins, the production of meat and other products from cattle, sheep, goats and chicken was taken into account, rather than considering just bovine density. In urban areas, the World Bank "Poverty headcount ratio at urban poverty line" was averaged across developing countries, and the resulting value (23.6%) was used as the share of vulnerable people in mountain urban areas. People living in protected areas and closed forests, instead, are not considered vulnerable in this update.

7 A fourth dimension – Availability – is not taken into account, as it is more relevant at the country level, rather than at the household level. In addition, data on food availability are only available at the national level. A detailed description of the food security dimensions can be found in FAO, 2013.

Poor hygienic conditions and the consumption of contaminated water, on the other hand, are in most cases the main determinants of health problems that may impact food utilization. In this study, access to improved water sources and presence of improved sanitation facilities are used as indicators of the utilization dimension of food insecurity.

Each dimension described above is associated to an indicator that can assume values of either 0 or 1, with 1 indicating a vulnerable household under a particular dimension and 0 indicating a non-vulnerable one. The final Composite Vulnerability Indicator (CVI) takes into account the three dimensions in order to come up with a final figure of people vulnerable to food insecurity under the assumption that, if a household is vulnerable according to one dimension, it is vulnerable to food insecurity as a whole. This means that each dimension is given the same importance and is not assigned any weight.

It is to be noted, however, that the concept of vulnerability to food insecurity should not be confused with food insecurity itself. A household "vulnerable" to food insecurity, indeed, may be or may be not actually food insecure, depending on exogenous conditions and the presence of safety nets.

3. Ecuador Mountains: Main Characteristics

Ecuador is the most densely populated country of Latin America and the Caribbean, and one of the most "biodiverse" countries in the world. With a 2014 GDP of about US$100 billion and a population of almost 16 million, the World Bank ranks it in the "upper middle income" group. At the time of the household survey, however, food insecurity was still an issue for nearly 13 percent of its population, according to the 2015 SOFI report (FAO, 2015). The Ecuadorian territory can be roughly divided into three geographic regions: the Pacific coast in the west, characterized by plains and coastal hills; the Amazon in the East, covered by rainforest; and the Andes in the Centre. Galapagos Islands are also part of the national territory.

The Andes are the longest mountain range in the world and the highest range outside Asia; they are made up of parallel ranges interspersed with high plateaus crossing the country from north to south, and covering about 40 percent of the national territory. More than one third of the mountainous territory is characterized by an elevation of 2,500 meters or more; however, due to their proximity to the Equator and hence to the lack of harsh climatic conditions, elevated plateaus have been chosen throughout history as locations for major urban settlements: nearly half of the total population of Ecuador live in mountain areas. In particular, twelve out of the 38 cities with 50,000 or more inhabitants are located in elevation class three, which is also the class with the highest value of population density (table 1). The capital Quito, located at an elevation of 2 850 m (Elevation Class 3[10]), is an urban area with infrastructure and subsidiary activities uncommon to most of the mountain areas around the world.

Table 1 - Population density and number of major cities per elevation class

Elevation class (Kapos et al., 2000)	Population density (people/km^2)	Number of cities with 50,000+ inhabitants
Class 1 (> 4,500 m)	.	.
Class 2 (3,500 – 4,500 m)	1.8	0
Class 3 (2,500 – 3,500 m)	**163.9**	12
Class 4 (1,500 – 2,500 m)	45.6	2
Class 5 (1,000 – 1,500 m)	15.7	0
Class 6 (300 – 1,000 m)	30.8	2
Class 0 (0 – 300 m)	44.9	22

Credits: Author's elaborations on data from Population Census 2010; INEC data on elevations.

Household Income and Expenditure Surveys (HIES) are a rich source of information on household livelihood. Matching survey data with the location of each household and its elevation[11] allows us to derive household statistics by elevation class and to identify patterns of living conditions and exposure to food insecurity along the different elevation classes.

8 The National Statistical Office of Ecuador (INEC) provides estimates of the national poverty line every 3 months by comparing per capita income with the consumption poverty line (línea de pobreza por consumo). All the individuals whose income is below poverty line are considered poor. As of December 2011, poverty line was set at $72.87 per month, corresponding to $2.43 per day. Using data of ENIGHUR 2011/12, per capita income of each interviewee was derived and deflated with base December 2011. Hence, while the original study used a urban poverty line averaged over the developing countries, here a national poverty line, specific for the country under analysis, is adopted.

9 See for instance: Skerrat, 2013.

10 To the aims of this article the UNEP-WCMC classification is used, described in Kapos et al. (2000).

11 No data were available on the slope of each household location, which is an important element to determine the elevation classes 4, 5 and 6; the results shown here may therefore slightly differ from those that would be obtained in presence of that piece of information. 12 Encuesta Nacional de Ingresos y Gastos de Hogares Urbanos y Rurales. Since the survey was not designed to be representative at the level of the mountain versus non mountain areas, the expansion factors have been recomputed to derive statistics representative of the population of the different elevation classes, based on the 2010 Census data.

Data presented in this case study were gathered by the Ecuadorian National Statistics Institute (INEC) in 2011–12 through a Household Income and Expenditure Survey (ENIGHUR[12]) that involved almost 40 000 households and about 150 000 people. Matching survey data with the location and the corresponding elevation of each surveyed household allowed the study to derive household statistics by elevation class and to identify patterns in the change of living conditions and vulnerability to food insecurity in the different classes. Food security statistics were derived using the ADePT-FSM tool[13], jointly developed by FAO and the World Bank.

A main feature of Ecuador mountain areas is that, while elevation Classes 2 and 5 have a strong rural character, with low population density and low number of cities, Classes 3 and 4 show the opposite characteristics. Classes 2 and 5 have the lowest percentages of dwellings with improved water sources and sanitation facilities, a high dependency ratio and the highest percentage of women among the elevation classes, suggesting that many adult men leave their families in search of better employment and economic conditions. This preliminary conclusion is supported by the results of the survey's "self-evaluation of living standards" module, which included questions on the causes of household poverty. In answering those questions, "unemployment" and "lack of good jobs" were the causes most frequently reported by respondents of those elevation classes.

The more urbanized elevation classes 3 and 4, on the contrary, are characterized by higher per capita income and a lower percentage of people working in the primary sector. Class 3 has the highest percentage of people holding a University degree and the highest standards of water and sanitation facilities among the elevation classes, but is also characterized by higher income inequality and higher food prices.

The main agricultural products by elevation class are reported in table 2. In the highest elevation class, roots, tubers and pulses compensate for the lower availability of cereals. In particular, potato is the most frequent crop in class 2, preceded by maize in the immediately lower class and also by beans in class 4. At lower altitudes, cash crops are more frequently cultivated.

The average number of cattle per household is much lower at higher elevations than at lower altitudes, while the opposite is true for sheep. Consequently, the average value of animals per person is lower (table 2).

Table 2 - Main agricultural products (based on the frequency of positive answers by respondents) and average value of sold and own consumed animals by elevation class.

	Class 2 (3500-4500)	Class 3 (2500-3500)	Class 4 (1500-2500)	Class 5 (1000-1500)	Class 6 (300-1000)	Class 0 (0-300)
Main agricultural products (ranking)	1. Potato 2. Onion 3. Broad bean 4. Barley	1. Maize 2. Potato 3. Beans 4. Broad bean 5. Alfalfa	1. Maize 2. Beans 3. Potato 4. Yucca 5. Banana	1. Maize 2. Yucca 3. Plantain 4. Beans 5. Coffee	1. Plantain 2. Yucca 3. Maize 4. Cacao 5. Potato	1. Maize 2. Plantain 3. Cacao 4. Rice 5. Yucca
Average total value of sold/own-consumed animals per hh ($)	**138**	170	223	**400**	361	283

Source: author's elaborations on ENIGHUR 2011-12 data; INEC data on elevations.

The food group "cereals and products" contribute the most to the dietary energy and protein consumption in all elevation classes, with white rice being the biggest energy contributor among the single food items. However, the share of energy derived from cereals on total dietary energy is lower in mountains than in the country as a whole, while the share of roots, tubers and pulses is higher. In quantitative terms, milk is the most consumed food item in Classes 1 through 5, while in Class 6 and in lowlands white rice is followed by green plantains. Meat and meat products contribution in total dietary energy, finally, are substantially lower in rural classes 2 and 5 if compared to more urbanized classes 3 and 4.

Households in the rural Classes 2 and 5 spend the highest income portion on food and are characterized by the lowest dietary diversity, measured in terms of total number of food items reported during the interview. The share of dietary energy obtained from own-produced food on total dietary energy in rural Class 5 is higher than in all other classes. The mostly urban Class 3, on the other hand, obtained its highest share of calories from purchased food.

12 Encuesta Nacional de Ingresos y Gastos de Hogares Urbanos y Rurales. Since the survey was not designed to be representative at the level of the mountain versus non mountain areas, the expansion factors have been recomputed to derive statistics representative of the population of the different elevation classes, based on the 2010 Census data.

13 Available at: http://www.fao.org/economic/ess/ess-fs/fs-methods/adept-fsn/en/

As to the food consumed away from home, an important component is represented by food received free by children at school. School feeding programs are aimed at addressing the issue of food insecurity in the more vulnerable areas; the higher shares of children receiving food at school are observed in rural elevation classes 2 and 5, although in absolute terms the greatest number of children receiving food is found in the urbanized class 3.

4. Vulnerability to food insecurity in Ecuador

The first question of the ENIGHUR 2011-12 questionnaire asks about the "main access" to the dwelling. This piece of information was used to derive an indicator reflecting the "physical access" dimension of food security. For values of the variable "main access to dwelling" ranging from 1 to 3[14] the household was categorized as non-vulnerable under the physical access dimension, while it was considered vulnerable for values of the variable ranging from 4 to 6[15]. The "Physical Access" Vulnerability indicator can therefore assume two values: 1 for vulnerable households and 0 for non-vulnerable households. Main results are shown in table 3; household weights[16] were used to expand the results to the entire population. About 650,000 mountain people, corresponding to 9% of mountain population, have poor or no access to improved roads and hence difficulties in accessing markets, against a share of 6% in lowlands. The percentage of household with poor or no access to roads is higher in elevation classes 2 and 5 although, in absolute terms, the highest number of people with poor access to markets is found in class 3. Clearly, isolation is a typical rural problem: while in urban areas the share of "isolated" mountain people ranges between 1 and 3 percent, in rural areas twenty to thirty percent of the population can be considered isolated (table 3).

Table 3 - Vulnerable people by elevation class and area - Physical Access dimension

	Isolated people (National, %)	Isolated people (National, 000)	Isolated people (By area, %)	Isolated people (By area, 000)
Elev. Class 2 (3500-4500)	32	9	Urban: - Rural: 32	Urban: - Rural: 9
Elev. Class 3 (2500-3500)	7	333	Urban: 1 Rural: 18	Urban: 39 Rural: 294
Elev. Class 4 (1500-2500)	13	144	Urban: 3 Rural: 24	Urban: 20 Rural: 125
Elev. Class 5 (1000-1500)	22	55	Urban: 2 Rural: 27	Urban: 1 Rural: 55
Elev. Class 6 (300-1000)	11	106	Urban: 2 Rural: 21	Urban: 9 Rural: 97
Mountain areas	**9**	**648**	**Urban: 2 Rural: 21**	**Urban: 69 Rural: 579**
Elev. Class 0 (0-300)	6	425	Urban: 1 Rural: 19	Urban: 46 Rural: 379
Ecuador	**7**	**1,072**	**Urban: 1 Rural: 20**	**Urban:114 Rural: 958**

Source: author's elaborations on ENIGHUR 2011-12 data; INEC data on elevation and population.

Reducing food expenditures is one of the possible coping strategies adopted by vulnerable households in a period of food/market crisis or after being hit by an external shock. The share of households adopting such strategy can therefore be used as a benchmark of vulnerability at the household level. The adoption of such coping strategy was surveyed by ENIGHUR over a period of one year preceding the interview. About 1.6 million mountain people[17] reduced their food expenditures, corresponding to about 23% of total mountain population[18]. About 1 million of these vulnerable people are located in elevation class 3, although the highest share of population that reduced food expenditures is located in elevation class 2 (about 40%).

The main causes behind the food expenditure reductions, as reported by the interviewees, were:

1. Lack of more rewarding job positions for the household head;
2. Death/illness of a household member;
3. Job loss (in urban areas) and failure of family business (in rural areas).

Based on the answers of respondents on the causes of reduced food consumption over the previous year, households are identified as „vulnerable" under the Economic Access dimension if the following situations occurs (see table 4):

14 Corresponding to (respectively): 1: Highway/paved road; 2: Cobbled Road; 3: Road (not paved).
15 Corresponding to (respectively): 4: Path; 5: River/sea/lake; 6: Other.
16 See note 13.
17 Without considering people of the highest income quintile. As explained in note 13, all the figures on population are referred to the 2010 Census of Population.
18 In mountain urban areas 20% of people reduced food expenditures, while in rural areas the share was 26%. At national level, around 4 million people - 28% of national population - reduced food expenditures in the previous year.

a) In rural areas: per capita income below national poverty line, and the household does not own land nor it benefits of any health/job insurance scheme[19].

b) In urban areas: per capita income below poverty line or, for the lowest two income quintiles, households not covered by any kind of health or job insurance.

Results are displayed in table 4 below.

As to the Utilization dimension, finally, the following water sources have been considered „unimproved": truck delivery; well; river, ditch; other sources; on the other hand, "public aqueduct"; "public tank, fountain"; and "pipeline – untreated water" were considered as improved water sources. For the sanitation facilities, all the different types of "toilet" were considered „improved", while "latrine" and "no sanitation facility" were considered as indicators of vulnerability.

Main results are shown in tables 5 and 6. Eight percent of mountain population, corresponding to about 0.5 million people, lack of improved water sources (table 5): this result reflects a better condition of mountain versus lowland populations in Ecuador, as lack of access to improved water sources mainly regards rural areas. As to sanitation, about 0.6 million of mountain people (8%) lack of improved sanitation facilities, against a national average of 10% (table 5).

Thus, also for sanitation facilities the situation in highlands is better than in lowlands, although in the rural elevation classes 2 and 5 about one quarter of the population do not have access to improved sanitation facilities. Similarly to the previous indicator, indeed, the lowest standards are observed in rural areas, where 19% of the population is vulnerable under this dimension, while only 1% of urban mountain population lack of improved sanitation facilities.

Table 4 - Vulnerable people by elevation class and area - Economic Access dimension

	Poverty/no insurance (% population)	Poverty/no insurance (000 people)	Poverty/no insurance (% population)	Poverty/no insurance (000 people)
Elev. Class 2 (3500-4500)	51	14	Urban: - Rural: 51	Urban: - Rural: 14
Elev. Class 3 (2500-3500)	17	775	Urban: 17 Rural: 17	Urban: 506 Rural: 269
Elev. Class 4 (1500-2500)	18	199	Urban: 23 Rural: 12	Urban: 134 Rural: 64
Elev. Class 5 (1000-1500)	24	59	Urban: 36 Rural: 20	Urban: 18 Rural: 41
Elev. Class 6 (300-1000)	28	272	Urban: 32 Rural: 24	Urban: 163 Rural: 109
Mountain areas	**19**	**1,319**	**Urban: 20** **Rural: 18**	**Urban: 821** **Rural: 498**
Elev. Class 0 (0-300)	24	1,801	Urban: 27 Rural: 14	Urban: 1,530 Rural: 271
Ecuador	**22**	**3,121**	**Urban: 24** **Rural: 16**	**Urban:2,352** **Rural: 769**

Source: author's elaborations on ENIGHUR 2011-12 data; INEC data on elevation and population.

Table 5 - Vulnerable people by elevation class and area according to the Utilization dimension (1)

	Unimproved water sources (% population)	Unimproved water sources (000 people)	Unimproved water sources (% population)	Unimproved water sources (000 people)
Elev. Class 2 (3500-4500)	16	5	Urban: - Rural: 16	Urban: - Rural: 5
Elev. Class 3 (2500-3500)	3	153	Urban: 1 Rural: 7	Urban: 38 Rural: 115
Elev. Class 4 (1500-2500)	4	48	Urban: 1 Rural: 8	Urban: 4 Rural: 44
Elev. Class 5 (1000-1500)	11	28	Urban: 1 Rural: 13	Urban: 1 Rural: 27
Elev. Class 6 (300-1000)	33	314	Urban: 25 Rural: 42	Urban: 126 Rural: 188
Mountain areas	**8**	**547**	**Urban: 4** **Rural: 13**	**Urban: 169** **Rural: 379**
Elev. Class 0 (0-300)	28	2,155	Urban: 16 Rural: 65	Urban: 878 Rural: 1,277
Ecuador	**19**	**2,702**	**Urban: 11** **Rural: 35**	**Urban: 1,046** **Rural: 1,656**

Source: author's elaborations on ENIGHUR 2011-12 data; INEC data on elevation and population.

[19] The security schemes taken into account are: IESS Seguro General; IESS Seguro Voluntario; IESS Seguro Campesino; seguro del ISSFA o ISSPOL; Seguro de Salud privado (con o sin hospitalización); Seguros Municipales de Consejos Provinsiales; Seguro M.S.P.

Table 6 - Vulnerable people by elevation class and area according to the Utilization dimension (2)

	Unimproved sanitation (% population)	Unimproved sanitation (000 people)	Unimproved sanitation (% population)	Unimproved sanitation (000 people)
Elev. Class 2 (3500-4500)	27	7	Urban: - Rural: 27	Urban: - Rural: 7
Elev. Class 3 (2500-3500)	6	260	Urban: 1 Rural: 15	Urban: 21 Rural: 239
Elev. Class 4 (1500-2500)	9	102	Urban: 1 Rural: 18	Urban: 7 Rural: 95
Elev. Class 5 (1000-1500)	26	64	Urban: 2 Rural: 31	Urban: 1 Rural: 63
Elev. Class 6 (300-1000)	14	135	Urban: 2 Rural: 28	Urban: 8 Rural: 127
Mountain areas	**8**	**569**	**Urban: 1** **Rural: 19**	**Urban: 37** **Rural: 532**
Elev. Class 0 (0-300)	11	844	Urban: 5 Rural: 29	Urban: 277 Rural: 567
Ecuador	**10**	**1,413**	**Urban: 3** **Rural: 23**	**Urban: 314** **Rural: 1,100**

Source: author's elaborations on ENIGHUR 2011-12 data; INEC data on elevation and population.

Once created the indicators of the single dimensions, CVI is derived as follows:

$CVI = \max(PA, EA, U_W, U_S)$

Where: PA is the indicator of the Physical Access dimension;

EA is the indicator of the Economic Access dimension;

U_W is the indicator of the Utilization dimension related with access to safe sources of drinking water;

U_S is the indicator of the Utilization dimension related with access to improved sanitation facilities.

As previously discussed, each of the above mentioned indicators can assume values of 0 and 1. Accordingly, the CVI is equal to zero when all the indicators are equal to zero, indicating a situation where a given household is not vulnerable to food insecurity, and is equal to 1 when at least one of the indicators is equal to 1, i.e. when a household is vulnerable under one of the food security dimensions.

According to this **Composite Vulnerability Indicator (CVI)**, about 5.8 million people in Ecuador are vulnerable to food insecurity, representing the 40% of national population[20] (table 7).

In mountain areas, the number of vulnerable people is 2.1 million, corresponding to 31% of mountain population. Hence, vulnerability to food insecurity is more severe in Ecuadorian lowlands than in mountain areas. As explained in previous sections, this is mainly due to climatic conditions that favor the presence of mountain urban areas served by many infrastructures, which does not represent a common situation in mountain areas all over the world.

The elevation classes with the higher prevalence of vulnerability are the mostly rural classes 2 and 5, although more than half of the mountain vulnerable people are located in the urbanized class 3. About 19 percent of mountain people have insufficient economic access to food (table 4), making of **economic access** the food security dimension that contributes the most to the final figure of vulnerable people in Ecuadorean mountain areas.

Table 7 - Vulnerable people by elevation class in Ecuador estimated with the Composite Vulnerability Indicator (CVI)

Elevation	Vulnerable People, National (%)	Vulnerable People, National (000)	Vulnerable People, by area (%)	Vulnerable People, by area (000)
Elev. Class 2 (3500-4500)	73	20	Rural: 73	Rural: 20
Elev. Class 3 (2500-3500)	26	1,162	Urban: 19 Rural: 38	Urban: 552 Rural: 610
Elev. Class 4 (1500-2500)	30	334	Urban: 24 Rural: 36	Urban: 145 Rural: 189
Elev. Class 5 (1000-1500)	48	121	Urban: 38 Rural: 51	Urban: 19 Rural: 102
Elev. Class 6 (300-1000)	53	509	Urban: 46 Rural: 61	Urban: 232 Rural: 277
Mountain areas	**31**	**2,147**	Urban: **23** Rural: **43**	Urban: **949** Rural: **1,198**
Elev. Class 0 (0-300)	48	3,627	Urban: 39 Rural: 74	Urban: 2,171 Rural: 1,457
Ecuador	**40**	**5,774**	Urban: 32 Rural: 55	Urban: **3,119** Rural: **2,655**

Source: author's elaborations on ENIGHUR 2011-12 data; INEC data on elevation and population.

20 See notes 13 and 18: population figures refer to the 2010 Population census data.

In mountain urban areas, the share of people vulnerable to food insecurity is 23%, mainly due to high income inequality, higher prices of food, and lack of job or health assistance: a percentage substantially higher than the value estimated by Huddleston et al. for urban areas, but in line with the World Bank indicator used for the study update. In mountain rural areas, on the other hand, vulnerability to food insecurity affects 43% of the population. Indeed, as discussed in the previous sections, isolation, poor quality of water and sanitation facilities, and lack of good job opportunities mainly impact rural mountain areas. Migration in rapidly expanding mountain urban areas, on the other hand, has determined poverty conditions for a substantial number of urban people.

Table 8 below compares the results obtained with the new CVI approach against the results obtained with: the spatial approach of the 2015 update; the FAO indicator "Prevalence of undernourishment" (PoU); and the share of people declaring to have reduced food consumption in the year prior to the survey (ENIGHUR 2011/12 data). At the national level, while 13% of people are estimated to have a caloric consumption below the minimum level for a healthy life, 28% of total population had to reduce food consumption in the year prior to the survey, and 40% are considered vulnerable according to the CVI approach. These results confirm that being vulnerable to food insecurity does not necessarily mean that a particular household is actually food insecure: only about one third of the vulnerable people is below the threshold of minimum dietary energy consumption, and only two thirds of the vulnerable people actually had to reduce food consumption in some way. As to mountain areas, CVI results are in line with those obtained through the spatial approach considering the LAC region, and are slightly higher than the results obtained for the South America sub-region.

Table 8 - Comparison of food security indicators in Ecuador

	National	Mountain areas
Prevalence of undernourishment[21] (PoU, 2010-12)	13%	.
Reduced food consumption (benchmark; ENIGHUR 2011/12)	28%	23%
Vulnerability to Food Insecurity (Spatial approach)	.	31% (LAC[1]) 27% (S.A.[2])
Vulnerability to Food Insecurity (CVI approach)	40%	31%

1: Latin America and Caribbean (Including: Caribbean, Central America and South America).
2: South America

Based on self-declared ethnicity, the two groups with the lowest share of vulnerable people (about 35 percent) are *Mestizo* and *Blanco*, which account for about 75 percent of the total population.

Among indigenous people, which account for about 7% of total population, vulnerability to food insecurity is about 60 percent, and among other minorities[22], the prevalence is higher than the national average as well. Indigenous people - almost 1 million - are mostly located in mountain areas, where they account for about 13 percent of the mountain population, and in rural areas. Vulnerability therefore shows differential patterns among different ethnic communities.

Vulnerability can be reduced by building resilience of both people and communities (UNDP 2014). Social safety nets are an important tool in order to guarantee a minimum acceptable level of household food security over time. They are policy measures adopted to prevent vulnerable people from falling under certain minimum levels of livelihood as a consequence of a shock, allowing households to stay food secure over time. To the aims of this study, a household is benefiting of social safety nets if it benefits of at least one of the following:

- Free breakfast at school (for children aged 5-14);

- Free lunch at school (for children aged 5-14);

- Received "Mi papilla"[23] (for children aged less than 5);

- Received food bags and/or fortified food and/or food education;

- Have been visited by a health care team.

Out of the 2.1 million vulnerable people living in Ecuadorian mountain areas, about 1 million belong to households benefiting from some form of social safety nets. This leaves out about 1.1 million mountain people who are vulnerable to food insecurity and do not benefit from any social safety nets, corresponding to 16 percent of total mountain population.

21 The methodology to estimate the prevalence of undernourishment can be found in SOFI 2015 (FAO, 2015).
22 *Negro, Mulato and Montubio.*
23 Complementary food with high nutrient density.

Again, in mountain areas the share of vulnerable people not benefiting of safety nets is lower than in lowland, with the higher shares observed in classes 2 and 6, and the higher share of people benefiting of safety nets living in class 5 (table 9).

Table 9 - Social safety nets and vulnerable people by elevation class

	Number of vulnerable people (000)	Vulnerable people benefiting of social safety nets (000)	Vulnerable people benefiting of social safety nets (%)	Vulnerable people not benefiting of social safety nets (000)	Vulnerable people not benefiting of social safety nets (% on TOTAL population of the class)
Elev. Class 2 (3500-4500)	20	13	64	7	26
Elev. Class 3 (2500-3500)	1,162	511	44	651	14
Elev. Class 4 (1500-2500)	334	170	51	164	15
Elev. Class 5 (1000-1500)	121	78	65	42	17
Elev. Class 6 (300-1000)	509	254	50	255	27
Mountain areas	**2,147**	**1,027**	**48**	**1,119**	**16**
Elev. Class 0 (0-300)	3,627	1,692	47	1,936	26
Ecuador	**5,774**	**2,719**	**47**	**3,055**	**21**

Source: author's elaborations using ENIGHUR 2011-12 data, and INEC data on elevations.

5. Conclusions

The present study introduces the use of household survey data in the analysis of vulnerability to food insecurity in mountain areas and a new composite indicator called Composite Vulnerability Indicator (CVI). While the spatial approach is mainly based on the presence of given crops and farm animals, and hence on the availability dimension of food security, the new approach takes into account the dimensions of physical and economic access to food, and utilization, which may affect stability of a household"s food security over time.

Based on indicators reflecting the dimensions of food security more relevant at the household level and using ENIGHUR 2011/12 survey data, around 31% of Ecuadorian mountain people - corresponding to 2.1 million people - are estimated to be vulnerable to food insecurity. Two different patterns of vulnerability to food insecurity can be identified in mountain areas of Ecuador: one of the rural areas and one of the urban areas. While in rural contexts vulnerability is often linked to isolation, poor water and sanitation infrastructures, and lack of good job and education opportunities - which in turn causes outmigration to urban areas - in urban settings vulnerability to food insecurity is driven by high income inequality and higher prices of food. In addition to that, the lack of any job or health assistance causes the inability of a household to cope with food related or economic shocks. The majority of vulnerable mountain people live in rural areas, although vulnerability to food insecurity also interests the 23% of the urban mountain population, corresponding to almost 1 million people. This is the reason why in Ecuador, as opposed to many other developing countries, mountain areas are better-off compared to lowlands, because they host densely populated urban areas served by infrastructure generally not available in mountain areas of other developing countries. Almost half of mountain vulnerable people belong to household benefiting from school feeding or other nutrition and health care programs. This means that about 16% of total mountain people, besides being vulnerable to food insecurity, do not benefit from any social safety net, and is therefore at a greater risk in case of a food or market-related shock. This new approach has the advantage of allowing for a precise characterization of vulnerable areas, describing where each of the different vulnerability factors play a major role not only at regional and sub-regional level, but also at national and sub-national level. It also allows to understand who the most vulnerable people are, and for a precise localization of vulnerability hotspots. This, in turn, has a huge potential to help target and facilitate policy interventions.

The results obtained with the new CVI methodology are consistent with those obtained with existing FAO and World Bank methodologies, encouraging to apply this new methodology to other country of different regions and income level[24], provided survey data and geographic location of the interviewed households are available for the analysis.

[24] Another case study, of Malawi, has already been published in the same FAO 2015 publication, although other countries should be analysed to test the robustness of the CVI methodology.

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Determinants of dietary Diversity in Namibian Children: Evidence from 2013 DHS

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ABSTRACT

This study aimed at establishing levels and factors influencing dietary diversity in Namibian children as a proxy of food security. The study made use of secondary data from the Namibia 2013 Demographic and Health Survey, from a cross-sectional representative women in the reproductive age group (15-49) from all 14 provinces. Dietary data was used to come up with a dietary diversity score (DDS) that was calculated by counting each of 11 food groups. A DDS ↓5 was regarded as reflecting poor dietary diversity and poor food security. A generalized linear regression model was fitted to model dietary diversity with independent variables such as socio-economic status, region, mother's level of education, religion, ethnicity, marital status and place of residence. Results indicated that dietary diversity was low in rural areas. There were significant differential in dietary diversity with socio-economic status, marital status, place of residence and ethnicity. Generally the majority of Namibian children consumed a diet which varied less.

Keywords: Dietary diversity, Food security, Children, Namibia

PAPER

1. Introduction

The three major components underlying food security are food availability, accessibility and utilization. Critical to ensuring adequate intake of essential nutrients that promotes good health and well-being is the intake of a variety of foods and food groups (Ruel, 2002). Dietary diversity is not only viewed as a proxy measure of food security (Hoddinott and Yohannes, 2002), but has become an important measure of the diverse diet and by implication an indicator of nutritional adequacy and quality (Foote, et al., 2004). Consumption of a higher number of food items and food groups is associated with positive health outcomes such as birth weight, child anthropometric status (Hoddinott and Yohannes, 2002); improved nutritional adequacy (Hatloy, et al., 1998) it also highly correlated with caloric and protein adequacy. Among adults, diversified diet is associated with reduced complications of diabetes (Wahlqvist, et al., 1989), reduced incidence of cancers (Fernadez, et al., 1996; Lucenteforte, et al., 2008). A number of studies have shown, using Dietary diversity score (DDS) which counts the number of food groups consumed over a specified reference period to assess dietary diversity, that DDS is positively associated with overall dietary quality (Steyn, et al., 2006; Kennedy et al., 2007).

In developing countries, deficiencies of selected micronutrients prevalent among young children and women of childbearing age were found to be associated with birth defects, growth restriction, impaired cognition and increased morbidity and mortality (Black, et al., 2008). A limited or lack of dietary diversity is primarily responsible these deficiencies particularly among population groups of concerns in developing countries. Understanding dietary intakes among children is important in order to develop evidence-based strategies. The purpose of the present study was to assess dietary diversity among children under five in Namibia as a proxy of food security. In addition, we examined the relationships between dietary diversity and socio-demographic variables.

2. Methods

Secondary data from the Namibia Demographic and Health Survey NDHS (2013), from a cross-sectional sample of representative mothers from all the regions was used. The woman responded to dietary questions regarding the feeding of their children. The responses were used to compute a dietary diversity score (DDS) given by the total number of food groups consumed by the children out of the recommended 12 (Bread, noodles, other made from grains; Potatoes, cassava, or other tubers; Eggs; Meat (beef, pork, lamb, chicken, etc); Pumpkins, carrots, squash (yellow or orange inside); Dark green leafy vegetables; Mangoes, papayas, other vitamin A fruits; Any other Fruits.

Liver and heart organs; Fish or shell fish; Food made from beans, peas, and lentils; and Cheese, yorghut, and other milk products). A DDS of ↓5 was regarded as reflecting poor dietary diversity and poor food security. A binary logistic regression model was fitted to model DDS (1=DDS of at least 5, 0=DDS↓5) with independent variables such as wealth index, region, mother's highest educational level, religion, ethnicity, marital status and place or residence, to establish the determinants of dietary diversity in

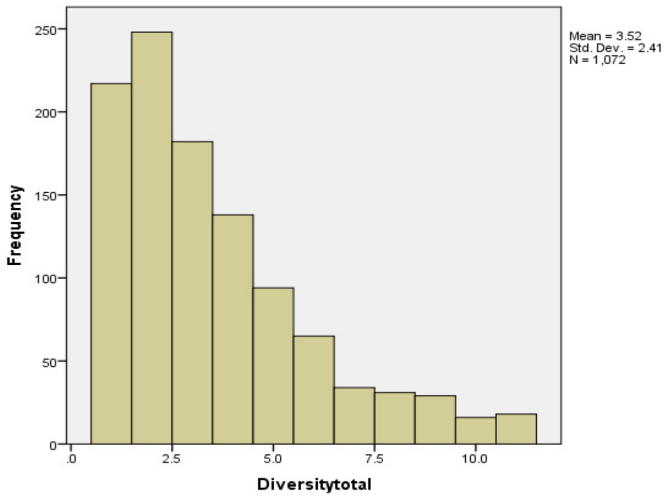
3.Results

Background characteristics of the sample

The composition of respondents by age-group was 15-19 (4.4%), 20-24 (16.4%), 25-29 (19.6%), 30-34 (17.8%), 35-39 (16.9%), 40-44 (13.7%) and 45-49 (11.1%). Their distribution by region was Zambezi (7.5%), Erongo (9.0%), Hardap (6.7%), !Karas (9.0%), Kavango (8.9%), Khomas (9.4%), Kunene (7.4%), Ohangwena (7.3%), Omaheke (6.5%), Omusati (7.1%), Oshana (6.4%), Oshikoto (6.6%) and Otjozonjupa (8.1%). Most of the respondents resided in urban areas (51.6%). With regard to their highest educational level, 7.6% of the respondents had had no formal education, 22.9% had primary education, 63.4% secondary education, and only 6.1% had higher education. Their religious affiliations ranged from Roman Catholic (21.1%), Protestant/ Anglican (23.2%), ELCIN (40.2%), Seventh Day Adventist (5.8%), no religion (1.4%), and others (8.3%). Most of the households were female headed (54.0%). The socio-economic status of the respondents (measured by the wealth index) ranged from poorest (17.2%), poorer (19.5%), middle (21.8%), richer (23.5%) to the richest (18.1%). Their distribution with regard to marital status was as follows: never in union (42.3%), married (25.9%), living with partner (22.5%), widowed (2.9%), divorced (1.3%), no longer living together / separated (4.9%). Their cultural diversity (measured by the main language spoken at home) ranged from Afrikaans (9.8%), Damara/Nama (16.2%), English (1.3%), Herero (10.3%), Kwangali (9.4%), Lozi (7.1%), Oshiwambo (41.5%), San (1.3%) and others (3.1%).

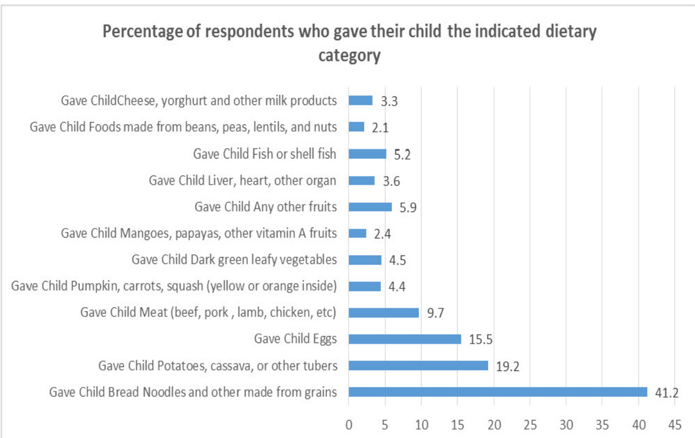
From the food groups proposed by FANTA (Swindale and Bilinsky, 2006), the dietary diversity score, which is the sum of the different food groups consumed by each child, ranged from 1 to 11 with a mean of 3.52 with a standard deviation of 2.41 [95% CI: 3.38 – 3.67]. The histogram of the dietary diversity scores are presented in Figure 1. The dietary diversity scores were skewed towards very few food groups.

Figure 1 - Histogram of Dietary diversity scores for children



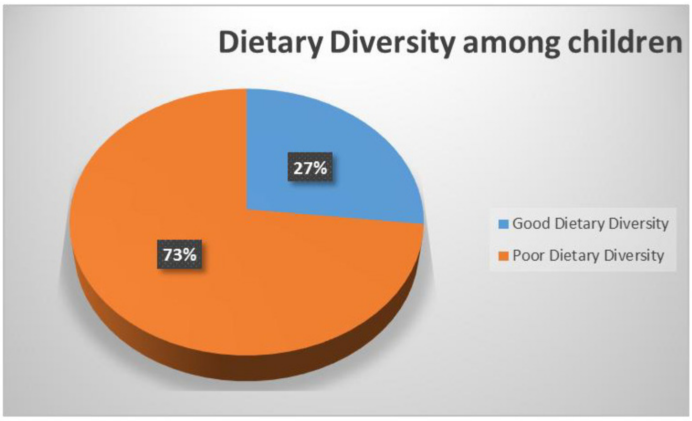
The proportion of children consuming foods from the various groups are presented in Figure 2. It was worrying to note that there was very little consumption of foods all other groups except for the Bread, Noodles and ... group (41.2%); and Potatoes, cassava, or ....(19.2%); and to a lesser extend eggs (15.5%).

Figure 2 - Percentage of respondents who gave their child food from the indicated dietary food group



A dietary diversity score of less than 5 was considered poor. The pie chart in Figure 3 shows that only 27% of the children had a good dietary diversity. The rest of the children had a poor dietary diversity (73%).

Figure 3 - Pie chart showing percentage distribution of dietary diversity in children



Bivariate analysis results

Chi-square tests of association between the dietary diversity score and potential predictor variables are given in Table 1.

Table 1 - Results of Chi-Square Tests of Association between the dietary diversity score and potential predictor variables.

Independent Variable	Pearson Chi-Square Statistic	P-value
Respondent Age-group	7.972	0.240
Region	95.077	P<0.001***
Place of residence	49.716	P<0.001***
Highest educational level	53.322	P<0.001***
Religion	4.315	0.505
Sex of Household Head	2.848	0.091
Wealth Index	72.753	P<0.001***
Marital Status	19.083	0.002
Main Language spoken at home	30.326	P<0.001***

The results of Chi-square tests of association at 5% level of significance indicated that dietary diversity in children was significantly associated with region (Chi-square=95.077, p<0.001); place of residence (Chi-square=49.716, p<0.001); highest educational level (Chi-square=53.322, p<0.001); wealth index (Chi-square=72.753, p<0.001); marital status (Chi-square=19.083, p=0.002); and main language spoken at home (Chi-square=30.326, p<0.001). There was no significant association between dietary diversity in children with the mother's age-group (Chi-square=7.972, p=0.240); religion (Chi-square=4.315, p=0.505) and the sex of the head of that household (Chi-square=2.848, p=0.0.091). Those potential indicator variables with significant associations were input into the binary logistic regression model to establish the extent of their effects on dietary diversity in children.

Results of logistic regression are presented Table 2. The regression results showed significant differentials in dietary diversity with respect to region. Children from Erongo (OR=2.073 ,CI:1.010-4.253, p=0.047); !Karas (OR=2.286 ,CI:1.120-4.665, p=0.023); and Khomas (OR=2.360 ,CI:1.158-4.811, p=0.018) regions were about twice more likely to have a good dietary diversity compared to their counterparts in the Otjozonjupa region. With regard to the highest educational level, children of mothers with no formal education (OR=0.150 ,CI:0.043-0.516, p=0.003); and those whose mothers had primary education (OR=0.337,CI:0.143-0.794, p=0.013) were less likely to have a good dietary diversity compared to those of mothers with higher education. Results also revealed that children from the poorest households (OR=0.387 ,CI:0.183-0.817, p=0.013) were less likely to have a good dietary diversity compared to those from the richest households.

Significant differentials were also observed with respect to the main language spoken at their homes (a proxy for cultural effects). Children from Afrikaans (OR=0.274, CI:0.101-0.743, p=0.011); Damara/ Nama (OR=0.270, CI:0.104-0.704, p=0.007); Herero (OR=0.334, CI:0.116-0.961, p=0.042); Kwangali (OR=0.217, CI:0.087-0.541, p=0.001); and Oshiwambo (OR=0.368, CI:0.146-0.924, p=0.033) speaking homes were less likely to have a good dietary diversity compared to those speaking other languages. However, the marital status of the mother, and the place of residence did not have a significant effect on dietary diversity among the children.

Table 2 - Logistic regression results

Predictor variables	Odds Ratio	95% Confidence Interval Lower	Upper	P-value
Region				
Zambezi	1.276	.297	5.479	.743
Erongo	2.073*	1.010	4.253	.047
Hardap	.625	.272	1.436	.268
!Karas	2.286*	1.120	4.665	.023
Kavango	2.298	.877	6.022	.090
Khomas	2.360*	1.158	4.811	.018
Kunene	1.099	.476	2.539	.825
Ohangwena	.695	.284	1.702	.426
Omaheke	.676	.294	1.551	.355
Omusati	.372	.136	1.018	.054
Oshana	.701	.276	1.779	.454
Oshikoto	.962	.420	2.206	.927
Otjozonjupa (Ref)	1.00	1.00	1.00	1.00
Place of Residence				
Urban	1.223	.819	1.826	.326
Rural (Ref)	1.00	1.00	1.00	1.00
Highest Educational Level				.012
No Formal Education	.150**	.043	.516	.003
Primary	.337*	.143	.794	.013
Secondary	.480	.224	1.029	.059
Higher	1.00	1.00	1.00	1.00
Wealth Index				
Poorest	.387*	.183	.817	.013
Poorer	.552	.301	1.012	.055
Middle	.715	.408	1.255	.243
Richer	.967	.588	1.590	.895
Richest	1.00	1.00	1.00	1.00
Marital Status				
Never in Unioin	.883	.417	1.869	.744
Married	1.429	.653	3.127	.371
Living with Partner	.809	.374	1.752	.592
Widowed	.446	.042	4.706	.502
Divorced	7.314	.991	53.963	.051
No longer living together/ separated	1.00	1.00	1.00	1.00
Main Language Spoken at home				
Afrikaans	.274*	.101	.743	.011
Damara / Nama	.270**	.104	.704	.007
English	.225	.049	1.036	.056
Herero	.334*	.116	.961	.042
Kwangali	.217**	.087	.541	.001
Lozi	.251	.058	1.085	.064
Oshiwambo	.368*	.146	.924	.033
San	.414	.068	2.519	.338
Other Languages	1.00	1.00	1.00	1.00

*p<0.05, **p<0.01, ***p<0.001

4. Discussion

In this cross-sectional analysis, we examined the dietary diversity of children under-five regardless of breast feeding status. Overall, our results of the regression tend to confirm the findings of previous work in neighbouring South Africa, as measured in the NFCS in 1999, where DDS had a mean of 3.6. Comparing it to Namibia, although different dietary methods were used, it should be recognised that the majority of children in Namibia have a very limited dietary variety. The adequacy of intake of some specific food items (especially lentils, Vitamin A rich fruits) implied means that micronutrients was particularly low. Folate intakes were also very low due to the limited quantities consumed by the children in lentils and green leafy vegetables (2.1% and 4.5% respectively). Only 3.3% of children consumed milk or milk products which are essential for providing Calcium. The children's diet consist primarily of starchy foods and by implication certain micronutrients were deficient. These children should be regarded as being at risk of undernutrition. DDS.

5. Conclusions

Our study shows dietary diversity among young children in Namibia is alarmingly low and primarily starch based. This limits the consumption of essential micronutrients leading to lack sufficient nutrient-dense foods to achieve micronutrient adequacy as shown by the limited dietary diversity. Although a small number of children did consume from a diverse food group this study was not able to determine the sufficiency and frequency of the quantities in order to assess the adequacy, as a limitation of the study. Another limitation was that the foods consumed by the children was based on the recall from their mothers who may not recall some food items consumed in between meals.

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THEMATIC SET

B12

FOOD BALANCE SHEETS DATA: COMPILATION AND ANALYSES

Session Organizer
C. Cafiero | FAO | Rome | Italy

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The Food Security Statistics of Iran

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ABSTRACT

Food balance sheets as comprehensive food and agricultural statistics play an important role to provide information on patterns, levels and trends of national diets in a country and it measures the food supply of the population. In this paper, tried to prepare the Food balance sheets of Iran for two years (2013-2014) .Firstly, built the Supply Utilization Accounts to enable comparison of food availability with food use and secondly prepared other measures and outputs including: Import dependency ratio (IDR), Self-Sufficiency ratio (SSR), and after standardization of commodities food balance sheets for analysis of the pattern of per caput food supply.

Keywords: Food balance sheets, Import dependency ratio (IDR), Self-Sufficiency ratio (SSR), Per Caput food supply.

PAPER

1. INTRODUCTION

The interest in food balance sheets in Ministry of Jahad agriculture increased considerably after focusing duties and authorities of commercial and industrial of agricultural sector to Ministry of Jahad agriculture in 2013, then access to Information of the food and agricultural situation like: production, utilization, stocks & trade were the major source of data to increase food market transparency and reduce volatility of the food prices and forecasting for raising standards of living and providing the policy analysis and decision-making needed to ensure food security.

National Food balance sheets were prepared by Agricultural Planning, Economic & Rural Development Research Institute in Iran from 1989 to 2012 and the latest two Food balance sheets were prepared by Information Technology and Communication Center. In constructing the Food balance sheets, both official and unofficial data available in ITC Center and missing data have been estimated on basis of surveys and other information as well as technical expertise. The purpose of this study is to provide comprehensive information on patterns, levels and trends of national diets.

The paper discusses about nature of food balance sheets, data sources, commodity coverage, supply and utilization elements, preparing and standardization of food balance sheets, analysis of the pattern of per caput food supply and Import dependency ratio (IDR), Self-Sufficiency ratio (SSR).

1. NATURE OF FOOD BALANCE SHEETS

Food balance sheets present a comprehensive picture of the pattern of country's sources of supply and utilization for each food item during a year. The total quantity of foodstuffs produced in country added to the total quantity imported and adjusted to any change in stocks that occurred since the beginning of the year, gives the supply side of the food balance equation. On the utilization side a distinction is made between the quantities of exported, fed to livestock, used for seed, processed for food use and non-food uses and lost.

The per *caput supply* of each food item available for human consumption is obtained by dividing the respective quantity by the population partaking of it. Data on per caput supply are expressed in terms of quantity and energy, protein and fat. They are an important element for projecting food demand, together with such other elements as income elasticity coefficients, private consumption expenditure and population. A comparison of the quantities of food available for human consumption with those imported will indicate the extent to which a country depends upon imports (Import dependency ratio (IDR)) to feed itself (Self-Sufficiency ratio (SSR)).

1.1. DATA SOURCES

Food balance sheets are assembled form a variety of sources. Production data are based on annual surveys, trade data are register based, information on stock changes and industrial uses is available from marketing authorities, feed rates are obtained from government agencies, seeding rates are obtained from cost of production surveys, lost rates and composition factors are obtained from FAO documents and the total population is register based.

1.2. COMMODITY COVERAGE

All potentially edible commodities were taken into account in preparing food balance sheets. Generally, food balance sheets are constructed for primary crops, livestock and fish commodities up to the first stage of processing in the case of crops and to the second stage of processing in the case of livestock and fish products. The major food groups were: Cereals, Roots and products, Sugars and Syrups, Pulses, trees nuts, Oil crops, vegetables and products, Fruits and products, Meat, Fish and products, Milk and Cheese, oil and Fats.

2. SUPPLY AND UTILIZATION ELEMENTS

Production - For primary crops, production is related to the total domestic production at the farm level and livestock items in terms of live weight for primary fish items. Production of processed commodities relates to the total output of the commodity at the manufacture level (it comprises output from domestic and imported raw materials of originating products).

Changes in stocks - This comprises changes in government stocks. Increases in stocks of a commodity reduce the availability for domestic utilization. They are indicated by the (–) sign and decreases in stocks by the (+) sign since they increase the available supply.

Imports - It includes commercial trade of all movements of the commodity in question into the country during the year.

Exports - It includes commercial trade of all movements of the commodity in question out of the country during the year.

Supply - The elements involved are production, imports, exports and changes in stocks then the definition for supply was:

Production+ imports- exports + changes in stocks = supply for domestic utilization

Feed - This comprises amounts of the commodity that are fed to livestock during the year, whether domestically produced or imported.

Seed - This comprises all amounts of the commodity used during the year for reproductive purposes such as seed whether domestically produced or imported.

Food Manufacture - The amounts of the commodity used during the year for manufacture of processed commodities.

Waste – This comprises amounts of the commodity lost at all stages between the level at which production is recorded and the household.

Food – This comprises the amounts of the commodity that are available for human consumption during the year.

Per caput food supply – These estimates are provided of per caput food supplies available for human consumption during the year in terms of quantity, caloric value, protein and fat content. The caloric value, the protein and fat content were calculated in base on FAO's food composition factors for Islamic republic of Iran.

3. PREPARATION AND STANDARDIZATION

The utilization of all the information which was assembled for construction of a food balance sheet often ends up in a rather long list of food commodities and standardization can be achieved by showing only primary commodities and processed commodities (except for sugar , oil and fats) are converted into their originating primary commodity equivalent. This procedure facilitates the analysis of food balance sheets with no loss of pertinent information.

4. IMPORT- DEPENDENCY RATIO (IDR)

An important aspect in assessing the food situation within a country – including food security –is the extent to which supply is dependent on external imports. The Import Dependency Ratio (IDR) measures precisely the percentage of a country's supply that is derived from imports, defined as:

*IDR = Imports / (Production + Imports – Exports) * 100*

The value of 100 indicates 100% of the country's supply for a given commodity is dependent on imports; value of 40 indicates 40% of a country's supply for a given commodity is dependent on imports or conversely, 60% of the country's supply for the commodity is produced within the country. The IDR can be calculated for individual commodities, groups of commodities of similar nutritional values, or even the aggregate of all commodities.

5. SELF- SUFFICIENCY RATIO (SSR)

The Self-Sufficiency Ratio (SSR) expresses the magnitude of production in relation to domestic utilization, defined as:

SSR = Production / (Production + Imports – Exports) * 100

The value of 100 indicates 100% of the country's supply originates from the country's own production; the value of 30 indicates 30% of the country's supply originates from the country's own production. In the context of food security, the SSR is often taken to indicate the extent to which a country relies on its own production and higher ratio, the greater the self-sufficiency.

Table1- Food Balance Sheet Year: 2013

Country: Islamic republic of Iran *Thousands metric tons* *Population 76942 Thousands*

Products	Supply					Utilization					Total Utilization	Food supply Per caput				
	Production	Imports	Changes in stocks	Exports	Available Supply	Feed	Seed	Waste	Food Manufacture	Food		Kg/ year	Grams/ day	Calorie /day	Protein /day	Fat/day
Vegetable	64288495.9	14216776.5	1008000	3286155.79	76227116.62	16045795.9	1961004.7	6277918.4	1736821.31	56949416.5	79094745.3	740.16	2027.8	3649.5	83.09	56.33
Animal	16882946.6	145473.02	-80000	228901.89	16845180.84	0.00	59911.04	329888.67	6396706.35	10092851.8	16845180.8	132.31	362.5	358.03	25.13	22.53
Grand total	81171442.5	14362249.5	928000	3515057.68	93072297.46	16045795.9	2020915.7	6607807.7	8133527.66	67042268.3	95939926.1	872.47	2390.3	4007.5	108.22	78.86

Table2-Food Balance Sheet Year: 2014

Country: Islamic republic of Iran *Thousands metric tons* *Population 77856 Thousands*

Products	Supply					Utilization					Total Utilization	Food supply Per caput				
	Production	Imports	Changes in stocks	Exports	Available Supply	Feed	Seed	Waste	Food Manufacture	Food		Kg/ year	Grams/ day	Calorie/ day	Protein/ day	Fat/day
Vegetable	61984997.8	20470694.1	-407000	4452540.2	74211977.77	15079396.6	1882202.6	5511236.03	1964449.99	49094724.75	72749844.99	633.37	1735.3	3507.91	80.83	52.26
Animal	30249192.6	189028.2	-71000	638303.6	17663321	0	59801.9	209737.7	7238403.8	10171346.24	17663321	132.19	362.2	363.28	24	22.68
Grand total	92234190.5	20659722.4	-478000	5090843.7	91875298.77	15079396.6	1942004.5	5720973.7	9202853.8	59266070.99	90413165.99	765.57	2097.5	3871.18	104.83	74.94

The total food balance sheet tables in detail is available with the Supply Utilization Accounts to enable comparison of food availability with food use and prepared other measures and outputs including: Import dependency ratio (IDR), Self-Sufficiency ratio (SSR), and after standardization of commodities food balance sheets for analysis of the pattern of per caput food supply. We have compared the results for 1991-2012 as fallow:

Table3- Daily Calories Per caput supply(Kcal) in 1991-2014

Year	Contribution of Calories			Percent Contribution of Calories	
	Total	Vegetable	Animal	Vegetable	Animal
1991	3052	2732.00	320.00	89.52	11.71
1992	3373	3029.00	344.00	89.80	11.36
1993	3306	2952.00	354.00	89.29	11.99
1994	3136	2789.00	346.00	88.93	12.41
1995	3519	3170.00	350.00	90.08	11.04
1996	3596	3234.00	363.00	89.93	11.22
1997	3520	3163.00	357.00	89.86	11.29
1998	3822	3454.00	367.00	90.37	10.63
1999	3631	3267.00	363.00	89.98	11.11
2000	3322	2946.00	376.00	88.68	12.76
2001	3535	3168.00	366.00	89.62	11.55
2002	3625.09	3254.85	370.25	89.79	11.38
2003	3516.65	3105.22	411.42	88.30	13.25
2004	3476.38	3062.19	414.20	88.09	13.53
2005	3602.13	3172.08	430.05	88.06	13.56
2006	3559.08	3107.47	451.61	87.31	14.53
2007	3883	3415.00	468.00	87.95	13.70
2008	3250	2831.00	419.00	87.11	14.80
2009	3399	2973.00	426.00	87.47	14.33
2010	3445	2994.00	451.00	86.91	15.06
2011	3111	2671.00	440.00	85.86	16.47
2012	3584	3120.00	464.00	87.05	14.87
2013	4007.49	3649.47	358.03	91.07	9.81
2014	3871.19	3507.91	363.28	90.62	10.36

Figure1- Daily Calories Per caput supply in 1991-2014

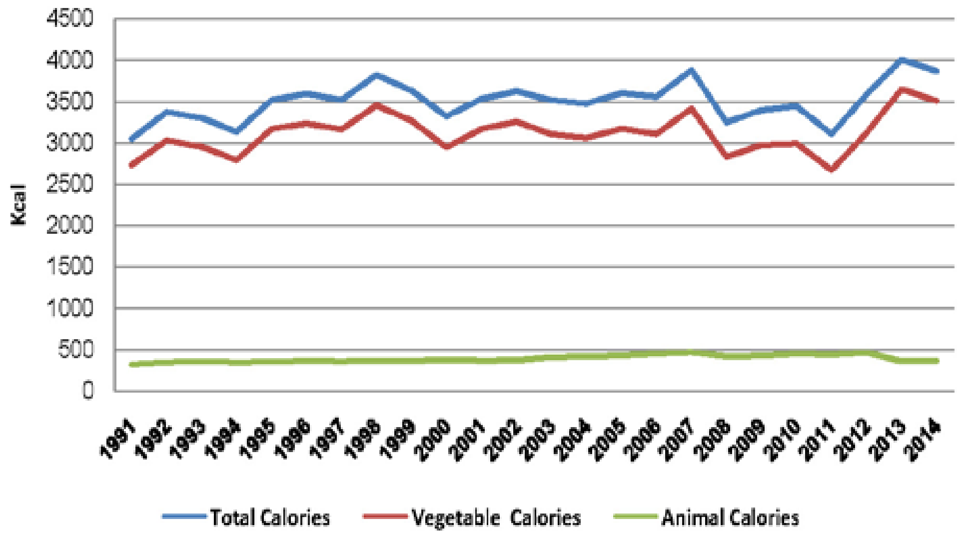
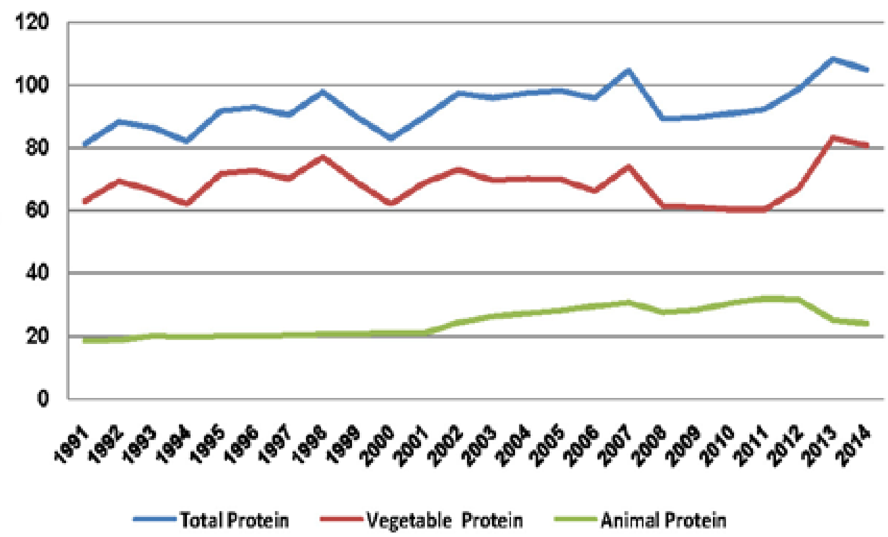


Table 4- Daily Protein Per caput supply (gr) in 1991-2014

Year	Contribution of Protein			Percent Contribution of Protein	
	Total	Vegetable	Animal	Vegetable	Animal
1991	81.20	63.00	18.50	77.59	29.37
1992	88.10	69.40	18.70	78.77	26.95
1993	86.40	66.40	20.10	76.85	30.27
1994	82.00	62.00	19.80	75.61	31.94
1995	91.80	71.79	20.01	78.20	27.87
1996	92.80	72.69	20.08	78.33	27.62
1997	90.40	70.10	20.30	77.54	28.96
1998	97.70	77.10	20.60	78.92	26.72
1999	89.80	69.00	20.80	76.84	30.14
2000	82.90	62.00	20.90	74.79	33.71
2001	89.90	68.90	21.00	76.64	30.48
2002	97.34	73.03	24.31	75.03	33.29
2003	95.86	69.57	26.30	72.57	37.80
2004	97.34	70.04	27.30	71.95	38.98
2005	98.10	69.96	28.14	71.31	40.22
2006	95.77	66.20	29.56	69.12	44.65
2007	104.68	73.93	30.75	70.62	41.59
2008	89.13	61.45	27.67	68.94	45.03
2009	89.60	61.20	28.40	68.30	46.41
2010	90.87	60.36	30.51	66.42	50.55
2011	92.28	60.36	31.92	65.41	52.88
2012	98.62	67.01	31.61	67.95	47.17
2013	108.22	83.09	25.13	76.78	30.25
2014	104.83	80.83	24.00	77.11	29.69

Figure2- Daily Protein Per caput supply in 1991-2014



Conclusions

The study of food security by food availability index during the period 1991-2014 in Iran shows that the average of total energy supply is 3506 kcal and it is more than the population average per capita requirement of 2870 kcal in the general case in the world and the average total calories supply is 93 grams and it is more than the population average per capita requirement of 80 grams in the general case. The average percent of vegetable products energy supply during the period 1991-2014, is 89% and the average percent of animal products energy supply is 13%. The average percent of vegetable products protein supply is 74% and the average percent of animal products protein supply is 36%. Increase of the annual growth rate of energy supply per capita of vegetable products (1.09 percent) from animal products (0.55 percent) and accordingly, Increase of the annual growth rate of protein supply per capita of animal products (1.14 percent) from vegetable products (1.09 percent) . In 2013, the main sources of calories are cereals 48%, fruits 13% and oils 7%. The main sources of proteins are cereals 47%, vegetable 15% and meats 13%. The main sources of fats are oils 41%, nuts 16% and meats 14%. In 2014, the main sources of calories are cereals 50%, fruits 14% and oils 8%. The main sources of proteins are cereals 51%, vegetable 12% and milks 6%. The main sources of fats are oils 45%, milks 11% and nuts 10%.

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Statistical trends in agriculture in light of the future sustainable food security in Slovenia

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ABSTRACT

The concept of a sustainable food security on the national or global level includes the availability to provide sufficient amount of food also in exceptional and critical circumstances, as well as a higher level of potential rates of self-sufficiency and traceability of safely produced agricultural products. The primary purpose of this paper is to outline the state and the importance of the Slovenian agriculture and to link the available statistical data with the academic assumptions.

Agriculture in Slovenia is carried out as a traditional industry in a specific geographical and climatic situation and has therefore certain specific characteristics. At the latest agricultural census in 2010 there were just over 75,000 agricultural holdings in Slovenia, of which 61% were smaller, with less than 5 hectares of utilised agricultural areas and were cultivating 22% of total utilised agricultural areas. Larger agricultural holdings represented only 2% of all agricultural holdings in Slovenia.

The dominant type of agricultural holdings were family farms, similarly to other European countries. Slovenia is also one of the European countries with the smallest area of arable land per capita and one of the countries with above European average share of permanent grassland. Economic accounts for agriculture data on agricultural subsidies, labour input and investments also enable more in-depth knowledge of the agricultural specifics.

Slovenia is traditionally a net importer of food, since domestic production does not meet the needs for agricultural products. Data of the national supply balance sheets show that the annual domestic agricultural production varied over the past decade, partly due to changes in the area set aside for individual agricultural products and partly due to the increasingly unreliable weather conditions and the increasingly unreliable yield per hectare. Domestic consumption, which can be consumed for various purposes (food, further processing, industry, animal fodder), was mainly gradually declining in the same period, but mostly exceeded the domestic production. Rates of self-sufficiency, which show to what extent domestic production covers domestic consumption, were mostly lower than 100%. Slovenia has higher self-sufficiency rates for animal products than for crops; the rates are the lowest for vegetables (38% in 2014), potato (68% in 2014) and cereals (78% in 2014).

Nevertheless, some expert and academic assessments show that Slovenia has sufficiently big potential in availability of agricultural land to improve its food security by 2030. To ensure greater food security in the future academics propose the increase of the agricultural areas and agricultural yield, conversion to organic farming, reduction of the quantities of food waste and a change of eating habits, especially the reduction of meat consumption.

The aim of the paper is therefore to show the statistical agricultural trends of the selected agricultural indicators with the purpose to support or reject the current academic positions and proposals for the future improvement of the national food security. The paper further aims to target the potential development areas of the Slovenian agriculture in this light and offer some suggestions for the potential future improvement of some segments of food security in Slovenia.

Keywords: agricultural holdings, indicators, supply balance sheets, self-sufficiency rate

PAPER

1. Introduction

Key problems of global so-called commercial (conventional) agriculture today are unequal distribution of globally (still) sufficient food production, "chemisation" of activity, soil erosion (on more than 900 million hectares of agricultural land in the world), large water consumption, building up of agricultural land, and a rapidly growing world population. On many agricultural areas consumption of mineral fertilisers per hectare represents an environmental burden. Conventional agriculture is distinctly capital and energy intensive, albeit productive, employs few people (in developed countries less than 5% of the population) and presents a large environmental burden (Stutz, Warf 2005). Fossil fuels are used for production and sustainable economy of local communities is neglected, since agricultural products are usually sold on distant markets.

Sustainable development model, which is a multi-layered growth of well-being among people, involves permanent protection of available natural resources. Sustainable development is development consistent with the capacity of the environment both in terms of permanent supply of the population with natural resources and in terms of the capacity to neutralise various environmental burdens (Plut 2014). It is characterised by the use of local natural resources and decentralisation of production due to the need for greater self-sufficiency (Stutz, Warf 2005).

In expected uncertain conditions of unstable food supply[1] at the global level due to climate change, local, regional and national self-sufficiency in food is becoming a very important issue. Slovenia cannot cover its needs for agri-food products on its own, but experts assess that Slovenia has sufficient potential of agricultural land to improve its food security by 2030 (Plut 2012). Due to many environmentally positive consequences, it is appropriate to treat the increase in self-sufficiency as one of the key areas of sustainable development. The concept of food security includes the ability to provide food even in exceptional and critical circumstances, secure level of potential self-sufficiency and traceability of safely produced agricultural products (Perpar, Udovč2010). Food security and own food production at the national level are again becoming the issues of strategic importance.

2. Global agricultural trends

The reasons for lack of food on the global and regional markets are negative consequences of climate change (more frequent droughts and floods), increasing prices of mineral fertilisers, use of larger agricultural area for producing biofuels (ethanol, biodiesel), extensive conversion of agricultural land into building sites, erosion, and growing wheat consumption for meat production. Large energy consumption and large emissions of greenhouse gases from traffic during the transport of food over large distances are key wider negative environmental impacts (Nierenberg, Halweil 2005). Agricultural systems contribute significantly to water consumption, to climate change, to reducing biodiversity and to soil depletion (Sage 2012). Production of 1 kilogram of wheat namely requires 900 litres of water, 1 kilogram of maize 1,400 litres of water, and 1 kilogram of beef as much as 15,000–20,000 litres of water (Nierenberg, Halweil 2005, p. 77).

In the opinion of environmental and agricultural experts, in the next few decades it might be possible to influence the expansion of agricultural land, an increase of yields on existing agricultural area, usage of new food sources, a decrease of food waste in developed countries, to distribute food more fairly and to change eating habits by not increasing the share of meat from animal farms (use of cereals) in the diet of people in developing countries and by constantly decreasing meat consumption in developed countries. Due to energy and environment reasons, meat consumption and the share of meat should decline in developed countries, while in globally and geopolitically strained conditions of food supply the consumption of wheat for meat production should be drastically limited. For a meat-based diet, on average four times more resources are necessary than for a vegetarian diet. Due to the lack of food and environmental reasons, some experts point out the need to move to a more vegetarian diet in developed countries (Maxey 2007). The predominance of the vegetarian diet of the world population would require 700–800 m2 of intensively farmed agricultural land per capita, while the predominance of the diet based on meat and dairy products would require up to 4,000 m2 per capita. To meet the average daily intake of 2,500 kcal per capita with 30% of animal products, around 1,500 m2 intensively farmed agricultural land per capita would be needed, while a high share of meat would require around 3,000 m2 per capita. To feed 10 billion people, in mid-21st century we would thus need 880–3,000 million hectares of land, most probably 1,100–1,300 million hectares. This means that in the case of a lower share of meat and dairy products in the global diet, no additional agricultural land would actually be needed (Sage 2012).

3. Slovenian characteristics in terms of sustainable development and agricultural trends

In terms of sustainable development, Slovenia is characterised by the stabilisation of the population and population pressures on the environment, smaller cities, large dispersion and small settlements, rich water resources, very well preserved nature and high-quality living environment on most of its territory. Our country is distinguished by exceptional landscape and biodiversity, but also by excessive consumption of natural resources and various forms of environmental burdening, including the existence of spatially delineated areas of intensive and multilevel landscape degradation.

[1] Food includes a set of agricultural products (meat, eggs, cereals, potato, vegetables, sugar and rice) in basic or processed form.

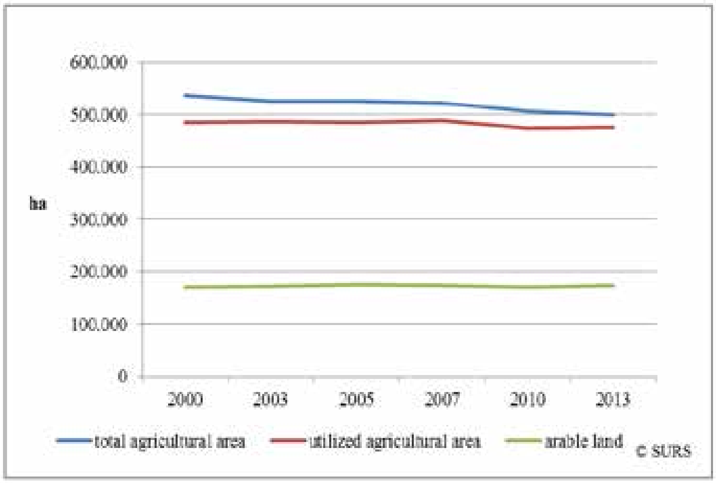
Between 2002 and 2007, 19,712 hectares of Slovenian's territory were built up, of which 65% was agricultural land (Odnos do kmetijske zemlje 2010; Perpar, Udovč2010). The draft Slovenia's Development Strategy for the 2014–2020 period points out increasing development differences among Slovenian regions.

Even though agriculture contributes only 1.2% of total GDP in the EU-27, and also in Slovenia in 2010, it is one of the most important industries. In addition to its most important task of providing people with high-quality food, agriculture takes care of preserving the cultural landscape, has a positive impact on rural development, on preserving settlement, particularly in demographically endangered areas, and creates jobs. The integration of agriculture into the environment and factors related to environmental protection – such as preservation of biodiversity, improving the well-being of livestock, sustainable farming, etc. – are being increasingly emphasized. Agriculture is an important part of the economy since it provides inputs for agro-industry, supplements tourism industry, performs municipal services, etc. The Common European Agricultural Policy focuses its increasing attention on comprehensive treatment of agriculture and rural areas and spends a considerable share of the total EU budget for these purposes (Agriculture in Slovenia and in the Rest of the EU 2014).

An average agricultural holding in Slovenia is less than half the size of an average agricultural holding in the EU-27 (according to 2010 data just over 6 hectares of utilised agricultural area). Half of agricultural holdings in Slovenia have less than 5 hectares of utilised agricultural area. Smaller agricultural holdings (less than 5 hectares of utilised agricultural area) represented 61% of all agricultural holdings in Slovenia; they were cultivating 22% of total utilised agricultural area in the country. Larger agricultural holdings (more than 30 hectares of utilised agricultural area) represented only 2% of all agricultural holdings in Slovenia; they were cultivating only a fifth of total utilised agricultural area in the country.

According to statistical data for 2010, utilised agricultural area in Slovenia represented less than a quarter of total area. Slovenia was thus one of the four EU-27 Member States with less than 0.1 hectare of arable land per capita. The most widespread crop in Slovenia was maize, which was sown on almost 37% of arable land (59% as maize for grain and the rest as green maize). Wheat was sown on almost 19% of arable land, but because the share of arable land is low, Slovenia is not self-sufficient in wheat. Cattle and milk production are the most important part of livestock production representing 58% of the total value of livestock production. Cattle breeders in Slovenia breed on average 13 cattle per agricultural holding. Pig breeding represents only 12% of the total value of livestock production in Slovenia. 23% of sheep and goats are bred on agricultural holdings having the status of organic farms or farms in transition to organic farming. In Slovenia there are more than 2,000 organic farms (Agriculture in Slovenia and in the Rest of the EU 2014). In 2014 the share of organically farmed utilised agricultural area was just over 8%.

Figure 1 - Agricultural area, utilized agricultural area and arable land, Slovenia



1) Due to rounding, the sum specified may not match.
Source: Statistical Office of the Republic of Slovenia

Around 1960 there were around 300,000 hectares of arable land and kitchen gardens in Slovenia; by 1991 the number dropped to 200,000 hectares, mostly on account of overgrowing and building up of agricultural land. In 1991 there were 246,000 hectares of arable land, which is 1.242 m2 per capita and in 2010 only 170,000 hectares (in 2011 only 168,700 hectares) or only 830 m2 per capita. As regards the area of arable land and kitchen gardens, Slovenia is among EU Member States with lowest values. More than half of arable land was used for producing cereals, particularly maize for grain and wheat, and almost a third was used for producing green fodder, mostly green maize, and grasses and grass-clover mixtures. Maize fields are also used for producing silage as the basis for an increasing number of biogas plants. The European provision on the necessary extent of biogas production reduces the production of crops for food (Perpar, Udovč2010). In 1991, there were 561,295 hectares of utilised agricultural area in Slovenia, which is 2,833 m2 per capita; in 2000 the number was 508,960 hectares or 2,571 m2 per capita, and in 2009 only 468,496 hectares or 2,297 m2 per capita, which is well below the EU-27 average (3,510 m2 per capita) (Keyfigures on Europe 2010). According to SURS's data and the agricultural census, in 2010 there were 474,432 hectares of utilised agricultural area in Slovenia or 2,350 m2 per capita. In geographically and climatically similar conditions, secure food supply in Slovenia would require at least 3,000 m2 of utilised agricultural area (arable land, permanent grassland, orchards and vineyards) per capita (Hrustel Majcen 2004).

In 2007 the global average area of cereals was 1,000 m2 per capita; at that time cereals in Slovenia were sown on around 100,000 hectares, which is only 500 m2 per capita; in 2010, 152,000 tons of wheat grain was produced on 7% smaller area (75 kilograms per capita), which is 8% more than the 2005–2009 average (140,000 tons). The yield per hectare of wheat (4.8 t/ha) was among the best in the five-year period. Maize output in 2010 was 300,000 tons, i.e. an average result in recent years. As regards the share of agricultural holdings breeding livestock, Slovenia is among the top EU-27 Member States (79%). As regards the intensity of livestock production, which is measured by the number of livestock units per hectare of utilised agricultural area, Slovenia is among the top ten EU-27 Member States. In Slovenia the average is 1.1 livestock units per hectare of utilised agricultural area, just above the EU-27 average of 0.8 livestock units per hectare of utilised agricultural area. To cultivate a hectare of utilised agricultural area, farmers in Slovenia spend on average a lot more hours per year (286) than farmers in the EU-27 (102).

The self-sufficiency rate, which shows the extent to which domestic production meets domestic consumption, depends on the weather conditions in an individual year, particularly for crops. In 2014, self-sufficiency in wheat was 70%, and for cereals in general 77%. Self-sufficiency was the lowest in vegetables; only 38% in 2014. As regards animal products, self-sufficiency rates were higher: meat 80%, milk (2006–2011) between 115% and 120%. Per capita meat consumption has declined over the past ten years; in 2005 it was 97 kilograms and in 2014 85 kilograms.
The most obvious reason for the strategically low self-sufficiency rates in Slovenia is decrease in arable land (and thus the area of cereals); also important is the low level of exploitation of the entire natural agricultural potential. The general decrease in agricultural land due to abandoning agricultural production and building up the most fertile flatland areas had a negative impact on self-sufficiency (Plut 2012).

Due to rich water resources, Slovenia is one of the countries that use very low shares of available water resources for water supply and is in this respect comparable to Austria, Switzerland and Finland. In the 2005–2007 period on average only 2–3% of all available water was abstracted (so-called water stress is practically non-existent) (The European Environment 2010). Nevertheless, due to climate change and expected larger needs for irrigation, it is expected that particularly in the western and north-eastern parts of Slovenia the problems with seasonal hydrological and agricultural lack of water in the vegetation period will become worse.
Among the mentioned national priority sustainable self-sufficiency issues, in the opinion of national experts (Plut 2012), achieving a secure rate of food self-sufficiency, production and consumption of locally produced, high-quality and healthy food will most probably be the most demanding strategic sustainable development task at the national level. We should also decrease the amount of food waste. According to SURS's estimate, in 2013 40% of food consumed in Slovenia was produced in Slovenia and 60% was imported. In 2013, 4 percentage points less locally produced food was consumed in Slovenia than in 2010 (44%); most of the food was imported from the neighbouring countries (Hungary, Austria, Italy and Croatia). According to SURS's rough estimates[2] the amount of waste food was falling in the 2010–2014 period. In 2014 a person in Slovenia generated on average 59 kilograms of food waste[3]; in 2010 the figure was 88 kilograms. Large enough agricultural land and preservation of natural soil fertility on around 75,000 agricultural holdings will be the key natural conditions for preserving food security in Slovenia at the time of the stabilisation of its population.

[2] The rough statistical estimate of the amount of food waste (food waste per capita) is the first attempt to calculate the indicator, so data should be used with caution. The national methodology for a more realistic calculation is being prepared.

[3] Food waste covers the following types of waste:

02 01 02 Animal-tissue waste (wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing)
02 01 03 Plant-tissue waste (wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing)
02 02 02 Animal-tissue waste (wastes from the preparation and processing of meat, fish and other foods of animal origin)
02 03 01 Sludges from washing, cleaning, peeling, centrifuging and separation (wastes from fruit, vegetables, cereals, edible oils, cocoa, coffee, tea and tobacco preparation and processing; conserve production; yeast and yeast extract production, molasses preparation and fermentation)
20 01 08 Biodegradable kitchen and canteen waste (municipal waste)
20 01 25 Edible oil and fat (municipal waste)
20 03 01 Mixed municipal waste
20 03 02 Waste from markets

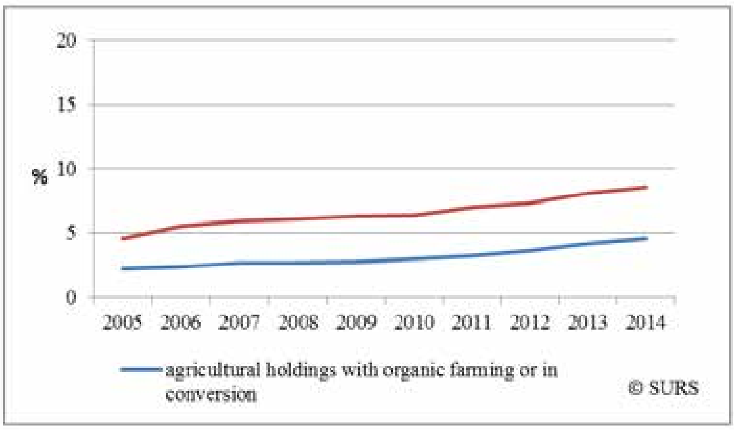
4. Strategic expert proposal for improving the level of food security for Slovenia

Despite relatively low self-sufficiency rates, in the opinion of experts, Slovenia has sufficiently large agricultural land potentials to be able to significantly increase the self-sufficiency rates (Plut 2013). The experts propose:
... Stabilisation of the extent of built-up areas
... Remediation of degraded agricultural area
... Preservation of biodiversity and landscape ecosystems
... Increasing the importance of hilly areas for food
... Protection of irreplaceable fertile agricultural area
... Increasing the extent of agricultural area by a third or at least a quarter of the current extent
... Increasing utilised agricultural area to around 600,000 hectares to achieve the strategic minimum of 3,000 m2 of utilised agricultural area per capita
... Increasing arable land to around 250,000 hectares (or 1,250 m2 per capita) instead of the current 170,000 hectares (less than 900 m2 per capita)
... Increasing the area of cereals to 140,000 hectares (by 2030) to achieve 700 m2 of area of cereals per capita instead of the current 500 m2 per capita
... Streamlining agricultural production into producing food in an integrated and organic way (despite lower yields), with the emphasis on cereals (particularly wheat, not so much maize)
... Increasing the self-sufficiency in vegetables; reducing local production and consumption of meat
... Limiting the production of fodder in flatland areas
... Focusing on orchards, vineyards, pastures and traditional livestock production in hilly areas
... Limiting the production of biofuels on agricultural land (rape seeds and maize for biofuel) to degraded areas

Organic farming responds to key challenges by providing a high level of public goods such as soil quality and biodiversity. It also contributes to the sustainable development of rural areas by creating a larger number of jobs and acting as a promotor of innovation in rural development. In 2004, the EU adopted the European Action Plan for Organic Food and Agriculture and the Government of the Republic of Slovenia adopted the Action Plan for Development of Organic Agriculture in Slovenia by 2015, with the help of which the following goals should be achieved by 2015: 15% of utilised agricultural area with organic farming, 20% share of organic farms and 10% share of organic food in total food supply. The stated goals have not yet been achieved (Slabe 2010).

The share of utilised agricultural area with organic farming is increasing (in the structure of organic farming in Slovenia grassland prevails with a 90% share). Between 2005 and 2012 the share increased from 4.5% to 7.3%, but it is still far from the goal of 15% of utilised agricultural area with organic farming (Green Growth Indicators 2014). Organic food production is an important opportunity for creating new jobs, revitalising agriculture and rural areas, and improving the quality of life. Fresh organic vegetables in particular are imported from Italy, Spain, the Netherlands and Austria. The Institute for Sustainable Development and the Biotechnical Faculty (Slabe 2010) found that in 2009 the share of organic food in Slovenia was only 1% of total food market, but that the demand for organic food has been growing in the past five years at an annual rate of 10–15%. The two institutions also found that organic farming in Slovenia covers only about 20% of the current (still growing) needs of the Slovenian market (Slabe 2010).

Figure 2 - Share of utilized agricultural area with organic farming or in conversion, Slovenia



Sources: Statistical Office of the Republic of Slovenia, Ministry of Agriculture, Forestry and Food

5. Conclusion

There are some key obstacles facing sustainable development: bad conditions for sustainable mobility (public transport is not functional), despite some measures *still insufficient support for organic farming and the resulting insufficient quantities of locally produced organic food, unsustainable construction of tourist facilities, marginalisation of the importance of fair relations in supply chains, general ignorance of sustainable practices* (Plan B for Slovenia 2012). Slovenia has low self-sufficiency rates and downward trends in a number of key crops (vegetables, cereals, potato, etc.), while in bovine meat and milk domestic needs are covered or even exceeded. Connected to declining self-sufficiency rates, Slovenia is facing a question of current agricultural land use. Does it really make sense that livestock production expanded from mountainous regions, with mostly grassland, to more favourable but limited fertile plains on which fodder (mostly maize) for animals is grown. On flatland there is a constant conflict with other activities (e.g. transport and other infrastructure, industry, construction of dwellings), particularly protection of drinking water (Slabe 2010).

Of all expected impacts, in Slovenia extreme weather conditions (floods, droughts, storms) will probably have the most negative impact on well-being in the coming decades, since as regards the damage in recent decades they are already here. The strategy of adjusting agriculture and forestry in Slovenia points out the following key measures (KajfečBogataj et al. 2008):
... Making the construction of water reservoirs and irrigation systems one of the most important targets of agricultural policy (including the provision of food security)
... Sustainable provision of economic security of farms at extreme weather events – via insurance companies and co-financing of premiums
... Providing the possibility of implementing supplementary activities that reduce the vulnerability of farms at extreme weather events
... Changing land use due to repeated droughts (also due to floods and landslides)

From the point of view of the potential of natural resources, key and recommended economic direction for Slovenia is reduced consumption of energy and material and decentralised regional use of domestic resources (Plut 2014). Additional national sustainable development projects for sustainable existence should be prepared and implemented by supporting the pilot sample eco-villages and urban eco-neighbourhoods, increasing food and energy self-sufficiency of its regions and municipalities (pilot sample self-sufficient municipalities), sustainable management and use of local resources in various types of protected areas, and eco-remediation of living and management at national, regional and local levels (Plut 2014).

In the opinion of ecological and agricultural experts, in the next few decades it will be actually possible to expand agricultural land, to decrease food waste in developed countries, and decrease the consumption and share of meat in the diet in developed countries, particularly due to energy-environmental reasons. The general decrease in agricultural land in Slovenia, which is shown by statistical data, due to abandoning of farming and extensive building on the most fertile flatland areas increased its food dependency (Plut 2012).

By 2030 the extent of agricultural land should be returned to the situation around 1960. In view of geographic conditions and ownership, a large share (two thirds) of agricultural area with limited natural conditions from food production (more difficult conditions for production), the large share of protected and water protection areas (on more than half of the national territory), priority water supply role of gravel plains (mandatory subsidies to farmers for lower yields) and other reasons, agricultural production should be focused on producing integrated and organically produced food (despite the slightly lower yield) for supplying the population with a significantly larger emphasis on cereals (particularly wheat, not so much maize), as well as much larger production of vegetables (currently only around 40% self-sufficiency), fruit and partly grapes. In the next 20 years utilised agricultural are needs to be increased from 470,000 hectares to around 600,000 hectares. In this way we would achieve the strategic minimum of utilised agricultural area, which is in our geographic conditions around 3,000 (3,500) m2 per capita. With a view to increasing the self-sufficiency rate of Slovenia, the key issue is increasing the area of arable land (including gardens), where at least 250,000 hectares are needed or at least 1,250 m2 per capita instead of the 170,000 hectares or less than 900 m2 per capita in 2010. Production of animal fodder should be limited, particularly in the flatlands; in the hilly part of the country in addition to orchards and vineyards, grassland should enable traditional, humane livestock production (cattle, sheep) (Plut 2012). The market situation shows that the supply of organic food in Slovenia is still lower than the demand; statistics shows increased share of utilised agricultural area with organic farming. The possibility to engage in such production is still not fully exploited (Perpar, Udovč2010).

A higher self-sufficiency rate (particularly in wheat) could be achieved by taking into account the assumption of reducing local production and consumption of meat (Potočnik Slavič2010). In 2014 the self-sufficiency rate in wheat was 70% (for all cereals in general 77%), which is more than in recent years. Per capita meat consumption has declined over the past ten years; in 2005 it was 97 kilograms and in

2014 85 kilograms. According to SURS's estimates, in the 2008–2013 period the amount of food waste in Slovenia decreased. In 2013 a person in Slovenia generated on average 72 kilograms of food waste; in 2008 the figure was 197 kilograms. These statistical data (some of them should be used carefully) indicate favourable trends and changes in eating habits and draw near to expert proposals.

In view of the needs for food, very limited production of agricultural crops for biofuel would only be possible on poisoned or otherwise degraded areas. The existing forms of pollution, particularly in urban ecosystems, are not irreversible, the quality of air and water resources can be significantly improved, and more effort should be invested in financially demanding recultivation of land poisoned by heavy metals. In the opinion of environmental experts, these areas could be built up, which should in the long run be stabilised (Plut 2014).

In view of the existing knowledge, economic structure and experience, Slovenia has the greatest opportunities in the following low-carbon technologies and value added chains (Climate Change Act 2010): sustainable management of forest, wood as a construction material, wood products and use of wood residues for energy production, and organic farming. In the entire forest-processing chain in particular, Slovenia could build a "green valley" image and could be a role model for how it is possible to sustainably manage national wealth. In the 2010–2020 period, the amount of logs processed in Slovenia could be increased by 70%, i.e. from 1,125,000 m3 to 2,100,000 m3 (Humar, Kutnar, Piškur 2013).

Large effort would be needed also for very important remediation of environmentally degraded areas (e.g. gravel pits, industrial, mining and coal areas), which are usually on flatland. Together with sustainable forestry and rural tourism, increase in importance of hilly areas for food production is essential for the implementation of harmonised, sustainable regional development in Slovenia.

Based on statistical data, the article tries to indicate current agricultural trends and in light of national expert proposals for improvement of food security in Slovenia point out some potential development areas of agricultural activities in the country. Some favourable statistical trends show convergence with proposals to improve food security, while others point out the urgency of future more comprehensive and complex treatment of all stakeholders in planning one of the most important industries.

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Estimation of real per capita consumption of meat in Italy

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ABSTRACT

Food consumption refers to the amount of food available for human consumption. The knowledge of food consumption is crucial to set production and food supply policies, to compare eating habits with other countries, to assess the nutritional status of a population and to study the relationship between diet and health. In the last years all these aspects have taken an increasingly important interest because epidemiological studies have indicated a possible association between high consumption of meat and an risk of several forms of cancer as well as metabolic and cardiovascular diseases.

Unfortunately meat consumption is often estimated by methods that are inappropriate for this use because they do not represent the actual amount of meat consumed or, better, eaten by the consumers. The actual food consumption may be lower than the quantity shown as food availability depending on the magnitude of wastage and losses of food during the slaughtering, in the household, e.g. during storage, in preparation and cooking, as plate-waste or quantities fed to domestic animals and pets, thrown or given away The consumption estimated by FAO and by statistical offices of the various countries through the national food balance sheets does not indicate the amount of meat, ie the weight of the skeletal muscles of animals with included or adherent tissues, but the amount of the weighted carcass at the slaughterhouse, including bones, tendons, connective tissues and fat.

This paper discusses a method of estimating the real per capita consumption of meat in Italy with accuracy comparable to that of individual consumption, developed by the Study Commission of Animal Science and Production Association (ASPA). This action responds to the need of producing statistical indicator related to health food, as recommended by many international organizations (FAO, Eurostat).

Keywords: Consumption, Meat, Estimation

PAPER

1. Introduction

There are different methods for estimating the per capita consumption of meat, highlighting the importance, purposes, advantages, disadvantages and uncertainty. They may be grouped into three categories: Food Balance Sheet, Household Budget Surveys, Individual Dietary Surveys.

1) Food Balance Sheets

Food Balance Sheets (FBSs) are annually published by FAO (2015b). They shows for each food item i.e. meat for human consumption which corresponds to the sources of supply and its utilization. The total quantity of meat produced in a country added to the total quantity imported and adjusted to any change in stocks that may have occurred since the beginning of the reference period gives the supply available during that period. On the utilization side a distinction is made between the quantities exported, fed to livestock + used for seed, losses during storage and transportation, and food supplies available for human consumption. The per capita supply of each such food item available for human consumption is then obtained by dividing the respective quantity by the related data on the population actually partaking in it. Data on per capita food supplies are expressed in terms of quantity and by applying appropriate food composition factors for all primary and processed products in terms of dietary energy value, protein and fat content. It is an apparent consumption because includes non-edible parts, such as tendons, cartilages and all the waste.

The estimated consumption of foods based on availability is the most popular method because it allows to derive the annual per capita consumption without difficulty and almost inexpensively. Another strong point if compared with other methods as detailed hereafter, is the ability to estimate the availability of food for the population in all the points of consumption: home, restaurants, canteens, community hospitals, prisons, barracks, etc. Moreover, the consumption can be estimated regardless of how foods are consumed: raw or cooked, fresh or processed.

At the same time FBSs presents some weak point. The method leads to a significant overestimation of the consumption compared to the amount actually eaten due also to the difficulty or impossibility of separating the product for human consumption from the amount of product given to animals. Another critical issue of FBSs regards the population participating in available consumption for human use. The apparent meat consumption is helpful to know the total amount of meat available in a country for human consumption.

2) Household Budget Surveys

Household Budget Surveys (HBSs) are national surveys mainly focusing on consumption expenditure. They measure the household expenditure to buy food and other goods and services, and in some cases also the quantity.

HBSs are used to compare expenditure and indices of consumer prices for different foods among states, regions or different socio-economic groups, to monitor the consumption of various foods over time and eventually to take decisions in social, agricultural and food policies. The consumption data measured by HBSs are also used to study the relationship between consumption of a particular food or group of foods and human diseases. But this use requires precautionary measures because the estimated consumption does not express what a person really eat but simply what a person buy. Meat consumption measured by a HBS is a less coarse index compared to that obtained with the FBSs because the meat bought at retail is already deprived of most of the bones, tendons and the separable fat and do not include waste.

However, HBSs do not provide the real consumption of meat, but the available amount for consumption; furthermore, the method is more complex and expensive. Another point of weakness of this method is represented by eating meals outside home. In addition, Household Budget Surveys do not take into account guests in the family, food purchased but not consumed during the survey period or those purchased before the reference period.

3) Individual Dietary Surveys

Individual Dietary Surveys (IDSs) are carried out by research institutes on a sample of individuals representative of the population. Individual surveys provide data on the amount of foods or food categories consumed by the selected individual over the period covered by the survey. The survey may also retrieve some information, such as the daily episodes when specified foods have been consumed, whether they were home-produced or bought and, in such cases, also the commercial label, the way in which foods were cooked, the place where they were consumed, whether there was any edible wastage and so on. Tables of food composition are used to calculate the energy and nutrient content of the consumed foods.

Basically, the methods for assessing individual dietary intakes can be classified into two main categories: the retrospective reporting of intake from the recent or remote past and the prospective recording of consumption. Some methods only measure consumed foods and the frequency of consumption, others also measure the weight scale or the standard weight portions. Food can be weighted raw or cooked. The costs are high and the diversity of methods makes no fully comparable data from different surveys. Data from these surveys are more appropriate than those obtained with FBSs or HBSs to describe the eating habits and to study the relationship between food intake and human health. The limitations and uncertainties concern the weight check, the study of domestic waste in the kitchen and on the plate, the conversion from raw to cooked food, the conversion of processed products into meat, the separation of meat in compound feed. They are very expensive and therefore they are occasionally carried out or with a multiannual periodicity and not in all countries.

Definitively, all methods overestimate the real meat consumption because they include non-edible parts, processing losses and waste. In IDSs the overestimation is minimum, but in FBSs it can reach values higher more than twice the actual food consumption. It is necessary to take into account the limitations and uncertainties that each method presents, to know the objectives and reasons for which they were designed and to interpret and use the data on consumption correctly.

To overcome this situation, the Scientific Association for Science and Animal Production (ASPA) has set up a committee of professors and researchers belonging to some Faculties of Agriculture and Veterinary Medicine, experts in the meat of different animal species, plus an ISTAT expert on animal production to develop an economic, fast and reliable estimative method to assess the real per capita consumption of meat and fish. In this paper we reported the results on the meat.

2. Method

To achieve the aim, the committee used the Food Balance Sheets (FBSs) method, the same with which in Italy is estimated the apparent consumption The method is even used in Italy to estimate the apparent consumption. This The actual per capita consumption of meat has been is calculated subtracting from the availability in kilogramms of carcass weight the processing losses as well as the parts that are not edible (bones, cartilages, connective tissue, etc) and excess fat, which is normally not eaten and is not currently classified on the nutritional and dietary plan as meat but it is considered as fat. In other words, the definition of the level of meat consumption was changed from equivalent carcass to fresh meat by conversion coefficients specifically determined. First of all it is necessary to have a wide knowledge of national availabilities. This was taken from surveys on the slaughter and records of imports and exports made by ISTAT.

Then it is of fundamental importance a detailed analysis of the losses that occur between primary production and the actual consumption (Table 1). The total losses and waste were estimated using data from scientific literature on slaughtering procedure and meat yield of carcass and several joints.

Table 1 - Losses that occur in the reduction of the animal's carcass to meat

Cold carcass

- ✓ **Processing losses**
- ✓ **Removing most of bones, cartilages, ligaments, tendons and aponeuroses**
- ✓ **Separable fat removal**
- ✓ **Partial or total skin removal in pigs and poultry**

Salable meat

- ✓ **Retail processing losses**
- ✓ **Retail scrap material**
- ✓ **Retail wastes**

Consumable meat

- ✓ **Scrap material at consumption in the kitchen and on the plate**
- ✓ **Consumption wastes**

Actually consumed meat

The estimates of losses at various levels of the supply chain are almost inexistent in Italy. Information are often inaccurate and confused: for example, no distinction is made between waste carried to a level as those carried out at previous levels, etc. In particular estimates of consumption losses both at home and outside home are scarce or non-existent.

Faced with this situation, the Committee has used a completely different approach to estimate with a good degree of approximation losses, scrap material and waste The processing losses are liquid losses and small body parts not recoverable that occur in the sectioning of the carcass, in the preparation of the cuts and of the portioned meat. The scrap materials are parts not edible (bones, cartilage, tendons and ligaments), or diverted from human consumption (separable fat with a knife, aponeurosis, glands, nerve tissue and blood vessels). Wastes include fresh or transformed meat discarded due to impairment, presence of defects, overcoming expiration date, lack of acceptance or because purchased or cooked in excess. With this approach the total of processing losses and scrap material waste, regardless of the stage of the supply chain in which they occur, were quantified using data from the scientific literature on livestock slaughtering, consulting experts in the field and in the case of cattle performing carcass dissection trials.

For processed products the determination of conversion coefficients was more complex because it was also necessary to take into account the weight loss due to processing and seasoning and the addition of fats and other ingredients in order to transform them into fresh meat. as defined above.

3. Results

The ASPA Committee calculated the conversion factors of the carcass, quarters, cuts and all meat products imported and exported of various animal species in consumable meat. An example of these coefficients is shown in Table 2.

The availability of consumable meat without considering retail waste was obtained multiplying the apparent availabilities by these conversion coefficients. The per capita availability of the retail consumable meat is achieved dividing the total availability by the population of Italy).

Table 2 - Conversion coefficients of carcass in consumable meat by species

Red meat	Conversion coefficients (%)	**White meat**	Conversion coefficients (%)
Lambs	0,573	Broilers less than 2 kg	0,610
Lambs >15 kgs	0,536	Broilers over 2 kg	0,620
Ewes and rams	0,565	Turkeys	0,621
Piglets	0,494	Guinea Fowls	0,582
Light pigs	0,528	Ducks	0,520
Heavy pigs	0,492	Gooses	0,520
Steers	0,593	Quails	0,452
Female bovine animals aged less than 15 months	0,575	Pigeons	0,501
Calves <8 months	0,524	Rabbits	0,553
Wild boars	0,707	Red deers	0,738
Fallow deers	0,722	Roe deers	0.789
Mouflons	0,632	Chamois	0,713
Horses, donkeys and mules	0,700		

Table 3 shows the amount of meat consumable obtained for the different animal species in the period 2010-2014.

Obviously the per capita availability of consumable meat, comprising the waste to the detail is much lower than the availability in carcass equivalent calculated for example by the FAO. In fact the latest figures published by the FAO, which for Italy relate to the years 2010 and 2011, respectively report an apparent consumption of 89.51 and 86.65 Kg (FAOSTAT). However the amount of available meat thus calculated provides an index much more close to the actual consumption.

Table 3 - Estimates of consumable meat per capita in Italy without considering retail waste in the period 2010-2013 (Kg)

Meat	2010	2011	2012	2013	Average
Bovine[1]	13,75	12,73	12,30	11,69	12,62
Pigs	20,57	19,97	19,52	19,47	19,88
Poultry	10,93	11,59	12,07	11,60	11,55
Sheep and goats	0,65	0,61	0,58	0,49	0,58
Horse	0,66	0,63	0,64	0,56	0,62
Rabbit	0,35	0,35	0,34	0,32	0.34
Wild animals [2]	0,06	0,06	0,06	0,06	0,06
Total	46,97	45,94	45,51	44,19	45,65

[1] It includes buffalo meat; [2] equal estimate all years

The accuracy of the estimate, which is a derived statistics, is dependent on the reliability of the statistics of supply and determination of the conversion coefficients. The data on national production, imports and exports are those collected by ISTAT. Therefore the accuracy of the estimate of the per capita availability of meat should be the same as that of the apparent consumption calculated by FAO, for example. As well as retail waste, the consumable meat still includes scrap material at consumption in the kitchen and on the plate and consumer waste (meat and meat products eliminated on the garbage for impairment, exceeded expiration date or because purchased or cooked in excess). In order to get the real meat consumed the waste produced at retail and the scraps and wastes at consumption level must be subtracted from the availability of consumable meat.

For retail waste some information obtained from a number of stores of a great distribution chain were taken into consideration. The retail wastes were calculated on the difference in value between the total receipts of meat put on sale and the amount of meat actually sold. Based on this information the retail wastes were estimated to be about 2% regardless all species. Taking into account these losses, it has been obtained the true consumable meat.

For consumer losses (scrap material in the kitchen and on the plate and wastes) both at home and away from home (restaurants, fast foods and services institutions,) the only information came from some researches carried out abroad. For European countries according to a study (2011) performed by FAO the meat losses at consumption amount to 11% of the quantity purchased. The same proportion of waste has been found in UK by WRAP (2009) for the group of food comprising meat and fish, The Economic Research Service of United States Department of Agriculture estimated the losses at consumer level to 23% for meat and to18% for poultry (USDA ERS, 2016), but in USA the losses include some inedible material, such as bones.

Based on these data, taking into account that bones have already been eliminated from the consumable meat estimate in this research, it was assumed as consumer losses a value equal to 10%. Subtracting this value to the meat consumable has been obtained the real consumption of the meat.

Table 4 shows the real meat consumption per capita in Italy in 2010-2013 The real consumption per capita obtained are almost identical to those observed in the years 2005-2006 in Italy by CRA-INRAN with the method of individual dietary survey (IDS) (Turrini et al. 2013).

Table 4 - Real meat consumption per capita in Italy in the period 2010-2013 (Kg)

Meat	2010	2011	2012	2013	Average
Bovine[1]	12,12	11,23	10,85	10,31	11,13
Pig	18,14	17,61	17,22	17,17	17,53
Poultry	9,64	10,22	10,64	10,23	10,18
Mutton and goat	0,57	0,54	0,51	0,43	0,51
Horse	0,58	0,56	0,56	0,49	0,55
Rabbit	0,31	0,31	0,30	0,28	0.30
Wild Animasi [2]	0,05	0,05	0,05	0,05	0,05
Total	41,41	40,52	40,13	38,96	40,25

[1] It includes buffalo meat; [2] equal estimate all years

This is particularly interesting because it shows that the method proposed by us, based on FBS but changing the definition level of meat, estimates the actual consumption with the same precision of IDS on individual consumption, but without the complexity and high costs of this. Obviously the method only provides the average consumption of a country and does not allow for the breakdown of consumption by different group population differing for socio-economic, geographical, age class, sex and other demographic characteristics. Therefore our method cannot replace individual dietary survey, but can be useful for monitoring the nutritional status of the population of a country in the long range of years that usually separate the IDS.

Table 5 - Apparent and actual per capita daily consumption (grams) of meat in Italy.

Meat	2010	2011	2012	2013
Bovine				
real consumption	12,12	11,23	10,85	10,31
apparent consumption	23,8	22,1	21,3	20,2
real/apparent %	50,9	50,8	50,9	51,0
Pigs				
real consumption	18,14	17,61	17,22	17,17
apparent consumption	38,4	37,3	36,9	36,7
real/apparent %	47,2	47,2	46,8	46,8
Poultry				
real consumption	9,64	10,22	10,64	10,23
apparent consumption	18,0	18,6	19,4	18,8
real/apparent %	53,6	54,9	54,8	54,4

In the four years period considered the real meat consumption per capita decreased by 2,45 kg, equal in relative terms to about 6%. The decrease has mainly affected the beef (1,81 kg) and pig (0,97 kg).

Table 5 shows the apparent and real daily consumption of meat of the three main species. The apparent consumption values are those calculated and published by ISMEA.

The actual consumption is compared to those apparent about 51% for beef, 47% for pork and 54% for the poultry. The method provides an estimate very close to that of the quantity of ingested meat and therefore may be a more suitable index for the studies on the relationship between meat consumption and human health.

Conclusion

The method allows to estimate the per capita real consumption on annual basis with the same precision of the individual dietary survey, but without the complexity and the high costs of the latter.

The developed method provides an estimate very close to that of the quantity of ingested meat and therefore may be a more suitable index for the study of the relationship between meat consumption and human health.

The method may represent a paradigmatic example to estimate real consumption of all foods, similarly to what it is done in the US by the economic statistics service of the Department of Agriculture (USDA ERS,2016).

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THEMATIC SET

B13

CAPTURING THE ENVIRONMENTHAL IMPACT OF AGRICULTURAL ACTIVITIES

Session Organizer
R. Smith | TIES | Edinburgh | United Kingdom

ABSTRACT

Agricultural activities have effects on the surrounding environment and often on a wider environment, through a number of pathways. Locally there is runoff of pollutants to neighbouring land and water bodies, with pesticides, use of excess fertilisers for whatever reasons, and hormones and medications from livestock production being some examples. There can be also other by-products of the agricultural practices, such as ammonia gas from intensive units, and greenhouse gases (carbon dioxide, methane and nitrous oxide) from various agricultural activities. Downstream impacts of agricultural include effects of use of water changing drought and flooding frequencies and water availability for other purposes. Many of these effects are now being modelled using statistics available, but the example of the local scale modelling of greenhouse gases under IPCC encouragement shows that our data sources may not be detailed enough for the tasks ahead. The session will look globally at some examples of data requirements for assessing agricultural impact and explore to what extent the current statistical base provides us with the information required

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E. Vaudour | UMR ECOSYS, AgroParisTech, INRA, Université Paris-Saclay | Paris | France
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How to evaluate the impact of agrienvironmental policies on biodiversity in rural areas. The case of High Nature Value Farming systems

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D. Longhitano | Council for Agricultural Research and Economics, CREA | Legnaro | ITALY
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The environmental effects of meat from livestock to slaughter in Italy: integration between data and GIS

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Regional prediction of soil organic carbon content over temperate croplands using different multiscale measurements by hierarchical modelling

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ABSTRACT

Spatial monitoring of soil quality especially in terms of soil organic carbon (SOC) content for the purpose of evaluating the effects of C-stocking practices at different spatial scales, is critical for both stakeholders and public authorities. Various studies have recently demonstrated the usefulness of hyperspectral satellite images for faster and cheaper prediction of SOC compared to standard soil chemical analyses. In this study we combine both sources of information by means of hierarchical modelling accounting for different spatial scales to provide an accurate map of SOC over a broad regional scale in a peri-urban region.

Keywords: SOC content, Hierarchical modelling, Multi-scale, Spatial statistics

PAPER

1. Introduction

The overall decrease of soil organic matter in peri-urban croplands has become a threat for soil sustainability in Europe (Ciais et al., 2010). The COP21 conference recently held in November 2015 in Paris resulted in adopting a "4p1000" initiative aiming at favouring C storage practices to mitigate greenhouse gas emissions. Among possible storage practices, the recycling of exogenous organic matter (EOM) issued from organic waste treatments originating from urban, industrial and agricultural activities provides a promising source of C stocking amendments which may also substitute synthetic fertilizers (Houot et al., 2014; Noirot-Cosson et al., 2015). This study, as a part of the French TOSCA-"PLEIADES-CO" project, basically aims at spatially simulating the effects of such practice at the regional scale of a 221 km² peri-urban area close to Paris, where animal breeding has declined. The spatial simulation of such effects of EOM use practice (Noirot-Cosson, 2016) requires spatially explicit and updated information about initial soil organic carbon (SOC) stocks. SOC stock, defined as the carbon mass per unit area for a given depth, is the product of SOC content by considered depth (for a given horizon), soil bulk density, and the percent volume of soil out of rock fragments. Goidts et al. (2009) identified SOC content variability as one of the main sources of predictions uncertainty of SOC stocks and whatever scale, from global to local (Minasny et al., 2013), most studies considered SOC content as the main target variable, and this mainly for the topsoil layer comprised between 8 and 30 cm, being most often the ploughed layer for cropland, i.e. the layer directly modifiable by C-stocking practices such as EOM use. At such detailed scale such as our study area, accurate predictors of SOC content are required: error uncertainties shall be specified to each potential end-user so that, jointly to the map of SOC contents, a map of prediction uncertainty should be provided.

Whatever scale, environmental covariates are the most commonly used to predict SOC content. Depending on the context, either terrain attributes derived from a DEM (Orton et al., 2012a, 2012b; Lacoste et al., 2014), land use/land cover (Lacoste et al., 2014), satellite images (Normalized Difference Vegetation Index (NDVI) derived from remotely sensed images, (Wu et al., 2009)), remotely and proximally sensed visible to near infrared (NIR) reflectance (Peng et al., 2015), geological data (Lacoste et al., 2013), or gamma radiometrics (Malone et al., 2009), may be considered in the modelling. Numerous methods have been developed for mapping soil properties generally using one or a combination of environmental covariates. They mostly rely on statistical modelling and can be classified into three categories: (i) remote-sensing methods, predicting SOC content by means of a regression from hyper/multi-spectral image reflectance spectra (Selige et al., 2006; Stevens et al., 2010, 2012; Gomez et al., 2012; Vaudour et al., 2013, 2016); (ii) geostatistical methods, based on a network of soil sampled sites and a set of environmental covariate data being mostly terrain attributes derived from a DEM (Marchetti et al., 2010; Hamiache et al., 2012; Conforti et al., 2015) and/or soil types (Kempen et al., 2011) and/or an airborne gamma radiometric image (Malone et al., 2009); a spectral or vegetation index band of a multispectral satellite image (Wu et al., 2009); (iii) machine learning methods, such as random forest (Grimm and Behrens, 2010), regression trees (Lacoste et al., 2014; Peng et al., 2015; Somarathna et al., 2015) or support vector regression (Somarathna et al., 2015).

In this study, we aimed at mapping SOC contents of agricultural topsoil over a 221 km² peri-urban area, the EOM sources of which need to be spatially managed across the 106 km² cropland area (Noirot-Cosson et al., 2014). The further use of this map into a soil plant model and for practical decision for end-users dictates the need for uncertainty assessment, as well globally as locally, at the scale of each cultivated field.

A previous study (Hamiache, 2012) provided maps of SOC content by means of multivariate geostatistical methods, from soil measurements and DEM variables. Here we aim at integrating all kind of available information, at different scales and from various sources : hyper/multi-spectral image reflectance spectra, remotely and proximally sensed visible to near infrared (NIR) reflectance, terrain attributes derived from a DEM and soil measurements, in a single hierarchical model to provide an as precise as possible map of SOC content together with its uncertainty assessment.

The core of the hierarchical model is a latent spatial random field representing the SOC content, which is linked to the available data through several relationships that take into account the scale change, and the measurement and modelling uncertainty.

2. Hierarchical modelling

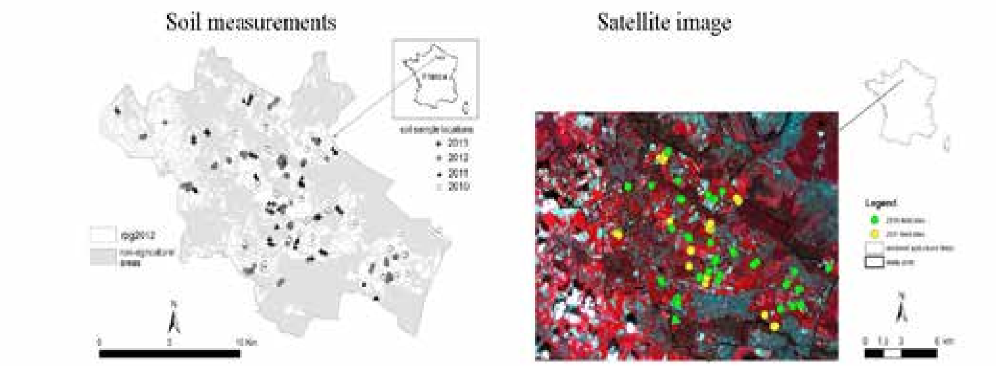
Let $C(s)$ the SOC content at location s, s in a domain S. We assume that C can be written as $C(s)=X(s)\beta+\varepsilon(s)$. $X(s)$ is a vector of covariates at position s and $\varepsilon(.)$ is a stationary Gaussian random field with covariance function $\rho(.)$. Covariates X stem from a DEM (elevation, slope, …) available at different resolution grids.

We have at our disposal two observation families that can be linked to the SOC content.

- $(Y_1^1, Y_2^1, \ldots, Y_{n_1}^1)$ are the values of a satellite image acquired on March 2013, at pixels of size $\delta_x \times \delta_y$ centred on sites $(s_{11}, s_{12}, \ldots, s_{1n_1})$ selected because the corresponding areas were bare soils at the moment the image was taken. Usually the Y^1s are vectors with dimension nb, the number of spectral bands, but here we consider only the first one (infra-red). We assume that a value Y_i^1 is a noisy affine transformation of the SOC average on the pixel centred on s_{1i}.
- $(Y_1^2, Y_2^2, \ldots, Y_{n_2}^2)$ are values of soil chemical characteristics, including Organic Carbon, acquired from 2010 to 2013 at locations $(s_{21}, s_{22}, \ldots, s_{2n_2})$.

Figure 1 shows the Plaine de Versailles region together with the locations of the soil measurements and a satellite image of the region acquired on 27 April 2010

Figure 1 - Plaine de Versailles: locations of the soil measurement by year and 2.5 m-SPOT5 image of 27 April 2010. SPOT/ISIS programme. Copyright CNES.



We consider a grid of mesh $\delta_x \times \delta_y$ so that the we can write $Y_i^1 = \frac{1}{4} \sum_{s_j \text{ neighbour } s_i} C(s_j) + \varepsilon_i^1$, $(\varepsilon_i^1)_i$ are i.i.d zero-mean Gaussian random variables with variance σ_1^2 .

If we assume that the measurement noise for SOC is normally distributed with variance σ_2^2 and considering an affine transformation of the DEM covariate elevation E , then the hierarchical model is written :

$$C_g \sim N(\mathrm{a}+\mathrm{bE}_g, \sigma_0 \Sigma_g)$$
$$Y^1 \mid C^1, \mathrm{c}, \mathrm{d}, \sigma_1 \sim N(\mathrm{c}+d\overline{C^1}, \sigma_1^2)$$
$$Y^2 \mid C^2, \sigma_2 \sim N(C^2, \sigma_2^2)$$

C_g and E_g are the vectors of the latent variable and the elevation on the grid, Σ_g the covariance matrix for C_g, C^1 is the vector of the C_g involved in the averaged calculation $\overline{C^1}$ linking the image and the SOC content, C^2 is the latent variable at locations $(s_{21}, s_{22}, \ldots, s_{2n_2})$ are not on the grid). The covariance function $\rho(.)$ is given by an exponential model and the matrix Σ_g can be written as $\Sigma = \sigma_0^2 \Sigma_0$ with $\Sigma_0(s, s') = \exp(-\|s - s'\| / \alpha)$. The range α parameter is estimated previously by usual geostatistical methods from the SOC measurements.

After straightforward calculations the two last equations of the model can be resumed as a linear model $\Upsilon = MC_o + \varepsilon$, Υ gathers vectors Y^1 and Y^2, and C_o is the vector of the latent variable C at all the locations involved in the observational layer.
Inferring the whole model consists then to infer the latent variable C at all the grid points and the parameter vector $\theta = (a, b, c, d, \sigma_0, \sigma_1, \sigma_2)$.
The inference is driven in a Bayesian framework, by means of a Gibbs algorithm from classical prior distributions to provide good conjugate distributions. Updating the parameters θ and the C^1 is given by the standard formulas for linear models, and the component of C on the grid that are not included in C^1 are obtained by Gaussian conditional simulation.

2. Simulations

To evaluate the algorithm performances and to evaluate to what extent the chains convergence hold, a simulation study is driven on a fine small size grid.
The size of the grid is 100×100, the scale parameter is $\alpha = 10$, and the θ parameters are $a = -4$, $b = 2$, $c = 10$, $d = 5$, $\sigma_0 = 5$, $\sigma_1 = 2$, $\sigma_1 = 2$. We pick at random $n_1 = 400$ and $n_2 = 300$ values of the corresponding simulated Y^1 and Y^2.
The inference algorithm is performed on several chains in order to enable a control of convergence of the distribution with several values for hyper-parameters to investigate the sensivity to the priors.

Figure 2 - Posterior distribution for $\theta = (a,b,c,d,\sigma_0, \sigma_1, \sigma_2)$

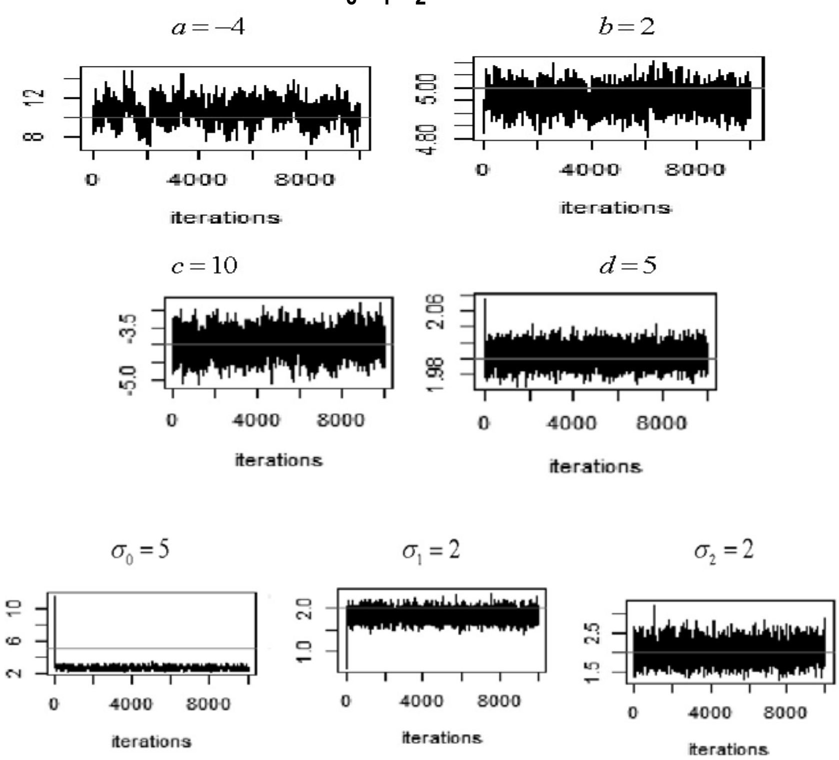


Figure 2 displays the posterior distribution for parameters 0. For all the parameters except 0_0 the convergence toward the real value is reached quite rapdly. The lack of convergence of 0_0 may be due to an identifiability issue, common for spatial fields although the scale is not inferred, and must be investigated.

Figure 3 - Latent field and averaged posterior fields

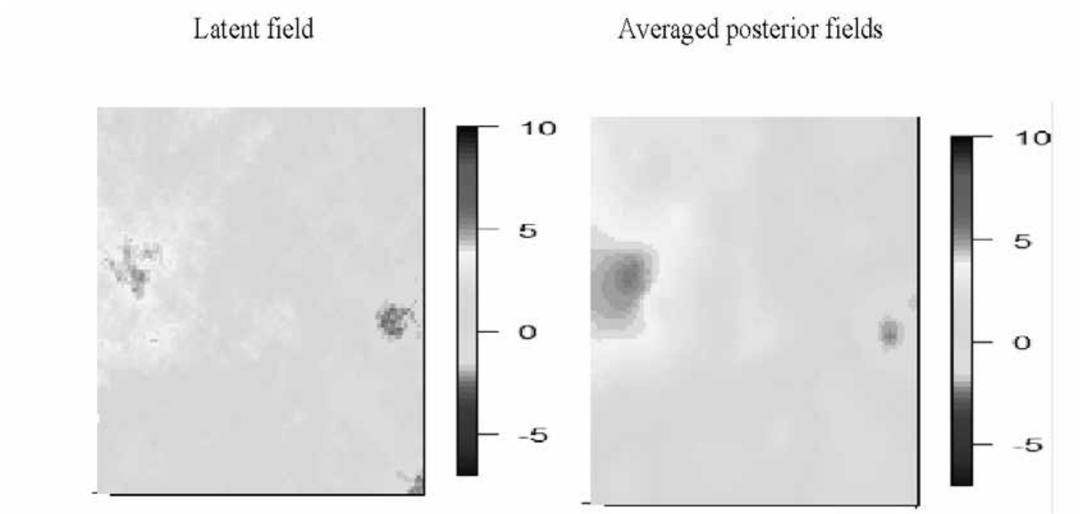


Figure 3 displays the simulated latent field C , together with some draws of the posterior distribution and the averaged posterior fields showing that the main features of the latent field are recovered in average.

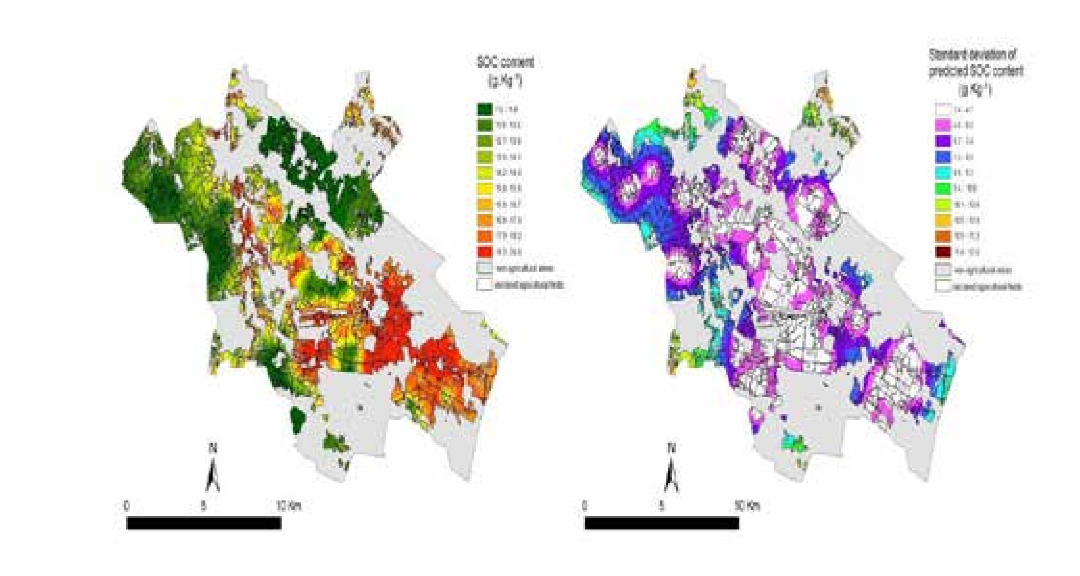
3. Real data

The simulation study shows encouraging results, but it is driven for a small dataset size. The dataset we are faced with in an operational framework is an image on a grid of 243x407 cells, n_1 10192 cells representing bare soils and n_2 253 top soil measurements.

This leads to severe computational issues, as the conditional simulation step of the Bayesian algorithm needs the inversion of a matrix of size $n_1 x n_1$. Using specific packages for very big matrices and storage utilities could help to carry out the inference, still it remains very time consuming. Making recourse to approximation methods seems unavoidable.

Figure 3 shows a map for the SOC content and the map of its standard deviation obtained with the same dataset except the image, but using geostatistical methods. This map will serve as a reference, to investigate to what extent data from satellite images may improve the mapping of SOC content and what would be the degraded performance using images instead of soil measurements.

Figure 4 - Mapping for the SOC content and its standard deviation by geostatistical methods



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Increased quality in statistics on crop residues and lime used as input to greenhouse gas inventories

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ABSTRACT

Updated and well documented agri-environmental statistics are key for the evaluation of national and international environmental goals and targets. The annual National Greenhouse Gas (GHG) Inventories according to the UNFCCC is one such example, and requires great amounts of input data. This paper focuses on methodological improvements of the statistics on crop residues and lime, which are needed to estimate the GHG emissions from the agricultural sector. Statistics Sweden conducts several surveys in the agri-environmental area and is the responsible government agency for the statistics on crop nutrients and cultivation measures in agriculture in Sweden. In a previous pilot study, coefficients for nitrogen in crop residues were reviewed, and compared with those used in the Swedish GHG calculations. Within the same project, updated official statistics were produced on the utilisation of crop residues, presented as shares of crop areas with different management in terms of crop residues. However, to make use of the new data in the GHG gas calculations, the areas need to be converted into quantities. This requires coefficients for the ratio between crop residue and yield. Stubble heights also need to be considered. A desk study was carried out to obtain updated coefficients for ratios between straw or tops and crop yield as well as for nitrogen content in the crop residues. The updated coefficients will increase comparability between the GHG inventories and other environmental reports, such as the OECD/Eurostat nutrient budget for nitrogen.

Regarding the estimation of GHG from lime used in the agricultural sector, annual sales statistics were used until the National Inventory Report for Sweden 2015 was submitted. However, indications of increased agricultural use of lime in the form of by-products that are not distributed through the ordinary market imply that sales statistics may no longer fully reflect the amount of lime applied to arable land. A test to move from sales statistics to statistics on farmers' actual use of lime has been conducted, utilising the existing sample surveys on fertiliser use and cultivation measures in agriculture. Data on farmers' application of lime to arable land were collected for the years 2010, 2012 and 2014. The questions covered type and amount of lime product and size of land area where lime had been applied. Results were compared with sales statistics for the years 2010 and 2012. It showed that for well-defined products available on the ordinary lime market, data from the sales statistics and from the sample survey were comparable and relatively similar. However, the sample survey showed larger total amounts of lime than the sales statistics. This was due to the application of lime products in the form of by-products from e.g. the paper and concrete industries, which were not completely accounted for in the sales statistics. Hence, for environmental monitoring, such as the GHG inventory, the statistics of farmers' lime application constitute a better basis for calculations, as it reflects the actual amount that is applied to soil and hence affects the natural environment.

Keywords: crop residues, nitrogen, straw, greenhouse gas, nutrient budgets, lime, sales statistics, sample survey, mixed mode

PAPER

1. Introduction

Updated and well documented agri-environmental statistics are crucial as they form the basis for several environmental reporting systems that in turn are needed for the evaluation of national and international environmental goals and targets. The annual National Greenhouse Gas (GHG) Inventories according to the United Nations Framework Convention on Climate Change (UNFCCC) is one such example, and requires great amounts of input data. Statistics Sweden conducts several surveys in the agri-environmental area and is the responsible government agency for the statistics on crop nutrients and cultivation measures in agriculture in Sweden. Statistics Sweden is also part of the consortium Swedish Environmental Emissions Data (SMED), which conducts the inventory and reporting of GHG.

This paper focuses on two of the input variables needed for the inventory of emissions from the agricultural sector, namely: estimates on the amount of crop residues that are left on the field and the amount of lime applied to soil. The specific aims are to:

- i) update the coefficients and the method to convert shares of land areas into quantities of nitrogen in crop residues

- ii) present a new methodology to collect data on the use of lime that reflects current situation in agriculture.

2. Crop residues

In a previous pilot study, coefficients for nitrogen in crop residues were reviewed (Andrist Rangel et al, 2013a; b). It was also observed that coefficients used in the Swedish calculations for the GHG inventory and for the OECD/Eurostat's nutrient budgets requested from all European Member states (MS) differed. Within the same project, updated official statistics were produced on the utilisation of crop residues, presented as shares of crop areas with different management in terms of crop residues. However, the areas need to be converted into quantities of nutrients before they can be applied in the GHG and nutrient budget calculations.

2. 1 Share of removed crop residues – definitions and source data

Crop residues are defined as dead biomass according to 2006 IPCC Guidelines (IPCC, 2006). In the model used in Sweden for estimating flows of nitrogen within the soil-plant-animal system for the GHG inventory, litter is considered to recirculate within the agricultural system as it is returned to the field mixed with the manure (Adolfsson, 2005; Swedish EPA, 2006). Hence, the litter, which constituted about two thirds of total removed crop residues in Sweden (Statistics Sweden, 1999), is therefore not included in the estimations of the removed part in the inventory. This corresponds with the estimations of nitrogen contribution from manure, since the excretion factors used in the calculations characterise freshly excreted manure and hence, stable litter is not accounted for on the input side. Hence, whether the part used for litter shall be treated as left on or removed from the field in the calculations depends on what the coefficient for applied live-stock manure describes, i.e. if it includes straw or not.

Until the reporting of 2014 year's emissions of GHG for Sweden (Swedish EPA, 2016) and until 2011 year's official Swedish nutrient balances (Statistics Sweden, 2013a) and OECD/Eurostat balances (OECD, 2012), input data on share of crop residue removal from fields originate from a survey from 1997 (Statistics Sweden, 1999). In that survey, three categories were used to describe existing management practices of crop residues on arable land at the crop level (hectares): "burnt on field", "incorporated into the soil" and "removed from the field". For the category "removed from the field", the area was further divided into four subcategories representing different uses (% of area): "fodder", "litter", "energy production" and "other uses". In 2012, a new sample survey on the utilisation of crop residues was carried out among farmers in Sweden (Andrist Rangel et al., 2013a; b; Statistics Sweden, 2013b). The results were presented and published as shares of crop areas.

2. 2 Crops harvested green

In the 2012 survey on crop residues, the category "burnt on field" was excluded since this type of land management is insignificant Sweden (Statistics Sweden, 1999). Instead, the category "harvested green" was added, which enabled new and more precise estimations of the areas from which straw and tops had been removed from the field as residues (=dead biomass) or as part of crop products harvested green (=live biomass), respectively. According to 2006 IPCC Guidelines, no above ground crop residues are generated from crop areas harvested green, except stubble. Comparisons of the results from the 1997 and 2012 surveys showed that if the area harvested green is not considered specifically in the questionnaire, there is a risk that the respondent (farmer) reports that area in the category "removed from the field" instead, and then into the subcategory "fodder". This seems to have occurred in the 1997 survey, and is notable for crops that in Sweden typically have a high share of the crop area being harvested green, such as mixed grain (Table 1).

In the interpretation of the results from the 2012 survey, the area harvested green of crop(T) should be deducted from the total crop area of crop(T), before the partition of different uses/management practices of "real" crop residues. If the area harvested green is not accounted for in the GHG inventory, the fraction of crop residues left on the field and corresponding N2O-emissions will be overestimated.

Table 1 - Crop residues from mixed grain according the 1997 and 2012 surveys on the utilisation of crop residues in Sweden.

Year	Crop area (ha)	Share of crop area (%)					Usage of crop residues from the area where residues have been removed from the field (%)			
		Harvested green[1]	Burnt on field	Ploughed into the soil	Removed from the field	⇨	Fodder	Litter	Energy prod.	Other
1997	30 200	n.a.	0	41	59		28	70	1	1
2012	15 900	19	n.a.	35	39		37	63	0	-

1) Per definition according to 2006 IPCC Guidelines, no above ground crop residues are generated from this area, except stubble.

n.a. = not analysed

Based on the categories as defined in the 2012 survey and the assumption that litter is circulating internally, the ideal estimation of above ground cereal crop residues that are left on the soil, $Above\text{-}ground_{Left}\ N_{(T)}$, that is needed for the GHG calculation, is given in equation 1:

$$Above\text{-}ground_{Left}\ N_{(T)} = (Area\ with\ grain\ harvest_{(T)} \times Grain\ yield_{(T)} \times R_{AG(T)} \times N_{AG(T)} \times (1 - Frac_{Remove(T)})) + (Area\ harvested\ green_{(T)} \times N_{Stubble(T)}), \qquad \text{(eq. 1)}$$

where

$$Frac_{Remove(T)} = (Frac_{Removed\ from\ the\ field} / (Frac_{Ploughed\ into\ the\ soil} + Frac_{Removed\ from\ the\ field})) \times (1 - Frac_{Litter})$$

Rag(t) = Ratio of above ground crop residues (including stubble) to grain yield for crop T

Nag (t) = Nitrogen content in above ground crop residues for crop T

$N_{Stubble(T)}$ = Nitrogen in stubble per hectare of area harvested green for crop T

Grain $yield_{(T)}$ = Actual annual grain yield in dry matter for crop T

Equation 1 has not been implemented in the Swedish GHG calculations yet. Areas for annual crops harvested green have been published for Sweden since at least the year 2000 (Swedish Board of Agriculture and Statistics Sweden, 2016). The use of Equation 1 would be an improvement in accuracy in the GHG inventory.

2. 3 Ratios between crop residues and yield

To make use of updated statistics on crop residues from the 2012 survey in the GHG calculations and in the nutrient balances, areas need to be converted into quantities (Equation 1). For this, data on crop grain yields combined with coefficients for the ratio between crop residues and yield (i.e. RAG) are needed. For cereals and oil seed rape, coefficients for RAG constitute the weight ratio between straw and grain. For other crops such as potato and sugar beets it is the weight ratio between tops and harvested yield.

Another factor to consider for cereals and oil seed rape is the stubble, as this is left on the field after harvest and should be included in the above ground crop residues, Above-ground N(T), according to 2006 IPCC Guidelines. Note that stubble will also be left on the field on areas where the whole crop has been harvested green, Area harvested green(T), i.e. areas not included in Area with grain harvest(T).

For the Swedish GHG inventory, coefficients for ratios between crop residues and yield (RAG) where reviewed and changed for a range of crops before the 2006 submission (Adolfsson, 2005). Adolfsson based a lot of his conclusions on a comprehensive study conducted by Mattsson (2005), who scrutinised and compiled results from previous analyses of crop material collected at Swedish field experiments from the 1950's and onwards. The coefficients are based on a total of 5 221 observations, from 536 trials and 278 different experimental sites. The coefficients from Mattsson were subsequently turned into area weighted means in terms of level of N fertilisation in Sweden (Adolfsson, 2005) using statistics on fertiliser use (Statistics Sweden, 2004). Adolfsson also suggested adding 25 percent extra on the calculated ratios to account for stubble. This was also implemented in the 2006 NIR submission (Swedish EPA, 2006).

Concerning crop residue removals in the calculations of nutrient balances, the 2013 Handbook on Nutrient Budgets (Eurostat, 2013) implies that methodology for county specific data should be coordinated with the GHG inventory. However, until the 2011 nutrient balances, the county specific data had not been harmonised in the different reporting systems. The study by Mattson (2005) is a comprehensive source of information for

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the cereal crops of winter wheat, spring wheat, winter rye, spring barley and oats. In addition, the suggestion by Adolfsson (2006) to account for different levels of N fertilisation is sound. However, for other crops such as sugar beets, potato and maize, further investigation was needed to obtain country specific coefficients. Therefore, an additional review was carried out in 2015, which resulted in an updated table for all crops (Table 2), which was used in the Swedish national nutrient balance calculations for 2013 (Statistics Sweden, 2015a). These are yet to be implemented in the OECD/Eurostat balances as well as in the GHG calculations.

Table 2 - Ratios of above ground crop residue to yield, RAG, dry matter/dry matter (d.m.); nitrogen content in above ground crop residues, NAG, (% of d.m.); and removed crop residues, FracRemove, (% of crop area) for crops in Sweden.

Crop	Ratio of above ground crop residue to yield (d.m./d.m.) (R_{AG})[a]	Nitrogen content, crop residue (% of d.m.) (N_{AG}*100)	Phosphorus content, crop residue (% of d.m.) (N_{AG}*100)	Removed crop residues[v] (% of crop area) ($Frac_{Remove}$*100)
Winter barley	0.70[b]	0.77[o]	0.12[l]	22
Spring barley	0.66[c]	0.77[c]	0.12[l]	10
Oats	0.71[c]	0.73[c]	0.12[l]	10
Winter wheat	0.70[c]	0.51[c]	0.12[l]	12
Spring wheat	0.77[c]	0.44[c]	0.12[l]	10
Triticale	0.78[d]	0.76[p]	0.12[l]	12
Winter rye	0.86[c]	0.59[c]	0.12[l]	22
Grain maize	1.00[e]	0.94[q]	0.21[q]	19
Mixed grain (cereals)	0.69[f]	0.75[f]	0.12[f]	27
Mixed grain (cereals and legumes)	0.76[g]	0.95[g]	0.14[g]	27
Winter rape	1.50[h]	1.07[l]	0.14[l]	5.5
Spring rape	1.13[i]	1.07[l]	0.14[l]	5.5
Winter turnip rape	1.50[j]	1.07[l]	0.14[l]	5.5
Spring turnip rape	1.13[k]	1.07[l]	0.14[l]	5.5
Peas	0.80[l]	1.18[l]	0.15[l]	1.4
Peas for conservation	0.80[m]	1.18[m]	0.15[m]	0.0
Oil flax	n.a.	1.43[r]	0.10[r]	57
Table potato	n.a	3.25[l]	0.20[l]	1.3
Potato for starch production	n.a	3.25[l]	0.20[l]	1.3
Sugar beets	n.a	2.25[l]	0.25[l]	0.7
Field beans	0.80[l]	1.18[m]	0.15[m]	2.2
Green fodder	n.a	2.0[s]	0.3[s]	0.0
Temporary grass for seed	0.84[n]	1.09[t]	0.15[t]	35
Temporary grass	n.a	2.4[u]	0.26[u]	0.0
Pasture	n.a	2.4[u]	0.26[u]	0.0

a) Not including the 25 % extra for cereals to compensate for stubble (see section 2.3); b) same as winter wheat c) Mattsson 2005 (area weighted according to Adolfsson (2006)); d) mean of winter rye and winter wheat; e) Spõrndly; 2010 f) mean of spring barley and oats; g) mean of oats and peas; h) Gunnarsson 2009; i) 75% of winter rape according to Lindén in Gunnarsson (2009); j) same as winter rape; k) same as spring rape; l) Claesson and Steineck 1991; m) same as peas; n) source not identified; o) same as spring barley; p) mean of winter wheat and winter rye; q) estimated from conc. in grain and ensilage; r) S-E Andersson, pers com; s) wholecrop silage, Swedish Board of Agriculture 2015; t) assuming 80% straw from temporary grasses for seed. 20% straw from temporary leguminous crops for seed, Swedish Board of Agriculture 2015; u) Statistics Sweden 2005 and Andrist Rangel et al 2013a; v) derived from Statistics Sweden 2013b (see section 2.2)
n.a.= not analysed or not applicable

There was an overall trend with decreased ratios compared with the ones previously used in the nutrient balances, which resulted in lower amounts of crop residues compared with previous estimations (Statistics Sweden, 2015a). This can be explained by the increased use of short straw varieties. The coefficients in Table 2 were primarily compiled for use in nutrient balance calculations. Hence, they do not include the 25 percent extra for cereals to compensate for stubble, as the focus in these calculations is on the (net) removed part, and stubble is not included in the removed part in practice. Accordingly, the coefficients for cereals in Table 2 need to be adjusted when used for the GHG inventory, where the focus is on the (net) part that is left on the field, and hence, inclusion of stubble would be justified.

2. 4 Nitrogen contents in crop residues

In a previous study on P and N contents in grain and straw of winter wheat, spring barley and oats, (see Table 2 in Andrist Rangel et al (2013a; b)), it was concluded that there is a deviation between the coefficients used in the Swedish nutrient balance calculations and the GHG inventory. Hence, in connection with the review mentioned above on ratios between crop residues and yield, contents of nitrogen in straw and tops (NAG(T)) of all corresponding crops were also scrutinised to obtain a complete and updated table to use in the different statistical and policy reports (Table 2).

Nitrogen coefficients in the GHG inventory were updated for cereal straw for the 2006 submission. The new coefficients were suggested in the review by Adolfsson but originate from the compilation study by Mattsson (2005), which considers the effect of nitrogen fertilisation, and is based on more than five thousands observations (see section 3.2). During the scrutinisation it was concluded that Mattsson (2005) was the most comprehensive reference for Swedish conditions and the results were also in line with foreign studies (see for example Table VII in Appendix I in Andrist Rangel et al (2013a)). It was therefore decided that this reference could be used for the updating of N coefficients of cereal grain and straw in the national and the OECD/Eurostat balances. This increases the coherence between the nutrient balances and the GHG inventories. For other crops not included in Mattsson (2005), more investigation was carried out during 2015 and the resulting coefficients and references are listed in Table 2. The updated coefficients were used in the Swedish national nutrient balance calculations for 2013 (Statistics Sweden, 2015a) but are yet to be implemented in the OECD/Eurostat balances as well as in the GHG inventory.

3. Lime applied to arable land

Regarding the estimation of GHG from lime applied to arable land, annual sales statistics have been used until submission 2015 (Swedish EPA, 2015). However, indications of increased agricultural use of lime in the form of by-products from industry, not distributed through the ordinary market, imply that sales statistics may no longer fully reflect the amount of lime applied to arable land.

3. 1 Background

Annual statistics on sales of lime for agricultural and horticultural purposes have been produced and published since 1986 (Statistics Sweden, 2013c). Data have been collected from manufacturers, importers and retailers with the aim to cover the Swedish market. The time series published for sales of lime for agricultural purposes has been used in the GHG inventories until the reporting of the 2013 emissions (Swedish EPA, 2015). However, in the last 5 to 10 years substantial quantities of lime products have been detected that are not included in the ordinary sales records, and hence not included in the sales statistics. This is primarily lime in the form of by-products from the pulp- and paper industries. After discussions with the main users of the statistics, it was therefore decided to try changing from statistics on sales to statistics on actual use of lime in agriculture.

3. 2 Data collection from farmers on lime application

The existing sample surveys on fertiliser use and cultivation measures in agriculture were used as the frame for data collection and estimation of farmers' application of lime to arable land. Data were collected for the reference years 2010, 2012 and 2014. The sample sizes were 5 150, 3 650 and 3 000 agricultural holdings respectively for the three years. In the two first surveys, only telephone interviews were used, whereas in the survey 2014, "mixed mode" was used, using paper and web questionnaires with follow-up telephone interviews. The questions covered type and amount of lime product and size of land area where lime had been applied (Figure 1). Parallel to the new data collection, statistics on sales continued to be produced until the reference year 2012. This was to create a time period over which the two different sets of data could be compared, and also to keep the continuity in the sales statistics in case the new method did not turn out to be successful.

Figure 1 - Section on application of lime in the paper questionnaire from the sample survey "Cultivation measures in agriculture 2014" (translated from Swedish) (Statistics Sweden. 2015b).

D | Application of lime 2014

6a Have you applied or will you apply lime to your arable land during 2014?
OBS! *Shall include all application of lime, even lime for lime filter ditches.*

☐ Yes
☐ No ➔ ***Go to question 7***

6b Fill in name of lime product, total amount of product and area that has been or will be limed during 2014.

	Product name. Maximum three lime products.	Total amount		Area	
1		,	ton	,	hectares
2		,	ton	,	hectares
3		,	ton	,	hectares

3. 3 Results

One of the main outcomes of the new method of data collection, where the farmer could state and describe the type of lime, was that significant amounts of lime in the form of by-products were detected to be applied to agricultural land. Further research into the origin of these products showed that they were not always sold and/or distributed through the ordinary lime market, but could be free of charge for farmers and could for example be delivered by companies dealing with waste management. Hence, these products were not possible to detect through the sales statistics. Another obvious difference between the sales and the use statistics was that the former was a complete enumeration, whereas the latter a sample survey, and thus different in terms of estimation method. However, by using well-defined products available on the ordinary lime market such as lime produced as a co-product of the sugar manufacturing process, the two methods of estimations could be cross-checked. The outcome of the comparison was that data from the sample survey and from the sales statistics were comparable for these products.

The results from the sample surveys of 2010, 2012 and 2014 showed similar results in terms of limed area, with about 3 percent of the of arable land being limed (Statistics Sweden, 2015b). On the regional level, the corresponding value varied between 0.7 and 5.8 percent. The average application rate was also similar between the years, around 2 tonnes of CaO per hectare. However, the results showed a significant increase in the use of soil structure lime between the years 2010 and 2014. This was partly due to the introduction of subsidies for this specific type of soil management practice. The collected data were also used to estimate the amount of cadmium applied to soil via liming and the results were published in the statistical series for the first time. For 2014 it amounted to a total of ca 110 kg of cadmium, which can be compared with the amount applied via phosphorus fertilisers in Sweden, which was 82 kg in 2014/2015 (Statistics Sweden, 2016).

When data from 2010 and 2012 were compared with the sales statistics from corresponding years, the sample survey showed larger use than the sales. The difference could be explained by the quantities of by-products from e.g. the paper and concrete industries that were not accounted for in the sales statistics. This confirmed the assumption that the sales statistics no longer fully reflected the application of lime to agricultural land in Sweden. Another advantage with the sample survey was the possibility to estimate the uncertainty of the point estimate. With this as a basis, it was decided to change from sales statistics to statistics on actual use of lime. In the GHG inventory, the new estimates on lime usage available for the emission year 2010 and forward were implemented in the 2016 submission (Swedish EPA, 2016). Regarding time series consistency in the inventory, sales statistics were still used for the period 1990 - 2009, but there is no major effect as these by-products have only recently been introduced as lime products and were negligible before the turn of the century.

4. Conclusion

A review of the method of estimating the amount of crop residues has resulted in a recommendation of a more precise way to calculate amounts of straw and tops left on the field in the GHG inventory. The main suggestion for change is to include considerations of areas where crops have been harvested green. The review and updating of coefficients for ratios between crop residues and yield as well as for nitrogen contents in straw and tops is a step forward in the harmonisation process between the OECD/Eurostat nutrient budget compilation and the GHG inventory in Sweden. Using the existing sample survey on fertiliser use and cultivation measures for data collection and estimation of the application rate of lime to arable land has confirmed the hypothesis that significant quantities of lime in the form of by-products were not captured by the sales statistics. The new method has increased the quality in the statistical output compared to the sales statistics. For environmental monitoring such as the GHG inventory, statistics on farmers' application rates of lime to arable land constitute a better basis for estimation of CO2-emissions, as it reflects the actual amount that is applied to soil and hence affects the natural environment.

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Environmental sustainability of the use of pesticides. A case study: "the Po River basin"

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ABSTRACT

Pesticides (plant protection products and biocides) are among the best regulated chemicals in Europe. An in-depth risk assessment is carried out before the placing on the market, also the final stage of the life cycle is regulated, with the definition of non-hazardous residues in food and environment. Recently it has also been regulated intermediate the life cycle stage, the use, with a series of measures to improve agricultural practices minimizing the use of chemicals, to protect water bodies and sensitive areas, to properly train the operators. Nevertheless, the monitoring shows a widespread pesticide contamination in surface and groundwater (GW). It seems, therefore, that the regulatory framework or at least its implementation is not fully adequate to protect the environment and human health.

The report presents a study of the contamination of the Po basin, the most important in Italy, both for its size and for the intense human activity, with particularly intensive agriculture with high input of pesticides. The considerable amount of data arising from an extensive monitoring network, allows to study pesticide contamination and its evolution since 2003.

Chemical pollution is one of the main factors considered in the approach "planetary boundaries", recently proposed. The "planetary boundaries" is identified as the boundaries that define the safe operating space for humanity with respect to the Earth system and are associated with the planet's biophysical subsystems or processes, (Rockström, J. et al. 2009). Unlike other anthropogenic pressures acting on a global scale, the complexity of chemical pollution has not yet possible to identify a sustainability limit.

Taking into account the fact that it is simplistic to analyze the problem on a regional scale, as large and important it may be, because you cannot ignore the long range transport of contamination, the study aims to contribute to understanding the capacity of' environment to respond to human disturbance, returning to the previous conditions (the phenomenon of resilience). For this purpose, the study focused on residual contamination of a banned pesticide in Italy and in Europe for several years (atrazine). A first analysis of the results suggests that the environmental response to a chemical stress is extremely slow and the return to the initial undisturbed conditions is not at all obvious. This requires a reflection on the actual environmental sustainability, which should not rely only on the comparison with the acceptable concentration limits.

Keywords: pesticides, planetary boundaries, water pollution

PAPER

1. Introduction

Pesticides are chemicals used to control weeds, insects and other pests in agricultural areas and as biocides in many other activities. Despite the acknowledged benefits, their use raises concerns in terms of possible adverse effects on human health and environment. Most of them are synthetic molecules conceived to kill harmful organisms and therefore they are generally hazardous to all living organisms exposed.

European regulatory framework addresses the risk raising in all life cycle stages of pesticides: production, use, residues in food and environment, nevertheless monitoring data show a diffuse pollution of surface water (SW) and groundwater (GW). Despite the well defined Regulatory framework, the national monitoring results, show a widespread contamination in water. In particular in 2014 pesticides were found in 63.9% of 1284 monitoring points, in surface waters and in 31.7% of 2463 points in groundwater as reported in the National report on pesticides in water (ISPRA, 2016).

The chemical pollution is one of the major anthropogenic factors used as reference in the recent years to develop the "planetary boundaries" approach, to identify a safe operating space for humanity with respect to the Earth system (J. Rockström et al. 2009) in which humans can continue to develop and thrive. Respecting these boundaries would greatly reduce the risk that anthropogenic activities could inadvertently drive the Earth System to a much less hospitable state. Since its introduction, the proposed approach has attracted interest and discussions within the policy, governance, and business sectors. A scientific debate is on-going on the criteria to identify the kinds of chemical substances that are likely to have influence at the global scale (Scheringer M. Et al. 2012; Strempel S. et al, 2012).

The paper aims to provide a contribute analysing the sustainability of pesticide pollution at regional scale. Bearing in mind that it is not possible to ignore the global impact, as e.g. the long range transport, the study analyses the contamination of the Po River basin, the most important in Italy, where intense industrial and agricultural activity are present. Data collected since 2003 through an extensive monitoring network allow to analyze the evolution of pesticide pollution. The study focused on residual contamination of atrazine, an herbicide banned from several years. This can be useful to understand the environment ability to respond to anthropogenic disturbance in restoring the previous conditions (resilience phenomenum).

2. Regulatory framework

The European regulatory framework covers the risk raising in all life cycle phases of pesticides. According to the Regulation (EC) No 1107/2009, substances are evaluated to prove the safety for humans and the environment before the placing on the market. Directive 2009/128/EC, on sustainable use of pesticides, aims to reduce risks in the use-phase with a series of measures to improve agricultural practices, minimizing the use of chemicals, protecting water bodies and sensitive areas, properly training the operators. Regulation (EC) No 396/2005 deals with the end of the life cycle of pesticides, establishing the maximum residue levels (MRLs) in foodstuffs, with the aim of limiting the exposure of consumers.

Moreover a number of other legislative acts regard pesticides. In particular, the Water Framework Directive (WFD) (Dir . 2000/60/EC) and daughter directives aim to ensure the water quality, identifying, among other things, a list of " priority substances " and setting limit values for environmental protection.

Despite the well-defined regulatory framework, monitoring data show a widespread pollution of surface and ground water. This highlights an inadequacy of the regulations or their implementation. In particular, a critical issue is the environmental exposure estimation. The forecasting models used in risk assessment do not always seem adequate to predict the environmental fate and exposure of substances. They lack of realism, as recognized by the scientific committees of the European Commission "to face the new challenges for risk assessment"(SCHER, SCENIHR, SCCS, 2013). Another critical aspect is the risk assessment of substances , such as persistent , bioaccumulative and toxic , or as endocrine disruptors,, which do not seem to have a threshold effect. In this case it is very difficult to recognize a safe level in the environment, and even very low concentrations could pose a risk. Furthermore, the regulatory risk assessment does not take into account the effects of mixtures.

Therefore, monitoring is a useful tool to check the real impact of pesticides on the environment and identify, through a retrospective analysis, the critical issues not properly addressed in the authorization process.

3. Case Study - Po river Basin

Po basin is the largest in Italy. The river (652 km length) flows through from west to east. The catchment area measures about 74,000 sq km of which approximately 71,000 are located in Italy, the rest in Switzerland.

Approximately 16,000,000 inhabitants live in the catchment area. Considering the density of the productive activities, the infrastructure and the water resources utilization, the Po Basin is the most important area in the Italian economy. Agriculture occupies over half of the basin area, with high chemical inputs (fertilizers, pesticides) in the lowland and in the hilly areas and part of the mountain "endovallive" areas.

The basin is divided essentially into three geomorphological areas: alpine area, in the north and north-west; the Apennines in the south; the plain area (Padana plain), which characterizes the entire course of the river, until the Adriatic Sea.

The average annual rainfall on the basin is 1,108 mm. The corresponding water volumes are therefore 77.7 x 109 m3/year. The average annual outflow corresponds at 664 mm, equivalent to about 46.5 x 109 m3/year, which represents 60% of inflow and is equivalent to 1,470 m3/s.

The river has 141main tributaries, coming from the Alps and the Apennines. The basin includes many lakes, the most important of which (Garda, Como and Maggiore) are located in the Lombardy region and are fed by alpine mountain streams.

The aquifers are fed mainly in the high plain near the mountain, whose geology consists mostly of coarse materials. In the pre-Alpine plains and in the Apennines the aquifer, in correspondence with impermeable barriers, emerges as springs ("risorgive"). The central part of the plain, both north and south, consists of fluvial deposits that gradually become finer and less permeable and host confined aquifer. The groundwater speed in the water table high plains may reach tens of meters per day, instead in the deep under pressure aquifers speeds are very low until the "stagnation " for certain very deep aquifers.

Monitoring network of pesticides in the Po basin includes 1,035 sites in groundwater and 570 in the surface water. Samples were collected every month in surface water and at least twice a year on the groundwater.

4. Atrazine

Before the ban, atrazine was one on the most widespread herbicide used in Italy, applied on corn and sorghum, but also for urban and industrial areas. A reasonable estimate of the quantities used in the Po valley is about 1,000 tons /year, for about 25 years. The substance is an herbicide of the triazine class; it has a selective, systemic action with residual and foliar activity and inhibits photosynthesis.

Atrazine was detected in the atmosphere, also far away from the use areas. In the atmosphere it tends to exist more in the particulate and precipitation is the primary mechanism for removal. Volatilization from water surfaces is not expected to be an important fate process based on a Henry's Law constant value.

It is expected to have high to slight mobility in soil, based upon a log Koc range of 1.96 to 3.38. Soil pH may affect the transport of atrazine (sorption to soils increases with pH decreasing). Atrazine is not expected to volatilize from dry soil, if released into water may adsorb to suspended solids and sediment based on the Koc value range.

According to Mackay I model (Finizio A., 1997), atrazine mainly distributes in water (about 90% of the amount released to the environment), fractions of the order of 4% are distributed both in soil and in sediment, little significant percentages in air and in biomass.

According to Regulation (EC) No 1272/2008, atrazine is very toxic to aquatic life, both acute and chronic effects (Aquatic Acute 1 – H400, Aquatic chronic 1 – H410), may cause damage to organs through prolonged or repeated exposure (STOT RE 2 - H373) and may cause an allergic skin reaction (Skin Sens. 1 - H317).

Atrazine is in the priority list within the EU-Strategy (EC, 1999; EC, 2000) for Endocrine Disruptors (ED); it is considered ED Category 1 (evidence in organism). In particular, the substance (Norwegian Pollution Control Authority, 2005) may induce hermaphroditism and demasculinize the larynges of frogs (Hayes TB et al. 2002).

The substance is persistent and toxic, but it is not considerd bioaccumulative. According to WFD, il has been identified as "priority hazardous substance" on the basis of ED concern.

Atrazine was banned in Europe since 2004, because of widespread groundwater contamination at concentrations exceeding the drinking water limit of 0.1 µg/L. For the same reason, in Italy it had been banned since the early 90s.

Metabolites

Desethylatrazine is formed in the environment through the N-dealkylation of atrazine.

Desethylatrazine is expected to have very high to slight mobility in soil, based upon Koc values of 24 to 3000. In water, some adsorption to suspended solids and sediment is expected. Desethylatrazine has been shown to biodegrade in soils under aerobic conditions, but it is generally stable in groundwater microcosms under anaerobic conditions. According to the classification provided by companies to ECHA the substance is harmful if swallowed, causes serious eye irritation and is harmful if inhaled.

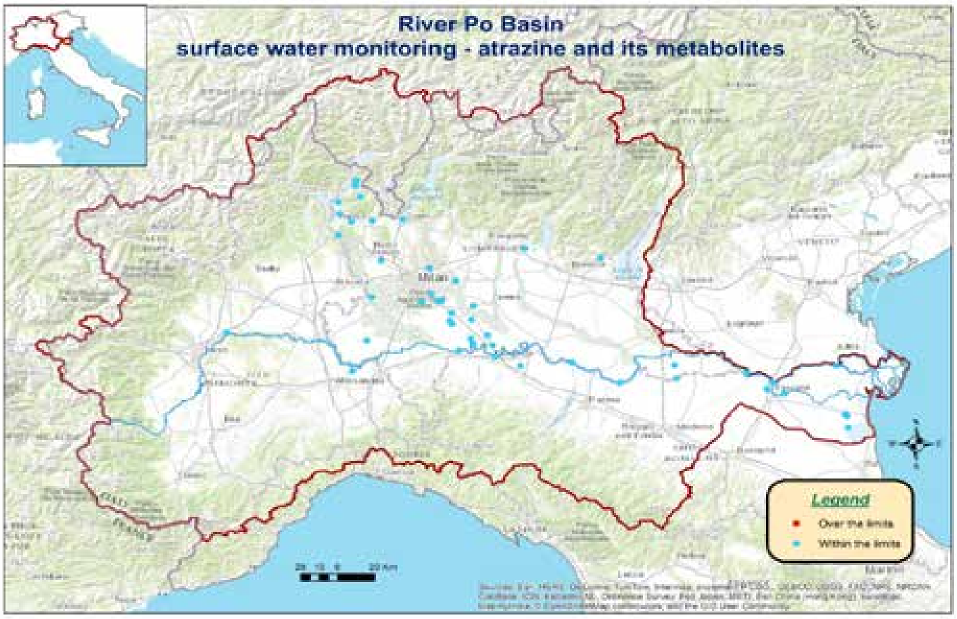
Deisopropylatrazine is formed in the environment through the N-dealkylation of atrazine. Deisopropylatrazine is more soluble than parental compound and less than deethylatrazine. The substance is not persistent to persistent in soil (half-life ranges from 32 to 172 days)and it is expected to have very high to moderate mobility based upon Koc values ranging from 28 to 130. Field studies show that it does not accumulate in the soil (Crobe A., et al, 2002). According to the classification provided by companies to ECHA the substance is harmful if swallowed, causes serious eye irritation and is harmful if inhaled.

4. Monitoring Results

Monitoring results show a widespread pesticide contamination of the Po valley, pesticides have been found in more than 70% of surface water sites and in more than 40% of groundwater sites. The triazine herbicides (atrazine, simazine, terbuthylazine and atrazine – desethyl, atrazina desisopropil, metabolites and desethyl - terbuthylazine) are among the substances most frequently detected in surface water and groundwater, often above the legal limits. With the exception of terbuthylazine, all other substances are no longer permitted in Europe.

The maps (Figure 1) shows the contamination level of atrazine and its main metabolites (atrazinedesethil, atrazine desisopropil) in the study area.

Figure 1 - surface water and groundwater contamination level of atrazine and its metabolites in Po basin (2014).



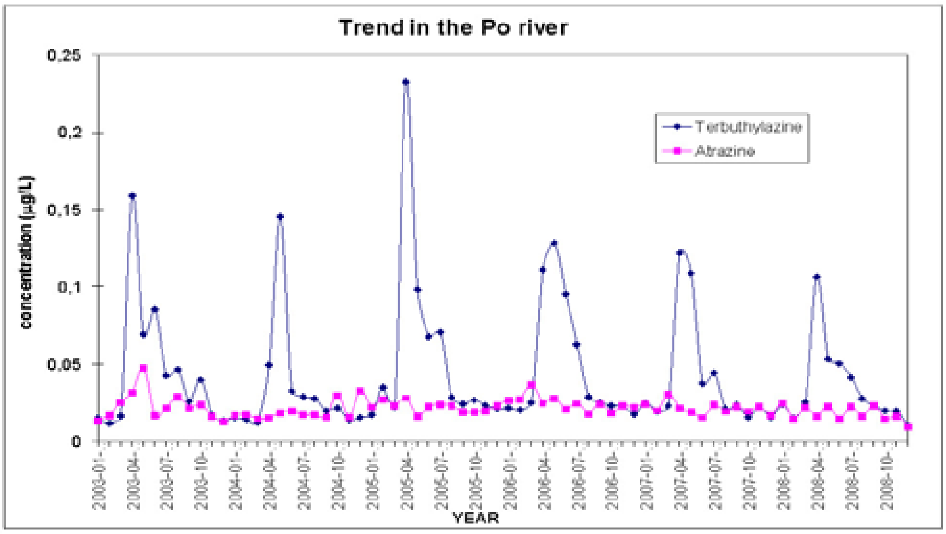
The contamination levels are referred to the limit value for the drinking water (0.1 g/L).

In 2014, atrazine has been detected in 46 sites of the surface waters (10.2% out of 453) and in 104 sites of the groundwater (10.8% out of 968). The concentration is never over the limit in the surface water and it is over the limit in the 0.7% of groundwater sites.

Taking into account that the substance has being banned for many years, the monitoring highlights a residue of a historical contamination, due to the widespread use in the past and to the environmental persistence. The detection of the its metabolites at levels generally greater than the parental substance supports the conclusion of a long-standing pollution.

Figure 2 compares the concentration trend in the Po river of atrazine and terbuthylazine, that replaced the use of atrazine after the ban. Terbuthylazine concentrations highlights a seasonal use related to an application in the spring (March–May) repeated year by year. Differently, the occurrence of atrazine shows a stable trend clearly indicating a residual contamination.

Figure 2 - Trend in the Po river of terbuthylazine and atrazine



Analysis of the Contamination Trend

The graph in Figure 3 shows that atrazine concentration (90%-ile of the medium values) in the river is significantly lower than the basin groundwater. Moreover it is highlighted that the concentration in the river decreases regularly with an asymptotic trend, while the concentration in the groundwater does not indicate any trend but ranges around a roughly constant value.

The purpose of the trend analysis is to follow how the pesticide and its main metabolites occurrence in surface and groundwater is changed over the last decade. From figure 3, it is possible to identify with a good correlation a well defined trend curve in the River and it allows to derive an half-time of about 8 years for disappearance of the parental substance. This value would trigger to a re-calculed average concentration referred to the period of the ban (early 90s) equal to ca. 1.0 g/L. This value seems to be consistent to the current average concentration of terbuthylazine in the river.

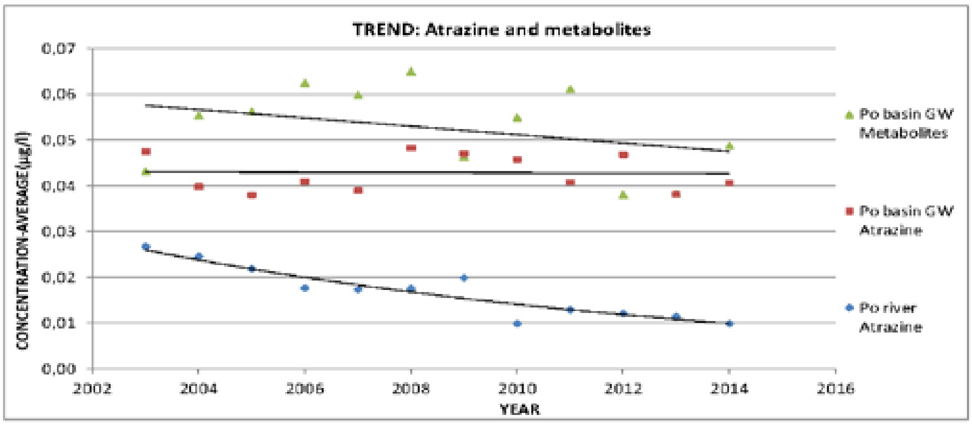
The possible explanations of the gradual decrease of the concentration in the river and the stable occurrence in the ground water are the following: the degradation of the parental substance in the groundwater is slow because lacks the degradating agents abiotic and biotic. Another possibility is that surface contamination is mainly due to the exchange with groundwater, which mainly concerns the shallow aquifer than the deep ones , well separated from the river, where the concentration is almost constant.

The stable trend of atrazine in groundwater, reasonably indicates that same situation is foreseeable for the future due to the very slow movement of the groundwaters, particularly, in the deep aquifers. The metabolites trend confirm the contribute of the overall stable contamination of the substance, once reached groundwaters.

In the surface water the contamination levels are lower than the regulatory thresholds and the Environmental Quality Standard (EQS). Nevertheless the hazourdous properties, in particular the ED property, (no-treshold) makes significant also the low measured concentrations.

The importance of very low concentration is also related to the concern for the mixture detected in the samples, for which it is still not well known the relevance for the Human Health and the environment. Infact in some samples there are mixtures up to tens of substances.

Figure 3 - Trend of atrazine and its metabolites (desethylatrazine, deisopropylatrazine)



5. Conclusion

The environmental sustainability of chemicals should be based on the capability of the environment to respond to anthropogenic stressors in restoring the previous conditions.

The present study allows to conclude that the regulatory framework does not comply the above general principle, as following summarised.

The regulatory framework seems not completely adequate to prevent a diffuse contamination of pesticides. In particular one of the critical issue is related to the exposure estimation in the authorization process. The estimations derived by models are not always representative of the real environmental behaviour of chemicals, at least on a large scale. A particular attention should be given to the substance persistence assessment. Standard information utilised seems not representative of the real persistence in the environment. Once the substances reach groundwaters, the degradation processes are very slow due to the lack of the biotic and abiotic degradation mechanisms.

The trend analyses of the occurrence in the Po basin of no more used herbicide, demonstrates that substances can persist in the environment longer than how estimated Evaluation of substances under authorization process may underestimate their ability to contaminate the environment, in particular the water compartment. It is necessary to take due account of the available measured information, considering the available monitoring data also on similar chemically substances.

Probably it is not enough cautelative to base the authorization process on the regulatory acceptable limits: e.g. concentrations in drinking water and EQS. This because some substances are considered "non-treshold" and it is not possible to define a safe concentration. Moreover the mixture concern is up to now an unsolved issue.

The reported results related to a herbicide banned since several years as atrazine can be useful to foresee the future critical issues of similar triazine substances still in use.

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B13

How to evaluate the impact of agrienvironmental policies on biodiversity in rural areas. The case of High Nature Value Farming systems

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ABSTRACT

Amongst all environmental public goods provided by farming, biodiversity is probably the most difficult to describe due to its multidimensional character that encompasses agronomic, environmental, social, cultural and economic dimensions. In spite of the efforts to guarantee a reasonable level of analysis in the different countries, to date methodologies applied for the evaluation have had limited success in detecting impacts. There are many reasons from lack of monitoring data to difficulties of establishing robust causal linkages between the action/measure/programme and impacts on biodiversity.

An attempt to assess the impacts of RDP measures on farm-related public good, such as high nature value farmland, has been carried out in a case study area dealing with different data availability and approaches for comparison groups. The aim of the study is to show how different methodologies can be used with fine- and coarse-scale variables, to disentangle the influence of site-specific circumstances and other intervening factors. In the context of rural policy spatial and temporal dimensions are interlinked with social dynamics while biodiversity responds to agricultural practices at different spatial and temporal scales. It is a methodological challenge to create consistent linkages between micro level, usually represented by beneficiary farms, and macro level that gives a comprehensive assessment of the RDP impacts.

Keywords: Biodiversity, Agrienvironment Policy, High Nature Value Farmland [9] Capturing the environmental impact of agricultural activities

PAPER

1. Introduction

The High Nature Value concept (HNV) was introduced in the research fields and policy arena in the beginning of the 1990s, aiming to demonstrate the role of certain farming systems in maintaining the biodiversity of the European countryside. This concept is grounded on the assumption that low intensity agriculturalmanagement often corresponds to an overall biological and landscape diversity in farmland (Baldock at al. 1993; Beaufoyet al. 1994; Bignal and McCracken, 2000; Cooper et al. 2007). A significant proportion of the European HNV farmland is located in Southern Europe mainly because agriculture in the Mediterranean region did not undergo the same levels of specialization and intensification as in the rest of Europe. As a consequence, it partially maintains its traditional farming systems (Beaufoy et al. 1994; Paracchini et al. 2008), especially those dependent on livestock grazing (Cooper et al. 2007).

The inclusion of the HNV concept into European policy, in the more general context of the integration of environmental objectivesin sectoral policies such as the Common Agricultural Policy (CAP), dated at the beginning of the first programming period 2000-2006 of the rural development policy under regulation (EC) 1957/1999. Only more recently the issue of farm-related biodiversity has been integrated among the measures of the first pillar of the CAP mainly focused on direct payments aimed to support farm income, through the greening practices established by regulation (EU) 1307/2013. Unfortunately, it does not produce reliable effects on the evolution of biodiversity, still under pressure with continuing loss of habitats associated with agriculture support threatened and declining species (Henle et al. 2008; Polákováet al., 2011; Pe'er et al., 2014).Agricultural intensification and land abandonment are important global drivers of biodiversity loss and ecosystem degradation.Market pressures and distortedfarm support policiesare increasingly making the farms in HNV areas economically unviable with the result of increasing processes of intensificationand land abandonmentthat adversely impact the HNVfarmland (Henle et al. 2008; Kleijn et al. 2009). The impact of policies on the evolution HNV areas was monitored and evaluated since the implementation of 2007-2014 Rural Development Programmes (RDP). In particular the Common Monitoring and Evaluation Framework (CMEF) foresaw a specific HNV indicator, mainly based on studies conducted at European level by European Environment Agency (Andersen et al. 2003) and the Joint research Centre (Paracchini et al. 2008; EEA, 2012). These first estimates were not considered exhaustive of the monitoring work to be done for targeting policy instruments at national or regional level. More context-based work needed within each Member States to estimate its extent and location. Among a range of efforts to develop HNV indicators atthe EU and Member States level (Keenleyside et al. 2014), it can be summarised three different types of approach to identify HNV farmland (HNVf): a) land cover characteristics; b) farming characteristics and practices; c) habitats or species of conservation concern. To some extent the farming system approach, based on investigations on the use of inputs, livestock density and other specific practices by farmers, presents more relationships with the implementation of agricultural policies where the beneficiaries are already directly monitored through surveys.

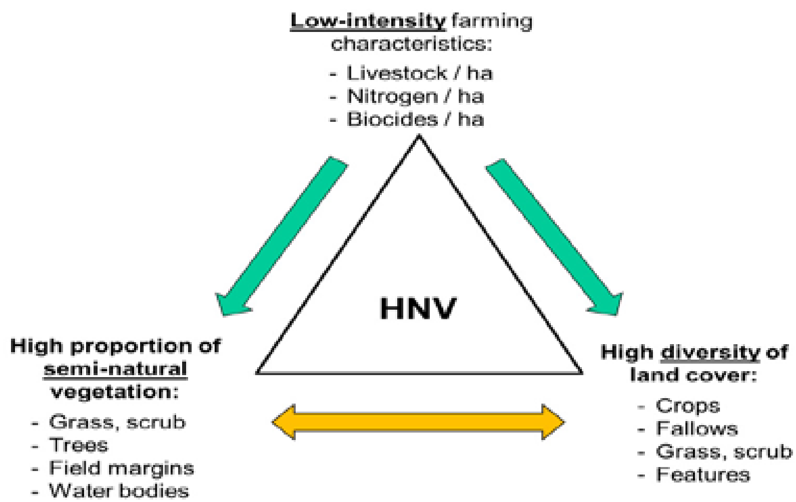
The identification of HNV farming systems (HNVfs) at farm level allows to show the links between nature values, agricultural practices and socio-economic characteristics where the farmer has seen as the main decision maker on (farm)land use and the key actor for adopting environmentally sensitive forms of farming also through the opportunity to obtain support under CAP policies. There were only few attempts to use farm level data to categorise HNVfs(Andersen et al. 2003; Pointereau et al. 2007) and even less to analyse the interrelationships among conservation efforts, production systems and policy implementation (Trisorio et al. 2008). In this paper, we discuss difficulties related to the development of HNV farming systems indicators, provide a short overview over current indicators, describe a specific approach to elaborate HNVfs indicators that are currently developed and give a short overview over the effects of policy instruments relevant to supporting HNV farming.

2. The concept of HNV farming systems

The European Environment Agency proposes three categories of HNVfarmland: 1) farmland with a high proportion of semi-natural vegetation; 2) farmland dominated by low-intensity agriculture or amosaic of semi-natural and cultivated land and small-scale features; and 3) farmland supporting rare species or a high proportionof European or world populations of conservation concern (Andersen et al. 2003). Although the third HNV farmland category may include intensively managed farming systemsthe vast majority of habitats for rare or significant species rely onextensive farming practices. On the contrary extensively or organically managed areas do not necessarily hold rare or endangered species but they have been recognized as potential HNV farmland areas.

Generally, the indicators able to assess the extent and location of HNV farmland are composed by sub-indicators considering all the three types of categories (Paracchini et. al. 2009). However,the physical extension of HNV farmland is mainly linked to both agricultural practices and farming systemsthat are essential for its maintenance. Some of the most critical nature conservation issues in Europe relate to changes to traditional farming practices on these habitats (Bignal and McCracken, 2000). To a certain extent the objective to produce maps of HNV farmland, excluding or including farms for the purpose of HNV support payments, is less important than using farm level indicators, adapted to local contexts, to assess the characteristics of HNV farming systems to increase the environmental effectiveness of the policy measures (Beaufoy and Cooper 2009; Poux and Pointereau2014; Keenleyside et al. 2014). According to the main studies on HNV (Andersen et al. 2003; Cooper et al. 2007) the key core characteristics of HNV farming systemsaround which a set of impact indicators can be set are: a) low intensity use of inputs and other technical means (fertiliser and pesticides, livestock, machinery); b) presence of semi-natural vegetation, such as unimproved grazing land and traditional hay meadows; and c) diversity of land cover with a mosaic of land cover and land use including unfarmed features (Figure 1).Generally farming systems,whose nature value results primarily from a high proportion of semi-natural vegetation or the presence of a diversity of land cover combined with semi-natural elements,are related to low input systems, corresponding to Type 1 and Type 2 of the HNV farmland categories. The difference between these farming and land use types is not perfectly dichotomous and many HNV farmland areas are a mix of different combinations at farm level.

Figure 1 - The Three Key Characteristics of HNV farming



Source: Cooper et al. 2007.

The way chosen at farm level to combine productive factors and land uses determines a continuum along which different varieties of interactions between farming systems and biodiversity can be found. Within this framework at farm level, the socioeconomic factors assume an important role because: This continuum can representsa sequence of changes over time towards both agricultural intensification orland abandoned, depending on local conditions,with loss of biodiversity value at parcel or landscape scale due to different levels of habitat fragmentation (Polákováet al. 2011; Keenleyside et al. 2014). a) the farm is the crucial level at which decisions are taken on land use and management; and b) the economic viability is the first condition for farm being at work (Trisorio et al. 2008). Indeed, one of the main threats to HNV farmland, that is abandonment or intensification of farming, strictly derives from the vulnerable economy of the farming systems associated. Moreover, the level of economic viability might affect the farm responsiveness to policy measures or, conversely, the policy measures in order to be effective should be differentiated according to the economic viability of farms.

The assessment of the socioeconomic characteristics of farms in connection to their environmental performance provides useful insights to policy design, allowing to better target instruments or to differentiate farming policies (O'Rourke and Kramm 2012; Keenleyside et al. 2014). Policy responses, indeed, are aimed at affecting farm behaviour that is mainly driven by economic and social factors. Therefore, also environmental performance of farms can be modified through economic measures.

Taking into consideration the above mentioned key characteristics of the conservation value of production systems and the nature of the land use decision making, HNV farming systems and the resulting farmland can be considered as socio-ecological systems, where human activities such as farming practices or crop and livestock breed selection have been influenced by local and regional socioeconomic, cultural and environmental conditions, and at the same time, ecosystems have been shaped by agricultural activities (Strohbachet al. 2015). HNV farming systems have in common that they are often, though not exclusively, based on traditional and extensive farming practices (Bignal and McCracken, 2000).

The variety of relationships among the different types of farming and land use creates a continuum of combinations that makesany classification quite difficult to assess. Andersen et al. (2003) used a categorical classification only based on few parameters (input cost; livestock; grassland; irrigation; set-aside) with clear-cut thresholds that do not allow to take into account all the different combinations showed by each farming systems. An alternative approach may be provided by the calculation of composite indicator that summarises the environmental characteristics of the farm and allows to rankthrough scores the level of nature value at farm level.

The use of composite indicators in order to analyse agricultural sustainability, or any other multi-dimensional concept such as HNV, is useful as a means of summarising the information provided by several specific indicators in an overall judgement or assessment of farm (environmental) performance. The development of transparent composite indicators allows to identify which aspects of agricultural sustainability (HNV) are relevant in practice, considering the high variety of combinations of farming practices and land uses.Several studies applied different techniques to build sustainability indices, although the main guidance remained almost the same (Bockstaller et al. 2008; Gómez-Limón and Sanchez-Fernandez 2010; Purvis et al. 2009; Reig-Martínez 2011; Westbury et al. 2011). The construction of composite indicators starts with a) the selection of relevant indicator based on data availability and a solid theoretical framework on the informative characteristics of each single indicator; b) the normalization of indicators that transform base indicators intoadimensional variables; c) the aggregation of indicators into one final index allowed by the normalization that makes indicators mathematically operational; d) the weighting of indicators if a different importance to each dimension/indicator has been assigned in the aggregation process,taking into account society's preferences if possible. The use of indices should be done with carefulness in all cases considering their pros and cons (OECD, EU and JRC 2008).

3. Materials and methods

The case study area is represented by Veneto region (NUTS 2 level) located in North East of Italy. The territory is 56% low-lying, 15% hilly and 29% mountainous and the regional Utilised Agricultural Area (UAA) amounts to 811,440 hectaresaccording to the 2010 agricultural census data. There are around 120,000 regional farms, with approximately 75,000 employed units. Veneto is located within the Po Valley, one of the most intensive agricultural areas of Italy. The sample used for the analysis is based on the Farm Accountancy Data Network (FADN), established in all the EU member States since 1965. Data on individual holdings are available for the period 2008 to 2013 which covers most of the years of the 2007-2013 RDP programming period. For each year a number of observations variable from 691 to 879 farms was collected and processed.

One of the advantages of using the FADN dataset is that it includes information on the intensity of farming that cannot be found in other EU wide datasets and, due to the common framework across the Member States and the yearly update, enables its use for monitoring purposes and comparative analysis at EU level. On the other hand there are also disadvantages due to the exclusion of economically small farms and "non-professional" farms that may in fact represent an interesting share of potentially HNV farms and in some areas they represent an important social pattern characterized by the presence of semi-natural elements (hedgerows, stonewalls, trees, etc.). However they generally have an extremely reduced significance in terms of farmland and income. Moreover, a considerable part of theirfarmed areas is run by contractor services or by other neighbouring farms and they may not show any particular difference from the large-size intensive farms.

The multi-criteria approach aims to assess a naturalness score which determine the level of HNVfor each farm. The method is based on different farming dimensions: management, cropping and livestock; and two relevant domains of definition HNV, namely: land use and farm biodiversity. In this case study nine measurable indicators are identified and calculated by FADN for each year. This allowed to define a score for each farm between 0 and 1 (0 min, 1 max), depending on the level of impact on biodiversity coming from the different farming practices taken into consideration in each farm. The values obtained were inferred to the regional population through a weighing operation of the sample FADN. The list of the base indicators with the weight associated and theiraverage values (with specific metric) with standard deviations are presented in Table 1.

After the identification of indicators, the normalization of indicator scales allowed to sum up different indicators. Indicator values were converted into scores according to the relationships between indicators values and level of sustainability. Relationships can be linear, non linear, and scaling can be categorical or binary. For each indicator scores are on a 0-to-1 scale. Before to aggregate the normalised indicators, a weight was assigned to each base indicators (table 1). The high variability of the parameters depends on the wide spectrum of typologies included in the FADN sample, representative of all the different type of farming and economic dimension of the regional farms.

Table 1 - List of base indicators used in the analysis

Indicators	Weight	Mean	Stand. Dev.
Permanent grassland (% of UAA)	0,24	9,6	26,0
Livestock Units per forage area	0,13	1,5	25,7
Irrigated UAA (% of UAA)	0,10	35,0	42,4
Fertilizer expenses per hectar (euros)	0,07	409	1.462
Pesticide expenses per hectar (euros)	0,08	296	707
Feed expenses per hectar (euros)	0,10	433	4.410
Organic farm (dummy Y = 1, N=0)	0,08	0,02	0,1
Number of crops	0,14	2,4	1,3
Set aside (% of UAA)	0,06	2,0	9,1

The FADN dataset covers all the aspects related to farming intensity, although in some cases only with measurementin monetary terms (input costs), and also gives some information on farm biodiversity (number of crops, type of grassland). The only aspect not covered by this survey concerns the presence of semi-natural vegetation and unfarmed features that require extra-time for surveying without any advantaged from the point of view of economic situation of the farms. The use of some proxies (e.g. presence of unproductive land or small patches of forest areas) did not prove very effective to identify other variables useful to assess some of the topics of Type 1 or Type 2 criteria for the classification of HNV farming systems.

4. Results and discussion

In general the average value of HNV-score remains more or less constant for all comparative periods, reaching around to 0.29 in 2008-10 and 0.28 per 2011-13. For the socio-economic analysis we create three different classes of HNV-score: i) No-HNV (HNV score ↓0.27); ii) Low-Medium HNV (HNV-score of between 0.27- 0:35); iii) Medium-High HNV (HNV-score↑ 0.35). The definition of classes took into account the frequency and distribution of the median HNV-score values of each year. In order to imply the naive approach before-and-after the average score values for the period 2008-2010 vs. 2011-2013were considered.

In terms of relative distribution of HNV farms (Table 2), there is a slight decrease of the number of farms from the first to the second period (from 44% in 2008-10 to 41% in 2011-13). In particular this reduction pertains to farms with medium-high HNV scores. The same trend occurs to Utilised Agricultural Area potentially classified as HNV switches from 33% (2008-10) to 26% (2011-13) for the medium-high HNV farms, while it is stable in the medium-low score. The most of UAA relates the permanent grassland in medium-high HNV farms, while arable crops are dominant for score low-medium farms, following the permanent crops. These dynamics are reasonable considering the farm reduction during the reporting period due to the economic situation. In fact, if in 2008-10 the economic situation has lowered the input costs, and it has increased the permanent grassland systems and extensive systems, in the latter period the worsening of the economic crisis has pushed out of the agricultural sector the marginal farms less intensive and uncompetitive. Similarly, the percentage of livestock farms is greater for holding with medium-high HNV score and in average fewer than 31 Livestock units (LU). Considering the LU on forage area, the ratio for HNV farms is very low compared to no-HNV farms (Table 3).

Table 2 - Percentage distribution of main economic indicators

	No-HNV	Low-Medium HNV	Medium-High HNV	Total
		Average 2008-2010		
No. farms	56,1	21,5	22,4	100,0
Utilised Agricultural Area	42,6	24,1	33,3	100,0
Annual Work Units	59,7	17,0	23,3	100,0
Farm Net Value Added	60,6	18,0	21,4	100,0
Subsidies	50,7	23,8	25,5	100,0
		Average 2011-2013		
No. farms	58,9	21,7	19,4	100,0
Utilised Agricultural Area	50,0	24,4	25,7	100,0
Annual Work Units	60,9	18,4	20,7	100,0
Farm Net Value Added	65,9	17,0	17,1	100,0
Subsidies	52,5	23,5	24,1	100,0

As for other features farms, there are not significant differences as to the farmers' age (values around 60 years for all classes considered). Taking into consideration a parameter measuring the percentage share of family annual worker units below 40 years old on the total worker units, any difference emerges. In fact, there is a tendency of youngFWU in the case of medium-high HNV score. However, the differences are very small and considered the socio-demographic factors - synthesised by the age proxies - do not seem to have such an effect on the farmers' choices as to generate differences between HNV scores of farms, probably due to the influence of other factors not currently taken into account. The size of HNV holdings is larger than non-HNV ones only in terms of farming area for both periods (17 ha vs. 11 ha), whereas the economic size as well as the number of worker units are basically larger in non-HNV farms (Table 3).

Table 3 - Structural profile of HNV and non-HNV farms

	No-HNV	Low-Medium HNV	Medium-High HNV	Total
		Average 2008-2010		
No. farms (sample)	481,7	150,3	171,0	803,0
Utilised Agricultural Area (UAA)	10,1	14,9	19,7	13,3
UAA distribution (%)				
- Arable crops	70,9	81,4	33,5	60,6
- Permanent crops	19,6	8,4	6,2	12,4
- Permanent grassland	0,7	1,5	45,1	15,8
Livestock farms (in % of total farms)	14,3	14,1	37,3	19,5
Livestock units (LU)	85,0	54,2	31,9	53,2
Livestock units / Forage area	12,2	5,9	1,6	3,7
		Average 2011-2013		
No. farms (sample)	434,0	128,0	140,0	702,0
Utilised Agricultural Area (UAA)	11,2	15,5	17,9	13,2
UAA distribution (%)				
- Arable crops	72,4	76,4	34,4	63,6
- Permanent crops	17,5	12,1	9,3	14,1
- Permanent grassland	0,5	1,9	41,1	11,2
Livestock farms (in % of total farms)	13,1	12,8	42,5	18,8
Livestock units (LU)	85,8	39,9	30,9	53,2
Livestock units / Forage area	10,2	3,0	1,4	3,6

Considering the comparison between the two periods, there has been a trend decline in the farm net value added for all classes of HNV farms, although more impressive for the high HNV score. The choice of adopting low intensive farming practices seems to depend mostly on soil-climatic factors. Nevertheless, the lack of good opportunities for the economic development seems to limit the ability of holdings to produce an adequate income. In terms of the subsidies, in general it detects a more or less equal distribution for all the years considered. The larger economic size and the possibility of allocating the production factors in a more effective way determine a remarkable difference in terms of labour productivity (Net Value Added per AWU), that is higher in non-HNV farms than in the HNV ones. In particular the analysis shows the increasing of the labour productivity for the no-HNV farms by +26% between 2008-10 and 2011-13,while increasing the values onHNV farms, only respectively of + 6% for low-score and + 7% for medium-high score. However the gap of labour productivity between HNV and non-HNV farms increases from 10% to 23% in both periods (Table 4). The differences described above can be explained by the hypothesis that more favourable soil-climatic conditions (generally in lowland farms) allow the farmer to choose among a larger number of productive combinations, thus favouring the specialised and intensive holdings. The greater difference between HNV and no HNV farms, located generally in mountain areas, where structural and social factors very likely determine a higher difference, is less intuitive.

Table 4 - Economic profile of HNV and non-HNV farms

	No-HNV	Low-Medium HNV	Medium-High HNV	Total
		Average 2008-2010		
Farm Net Value Added (NVA, euro)	40.229	30.856	34.825	36.979
NVA / UAA (euro)	3.948	2.063	1.799	2.776
NVA / AWU (euro)	31.225	32.430	28.104	30.739
Farm Net Income (FNI, euro)	31.293	21.490	31.033	29.148
Subsidies (euro)	6.307	7.503	7.638	6.854
Subsidies / UAA	612	502	394	513
Subsidies / AWU	4.869	7.889	6.190	5.696
Subsidies / NVA (%)	15,4	24,3	21,9	18,4
Distribution of subsides (%):				
- Direct payments	94,7	93,3	81,3	90,8
- Agri-environment payments	0,2	0,0	2,4	0,7
- LFA payments	0,0	0,0	4,8	1,3
- Other RDP subsides	4,9	5,0	10,4	6,5
- Other subsides	0,2	1,6	1,1	0,7
		Average 2011-2013		
Farm Net Value Added (NVA, euro)	48.477	35.413	39.567	43.314
NVA / UAA (euro)	4.314	2.292	2.164	3.273
NVA / AWU (euro)	39.190	34.347	30.066	36.274
Farm Net Income (FNI, euro)	34.808	24.877	27.833	30.923
Subsidies (euro)	7.986	10.06 5	11.20 4	8.950
Subsidies / UAA	710	652	637	677
Subsidies / AWU	6.462	9.747	8.708	7.496
Subsidies / NVA (%)	16,5	28,6	30,2	20,7
Distribution of subsides (%):				
- Direct payments	85,9	82,5	68,7	80,8
- Agri-environment payments	2,6	2,9	9,8	4,5
- LFA payments	0,0	0,0	6,5	1,6
- Other RDP subsides	9,3	13,3	13,5	11,3
- Other subsides	2,2	1,3	1,5	1,8

This analysis confirms the essential contribution of the subsidies to the economic viability of the HNV farms. The subsidies per Annual Worker Unit are greater in HNV farms compared to non-HNV farms, where the amount of subsidies reaches higher levels in terms of area units. More precisely in the periods

2008-10 and 2011-13 the subsidies per AWU generally increase: + 41% for the farm HNV at high score; of + 24% for medium-low score; + 33% for no-HNV farms. Also the gap between no-HNV and HNV farms increases, from 27% to 35%. At least, comparing the net-of-subsidies labour productivity (net value added minus subsidies per AWU) the difference between the two periods for the all HNV farm types comes out very clearly: the "net" labour productivity of the medium-high HNV score farms (coming from the market) is about two-thirds than the productivity of non-HNV farms in 2011-13, whereas many more share in the previous period (83%) (Table 4).

The FADN dataset allows the analysis of the RDP impact on HNV farming systems. In the assessment of the RDP effects, we considered Measures 211, 214 and other RDP subsides. The sub-measures are not considered because FADN does not allow this differentiation. In general between 2008-10 and 2011-13 the beneficiaries farms located in HNV areas arise. In terms of distribution of all subsidies, those related to the RDP doubled from about 8% to 17% of the total. In particular, the share of subsidies related to agrienvironment payments increases from 2% to 10% of the total for HNV-farms at high score, as well as the payments for Less Favoured Area (LFA) which increased from 5% to 6.5% for HNV farms at high score. In general the same growth trend occurs for no-HNV farms and low-score (Table 4). The source of the subsidies is slightly different between HNV (low-medium and medium-high score) and non-HNV farms: the latter rely more on direct payments, whereas HNV farms received a more significant part of the payments through the agrienvironment payments and the LFA allowance. The higher share of HNV farms in mountain and other marginal areas can explain this difference. The choice to adopt a less intensive farming system should be favoured by the AES payments. In particular these results show that public expenditures play an important role in HNV farms. In fact, this subsides represent on average 30% of the net value added for medium-low and medium-high HNV score farms, against 16% registered in non-HNV farms in the 2011-13 period (while in the previous period the share of subsides on value added was respectively of 23% and 15%).

3. Conclusions

The availability of a farm sample yearly updated such as FADN gives the chance to monitor over time the evolution of HNV farmland at micro level. Structural characteristics and information on crop and livestock management already present in the current database allow to create good indicators that can lead to the final composite indicator measuring the nature value of the farming system. The FADN sample has the same structure all over European countries, so a relatively good comparison is possible among Member States.The integration with other statistical surveys such as the Farm Structure Survey(FSS) and administrative dataset such as the Integrated Administration and Control System (IACS) potentially could increase the whole information system at farm level.

FADN data allow for the distinction in comparison groups (participant/non participant) where the HNV characteristics can be assessed. A score at farm level - based on the aggregation of appropriate indicators previously standardised and weighted - has been set in order to calculate the HNV degree of farmed areas treated or not treated by RDP or other CAP measures. The efficiency analysis of HNV farms vs non-HNV farms would provide useful insights into the role of subsidies supporting biodiversity friendly practices. At the same time without an adequate knowledge of the economic and social mechanisms which regulate the farmers´ behaviour it is not possible to understand the cause-effect relation between farming and the preservation of biodiversity. The investigation of farming systems is therefore essential to provide a complete picture in order to design appropriate measures for HNV farming systems conservation. Well targeted measures design to reward for positive externalities generated by farming activities can motivate farmers to modify their behaviour.

The FADN sample is more suitable than the one created by the Farm Structure Survey, since the survey of economic and financial aspects allows a more appropriate description of farm-holders´ behaviour. In order to exploit to the best the economic and financial information contained in FADN it is necessary to integrate data gathering with information about farming practices, agricultural land use and the management of the unfarmed features within the holdings. A major data limitation, observed in the case study and cited in other references of this paper, concerns the lack of information on the extent of semi-natural features in the farms and more generally in terms of land cover. Semi-natural vegetation plays a major role in the provision of green infrastructures that increase significantly the biodiversity values of a farmland area. Until now other indicators have proved not to be sufficiently informed to create good proxy indicators. On the other hand the increasing availability of data concerning large and small patches of perennial vegetation detected in fine-resolution satellite images should increase the reliability of land cover in agro-ecosystems at reasonable monitoring costs (García-Feced et al. 2015).

An important challenge for the future regards georeferencing FADN data which might permit an upscaling to regional level. The complexity of the georeferencing process – in spite of the progresses achieved in recent years in terms of information technologies – further widens the difficulties related to the availability of resources for this kind of surveys. It is necessary a better statistical representativeness for more robust extrapolation from the FADN sample to regional estimations. Of course this could increase the number of observations needed to have a sufficient statistical significance of the estimated parameters and, consequently, the cost of the analysis. An alternative option could come from a link between FADN and FSS samples and IACS databases that could guaranteed a more appropriated georeference for the farm samples. In this case special attention has to be given to data access that at the moment represent one of the major obstacles for a better use of already existing databases both from statistics institutes, monitoring agencies and administrative bodies.

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The environmental effects of meat from livestock to slaughter in Italy: integration between data and GIS

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ABSTRACT

The food production chains are subject to increasing attention to food quality and safety aspects and to the environmental impacts that they produce. The livestock sector has significant impacts on different environmental matrices including soil, air and water.

Related to the atmosphere, the Carbon Footprint is one of the major indicators; it describes the emissions of greenhouse gases generated by a set of agricultural and industrial processes. Irrespective of the rules of calculation and from the selected indicators, it is clear how the meat is the principal food with the highest environmental impact per unit mass (the kg, for example). In particular livestock cause significant methane production resulting from the digestive processes (enteric emissions). In this paper will be presented some evaluations of these environmental impacts through the use of several indicators in order to evaluate the polluting effect of cattle and buffaloes, sheep, goats and pigs emissions at the local level. This will be estimated integrating administrative.

The environmental effects of meat from livestock to slaughter in Italy: integration between data and GIS data and data from statistical surveys. Livestock farms surveyed from the Ministry of Health Registry, data derived from Istat survey on the slaughter of red meat will be taken into account. Through the use of geographic coordinates related to livestock farms, it will be possible geo-referencing the proposed indicators and representing cartographic products.

Keywords: GIS, Environmental, Livestock

PAPER

1. Introduction

The evaluation of the environmental impacts of a product can be performed using different methods that, based on the specific characteristics of the object, focus particularly on some characteristic indicators. The livestock sector has significant impacts on environmental aspects including air, water and soil (Williams et al., 2006). The most common indicators in the calculation of the environmental impacts are related to the use of water resources (water footprint) and to the greenhouse gas emissions (carbon footprint). Regarding water plays a very important role is played by nitrate pollution, caused by the release of nitrogenous substances in the surface aquifer. In the atmosphere, the major impacts are on the emissions of ammonia (NH3), methane (CH4) and nitrous oxide (N2O) (Campbell et al., 2008). Ammonia emissions from the agricultural sector are primarily produced by intensive farming and animals.

An emission inventory is an accounting of the amount of pollutants discharged into the atmosphere. It usually contains the total emissions for one or more specific greenhouse gases or air pollutants, originating from all source categories in a certain geographical area and within a specified time span, usually a specific year.

An emission inventory is generally characterized by the following aspects: types of activities that cause emissions, chemical or physical identity of the pollutants included, geographic area covered, time period over which emissions are estimated, methodology to use. Emission inventories are compiled for both scientific applications and for use in policy processes.

In this work it was decided to investigate the environmental impact in terms of carbon footprint being the most widely used indicator, and interpretation easier. The project is expected to consider livestock farms surveyed from the Registry from the Ministry of Health, data derived from Population Census for Emilia Romagna region and at the provincial level. The data refers to 8,822 farms on a total of 10,000 in Emilia Romagna who hold cattle, buffalo and pigs in the year 2015.

Livestock farms within the territory of Emilia Romagna are of a primary importance as the value of dairy cows in the production of "Parmigiano Reggiano" and of pigs for "Prosciutto".

In this area data related to various features have been gathered: data on livestock, on the type of animal bred and geo-referencing data (geographic coordinates that identify the farms). In the next table it is presented the distribution within the province of the animal types considered: dairy cows, bovine, buffaloes, pigs.

2. Emission factors

In order to calculate the emissions of livestock pollutions it has been considerate three elements:

- Ammonia (NH3): ammonia emissions in the agricultural sector contribute to the increase of the greenhouse gases for the production of gases. These emissions also contribute to the formation of fine particles. The formation of ammonia from animal manure depends upon the enzyme urease, whose activity is affected by the pH and temperature.
- Methane (CH4): methane livestock formation depends on the digestive processes (enteric emissions).

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- Nitrous oxide (N2O): in the livestock farming, the nitrous oxide emission depends on the storage and the spreading of manure on the land.

So, these three factors have been taken into account (ARPA, 2013), as well as the number of heads for animal typology (just for dairy cows, bovine, buffalo and pork) in three phases of livestock process:

- Livestock housing;
- Storage of manure;
- Spreading manure.

In the following table we show values of the emission factors (kilo for head) for the three pollutants and for the three process steps involved. The factors of emissions are calculated considering several studies (IPCC, 2006), using specific weights depending on different animal species.

Table 1 - Emissions factors, kilo for head and animal typology

	NH3			CH4		N2O
Animal typology	**Livestock housing**	**Storage of manure**	**Spreading manure**	**Livestock housing**	**Storage of manure**	**Livestock housing and Storage of manure**
Dairy cows	15.46	20.36	12.65	113.24	15.04	2.1497
Bovine	6.66	8.96	5.46	44.72	7.65	0.6683
Buffalo	12.61	16.61	11.95	69.74	11.96	1.89
Pork	2.39	2.00	1.39	1.5	7.94	0.0202

Final results of emissions per provinces are shown in the following table:

Table 2 - Total emissions per province, year 2015

Provinces	NH3 (Kg)	CH4 (Kg)	N2O (Kg)
Rimini	117,007.80	417,347.22	51,421.26
Piacenza	4,975,971.03	7,178,382.13	88,349.12
Parma	7,424,407.50	10,774,264.21	142,990.23
Reggio nell'Emilia	7,171,421.04	10,309,793.92	134,397.42
Modena	6,458,882.35	9,621,531.77	128,905.33
Bologna	5,501,862.58	7,985,779.79	110,200.00
Ferrara	1,102,631.27	1,663,968.47	21,765.89
Ravenna	1,364,916.02	1,997,112.97	26,730.18
Forli-Cesena	3,771,979.30	5,475,044.37	71,996.43
Total	**37,889,078.89**	**55,423,224.85**	**776,755.86**

The assessment of health effects from environmental hazards involves people who lives close to the livestock. To compute the risk it was built an indicator that put in relationship the emissions and population under potential health risk.

We have created multiple buffers at specified distances around the urban areas and we have selected farms inside them.

The distances considered are: 100 mt, 200 mt, 300 mt and 500 mt.

In other words let Ai be the area of the i-th urban area, i=1,2…m for each province and *Ai the buffer area corresponding to i-th urban area for a distance D. Then the risk is defined as:

$$r_i = \frac{P_i}{e_i}$$

where P_i is the population in $^*A_i$ and e_i is the total emission from the n_i farms in $^*A_i$

$$e_i = \sum_{j=1}^{n_i} e_{i,j},\ n_i \geq 1$$

for $i \in I$ where I is the subset of urban areas $^*A_i$ that contains at least one farm.

The locations building for the Population Census are been considered: urban areas, inhabited areas and production areas (Istat, 1992).

If the indicator is high it means that the proportion of the population exposed at health risk is higher.

The results are reported in table 3 for provinces. The column "total" expresses the values for provinces total population. Considering the total values, every indicator is high for Rimini, Parma, Piacenza and Reggio nell'Emilia provinces. It's important to underline the different results based on the distances by the livestock houses. Obviously the population size nearest to the farms is small but the pollution risk is higher. So it's important to highlight also the high results of the indices for Modena and Bologna for the indices relative to N2O and Ferrara provinces for all the indices (N20, NH3 e CH4). Note that it was possible to achieve this because the data refer to a geographic scale more accurate than the provincial one.

Table 3 - Potential population espoused at health risks for distance

Provinces	Meters (N2O)				Total	Meters (NH3)				Total	Meters (CH4)				Total
	100	200	300	500		100	200	300	500		100	200	300	500	
Rimini	3,9	7,2	13,6	19,2	335,5	39,0	63,7	112,4	144,9	1.748,9	33,9	60,2	108,2	148,2	2492,1
Parma	139,9	195,7	231,4	321,6	498,0	619,3	863,9	1.031,6	1.441,1	2.262,0	966,3	1.337,4	1.590,1	2.214,7	3.482,7
Reggio nell'Emilia	171,9	187,5	219,0	283,8	384,9	801,3	877,7	1.043,1	1.341,2	1.888,4	1.246,3	1.356,0	1.619,6	2.082,3	2.873,4
Piacenza	174,2	192,8	200,0	265,9	458,8	830,5	920,3	965,8	1.280,2	2.402,2	1.200,3	1.318,8	1.379,2	1.853,2	3.590,4
Forlì-Cesena	4,5	6,0	9,8	12,8	85,2	42,0	58,1	100,2	128,4	501,7	43,6	59,6	114,5	145,6	633,1
Ravenna	3,9	5,4	6,1	7,2	47,2	50,1	55,7	63,3	91,2	401,5	61,2	68,2	74,7	117,2	444,8
Bologna	12,8	14,8	16,2	21,7	10,9	70,9	80,8	93,5	124,0	100,4	95,4	108,6	122,9	162,6	137,6
Modena	58,3	65,8	87,1	127,8	18,0	269,2	321,7	426,4	652,5	197,9	411,4	480,1	645,2	974,0	213,0
Ferrara	34,5	33,3	37,3	46,6	18,2	272,1	263,3	308,7	354,0	138,7	255,7	247,4	280,8	342,0	147,3
Region	**63,2**	**75,8**	**90,3**	**122,9**	**168,5**	**306,2**	**367,3**	**447,0**	**608,1**	**880,6**	**452,8**	**540,8**	**656,7**	**896,5**	**1.278,1**

3. Maps data analysis

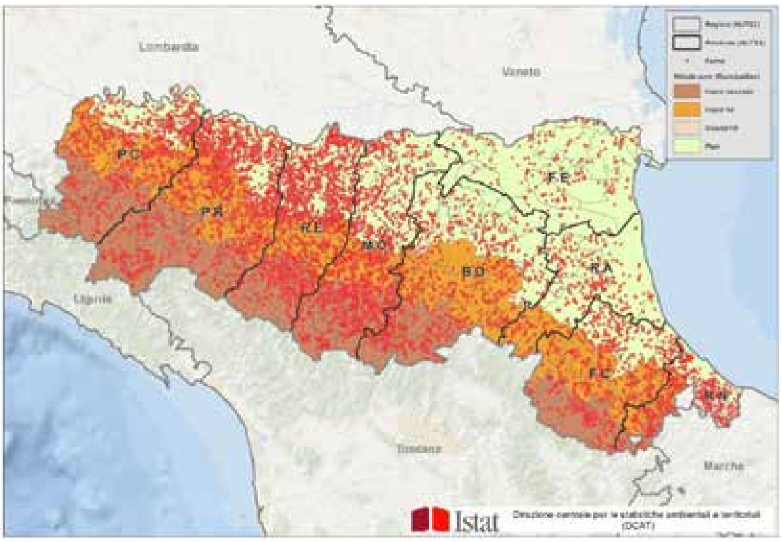
In Emilia-Romagna 8,822 farms have been georeferenced of a total of about 10,000[1]. The difference depends on the inexistence of a validated coordinates for few livestock houses. The farms without geo-referred data are little in terms of heads and uniform distributed on the territory. The emissions calculated and the relative indicators are represented on the following maps.

The farms with livestock are concentrated in the provinces Forlì-Cesena, Modena, Reggio nell'Emila, Parma (figure 1), Parmiggiano Reggiano e Prosciutto production areas. On the coast the number is lower, probably because this is an area with a great sea tourism vocation (Bologna, Ferrara, Ravenna and Rimini provinces).

In the figure the farms are represented by altimetric area (each farm is a geo-referenced point). It's clear the independence between this matter and the presence of animals. Very interesting could be the evaluation of environmental and health risks for people who lives close to the livestock.

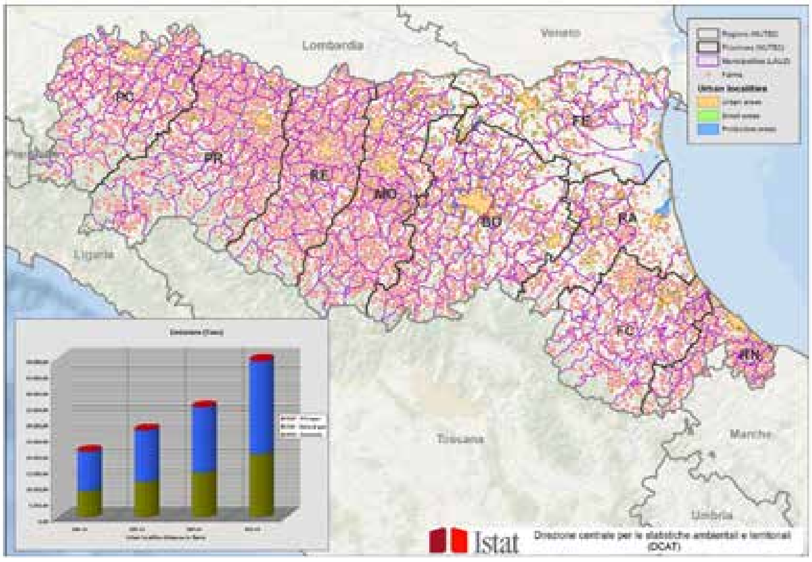
[1] Source Registry from the Ministry of Health

Figure 1 - Farms by municipality and altimetric area.



In the urban localities, delimited by a geographic information system (GIS) and available on the Istat site web[2], are detected and localized people and local units of the general censuses of population, enterprises and agriculture. The integration between the thematic maps of territorial bases (Lipizzi, 2013) and geo-referred farms, estimates the potential health risks on humans.

Figure 2 - Farms and emissions for distances from built-up, inhabited and production.



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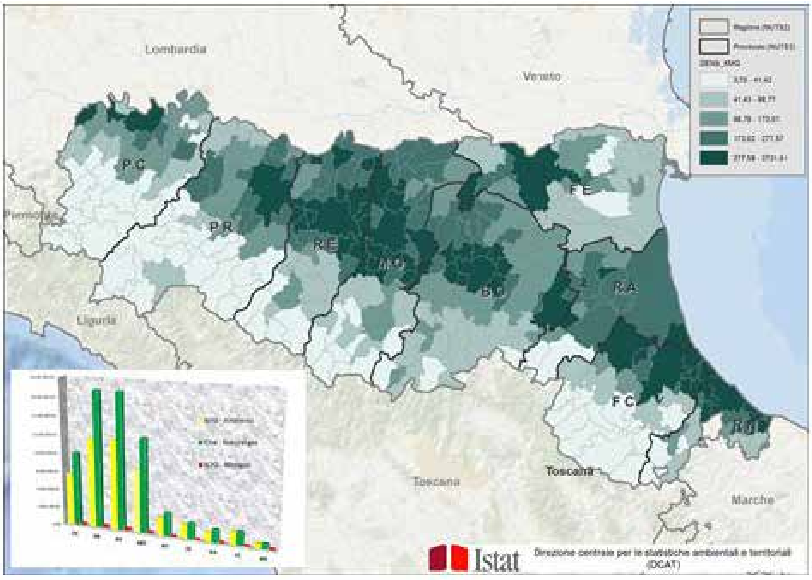
In the figure 2 are geo-referred the livestock houses and the urban localities, urban area (high density population) in yellow color, small area (inhabited areas) in green, production areas in blue. Each municipality is categorized according to quintiles of regional distribution. In figure it is also shown a graph, which indicate the sum of pollutant emissions by distance to the livestock houses. Methane and ammonia are the elements more consistent in the region Emilia-Romagna.

The figure 3 show the density population. The soft green indicate a low density and the deep green an high density. The population is concentrated in the north of motorway, into the Po valley.

The graph shows the total pollution per province. Methane and ammonia production caused by livestock are concentrated in Piacenza, Parma, Reggio Emilia and Modena provinces, how reported in table 2.

[2] http://www.istat.it/it/archivio/104317

Figure 3 - Density municipal population and total pollutants per province.



The last three figures are the overlapping of figure 1 and 2: they show for municipality the three components of carbon footprint (ammonia, azote and methane) normalized based on the population density. The theming is done by classifying quantile. In other words, they represent the table 2 calculate at municipal level.

Considering the single factors the situation is quite different respect to the total pollutant. It's clear the high concentration of polluting factors in interior area of the Region (particularly in Piacenza, Parma and Reggio nell'Emilia provinces), where is more incisive the presence of nitrous oxide (figure 5).

The areas near the cost are deeper because of the presence of Valli di Comacchio, a vast uninhabited wetland located in Emilia-Romagna, in the provinces of Ravenna and Ferrara. So even if the density population is lower, people lives nearest the farms and the health risk is higher.

Figure 4 - Ratio between ammonia produced in the municipality and density population

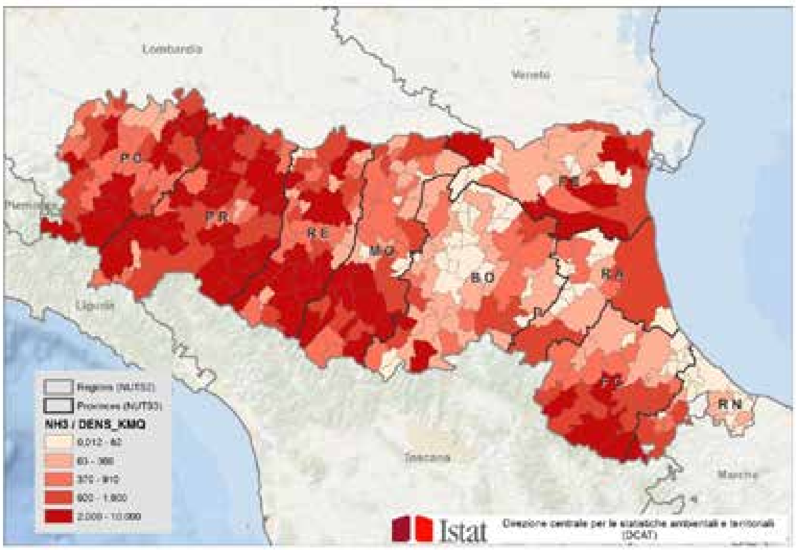


Figure 5 - Ratio between nitrous oxide produced in the municipality and density population

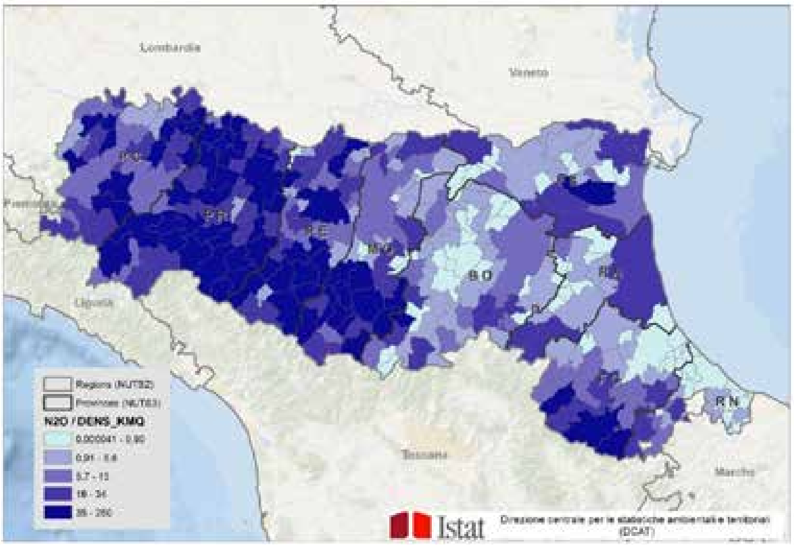
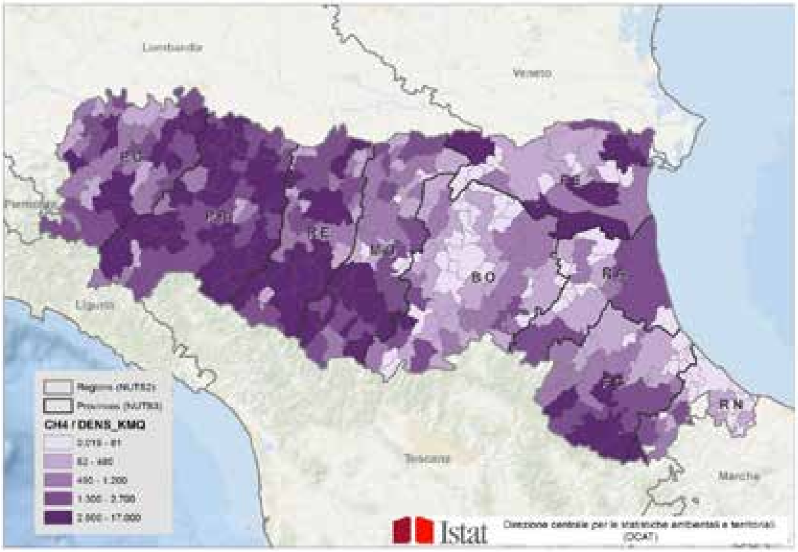


Figure 6 - Ratio between methane produced in the municipality and density population



Conclusion

The exercise carried out shows the increasingly important need to overlap geo-referenced data coming from multiple sources in order to obtain a broader and more detailed information linked with the territory . Data previously heterogeneous now take the chance to a new interpretation . It should be stressed that the potential of georeferenced information depends on the easy availability of them.

This study highlighted the strong connection between data related to bovine and data relate to the atmosphere. The results of this paper allow a more accurate definition of emissions from livestock activities and the evaluations obtained may also be useful to develop abatement strategies of pollutants in order to reduce emissions from the livestock sector.

Furthermore the analysis on a sub-municipal level, is a discriminating factor in assessing more accurately the health risk to the population. It would be interesting to extend the analysis to all regions and in other critical areas.

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THEMATIC SET

B14

COMMUNICATING YHE COMPLEXITY OF SUSTAINABLE FOOD AND AGRICULTURE

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ABSTRACT

Composite indicators (or performance indices) are recognized as a useful analytical and communication tool. Their attractiveness lies in their potential to synthesize multidimensional phenomena such as human development or food security into a single score, rank entities (such as countries) when appropriate, and facilitate advocacy. Furthermore, rankings force institutions and governments to question their standards; rankings are drivers of behaviour and of change. Hence, it comes as no surprise that there has been a turbulent growth of performance indices over the past two decades.

On the other hand, there is a more sceptical audience warning that composite indices may be misleading and difficult to interpret since much information may be lost or concealed. Others question how a single index may inform decision-making since more detailed disaggregation is needed for this. Further, the methods to make up such an index are not universal and are under constant revision. Much revolves around the problem of assigning appropriate weightings to the different components in the calculation of a single index.

For this type of audience, scorecards, dashboards and key indicators might be the preferred option. One cannot disagree that there are many low quality composite indicators out there but this should not imply that composite indicators are altogether useless in informing debates. What is most important is that one systematically assesses the quality of existing composite indicators. There are already well-established principles of good practice which would allow the users of these new statistical artefacts to gauge their quality:

(a) a handbook, published jointly by the OECD and the European Commission's Joint Research Centre, offering guidelines on constructing composite indicators;

(b) sensitivity analysis offers tools to assess the extent to which a composite indicator is volatile to the specificities of its underlying assumptions;

(c) sensitivity auditing assesses whether and to what extent models (including composite indicators) conform to the scientific standards of accessibility, transparency, and reproducibility.

Taken together, these tools at least facilitate a public debate based on explicit reasoning in which composite indicators play a role. This session will engage presenters and participants in discussions of methods and applications of composite indicators in agriculture and social sciences. Are performance indices considered more as a means to an end or an end in itself? What are the latest developments for identifying suitable and general criteria for judging their quality and ability to summarize the underlying phenomena? Are scorecards, dashboards and key indicators to be preferred over composite indicators or are they complementary tools?

LIST OF PAPERS

Developing the Indicator System of Sustainable Agriculture – Application of Composite Indicators

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B14

Developing the Indicator System of Sustainable Agriculture – Application of Composite Indicators

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DOI: 10.1481/icasVII.2016.b14

ABSTRACT

The sustainability of agriculture has become one of the most important areas of agricultural research in the last decade. The focus of research has changed from efficiency of production, quality and quantity of product to the impact of agriculture on environment and rural population. An important area of research is the development of indicator systems measuring the sustainability of agricultural systems on micro or macro level.

The aim of this paper is to present the results of the author's research focusing on the development of an indicator system measuring the sustainability of agriculture. The indicator system is built on macro level statistical data and its structure is based on a theoretical framework that was developed using the definition of sustainable agriculture. Data were gathered for the EU Member Countries for the time period of 2000 to 2012. Composite indices of the overall sustainability of agriculture and separately for the four domains (food supply, environment, economy, society) were calculated. The weight system was established based on the results of a primary expert survey.

The indicators and composite indices are suitable for carrying out temporal and spatial comparisons and can also be used for analysing the causes of trends in the European agriculture in terms of sustainability.

Keywords: sustainability, agriculture, indicators

PAPER

1. Introduction

Agricultural production is a nature-related activity, and has a significant impact on the state of the environment, but also is an integral part of rural life. On the one hand it has a remarkable influence on rural areas and on the other hand it is dependent on them in many aspects. Agricultural production is multi-purpose: there are economic, environmental and social roles of agriculture (OECD, 2001; Boody et al., 2005; Rossing et al., 2007; Huang et al., 2015). The Earth's growing population will require a huge amount of surplus production of food; so the increase of utilised agricultural area and / or the increase of production efficiency are inevitable if consumption patterns remain unchanged. Therefore, the efficiency and the economic dimension of sustainability for agriculture – similarly to the energy sector – are more emphasised within the topic of sustainability compared to other economic sectors.

A reliable indicator system describing sustainability has become a more and more pronounced requirement of decision-makers. Besides, there is also an intensified expectation among the population to gain information on the social and economic processes in terms of sustainability. Many organizations and scientific institutions have developed indicators and indicator systems that attempt to measure the performance of agriculture in terms of sustainability. However, they are not fully adapted to the Hungarian and European Union agriculture, and most of them do not allow temporal or spatial comparisons.

2. Material and method

The theoretical framework of the indicators of sustainable agriculture is based on the definition of sustainable agriculture, which was created by synthesizing the literature sources including the following: EU, 2012; Kirchmann and Thorvaldsson, 2000; National Research Council, 2010; OECD, 2001; RISE, 2016; SARE, 1997; Smith and McDonald, 1998; USDA, 1999; Valkó and Farkasné Fekete, 2014; Van Cauwenbergh et al., 2007. Four points of the definition identified the domains of the indicators system, which are as follows:

• production of good quality, safe and healthy foods, satisfaction of needs – food supply,

• conservation of natural resources, protection of the environment, creation of animal welfare – environment,

• efficiency, competitiveness, economic viability, ensuring profitability – economy,

• improving the quality of life in rural areas, social justice, and development of attractive rural landscape – society.

According to the theoretical framework, 44 indicators were chosen and grouped in 4 domains (food supply, environment, economy and society). The themes covered by the indicators are listed in Table 1. Only those indicators were selected, for which data were available for the EU Member Countries for the years 2000-2012. The most important data source was the Eurostat database, but to a lesser extent, other data sources were also used (FAO, WHO, etc.). 15 thousand data items were gathered, which phase was followed by their check and editing, as well as the imputation of missing data. Through the phases of selection of indicators and collection of basic data, quality requirements developed by Eurostat and the OECD were followed. An examination of the relationship between indicators using correlation matrices was carried out prior to the finalization of the indicator system. The revealed relationships between the individual indicators in several cases exist and can be explained. However, the number and strength of these relationships is not such that would reduce the reliability of the indicator system. Based on the correlation analysis, the inclusion of each indicators in the indicator system is reasonable. The weights required for the calculation of the composite indices were determined by expert opinion. In the literature (OECD, 2008), this procedure is referred as the Budget Allocation Process (BAP).

Table 1 - Themes covered by the indicators in the indicator system for sustainable agriculture

Food supply	Environment	Economy	Society
Organic farming	Resource use	Resource use	Production of value
Production of genetically modified crops	Energy use	Efficiency of land use	Employment
Food security	Land use	Labour productivity	Rural development subsidies
Food processing capacity	Livestock density	Competitiveness in foreign trade	Change of population
Food price	Emission of greenhouse gases	Yields	Poverty
Consumption of healthy food	Emission of ammonia	Utilization of agricultural land area	Housing conditions
Safe food	Nutrient balance of soil	Replacement of means of production	Age composition of population
	Manure use	Diversification of production	Internet access
	Pesticide use	Research and development	Environmental harm
	State of flora and fauna	Age composition of farmers	
	Environmental commitment	Agricultural income	
	Organic farming	Subsidy dependency	
	Own produced inputs		
	Land use		
	Training of farm managers		
	Agricultural education		

Source: own research

In order to develop the Sustainable Agricultural Index, first the normalization of data of the indicator system was carried out using min-max method with the application of the following formula (OECD, 2008):

$$I_{qc}^{t} = \frac{x_{qc}^{t} - \min_{t \in T} \min_{c}(x_{q}^{t})}{\max_{t \in T} \max_{c}(x_{q}^{t}) - \min_{t \in T} \min_{c}(x_{q}^{t})}$$

where

x_{qc}^{t} = value of indicator q for country c and year t,

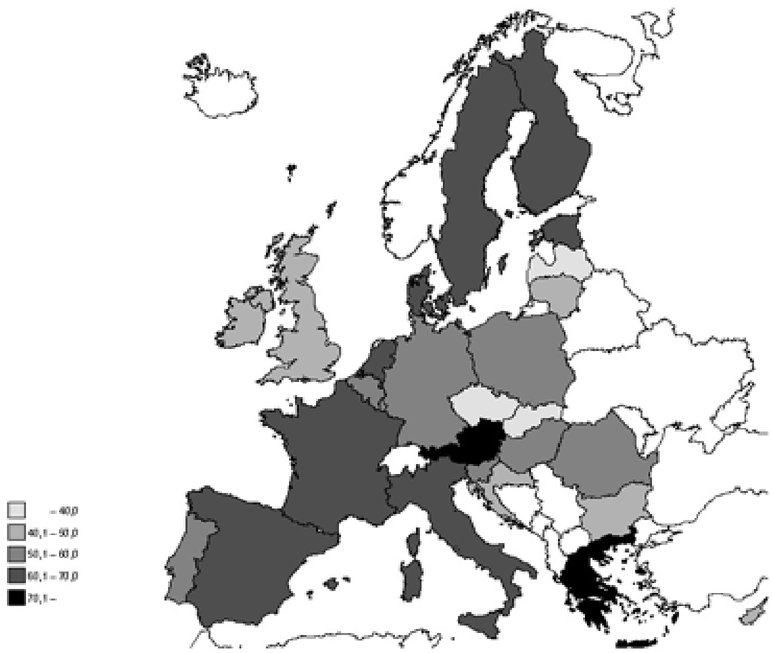
I_{qc}^{t} = normalised value of indicator q for country c and year t.

During this process, the experts distribute 100 points for the indicators according to their importance in terms of the target determined by the theoretical framework of the indicator system. Determination of the weights is complex, and it is very difficult to make an informed decision because of too many circumstances to be considered and the limited information. For this reason, an opportunity was offered for the experts who had difficulties in the distribution of 100 points to determine the rank of indicators in terms of their importance. The aggregation of indicators was performed using the method of linear aggregation by adding the normalised and weighted values of the indicators. The weight system of the composite indicators was developed by using the results of an expert survey. Sub domains were created for two domains of the indicator system in order to facilitate the work of experts in valuing the different indicators in terms or their contribution to sustainability of agriculture. These sub domains are: Resource use; Environmental pressures, state of the environment and Proper farm management in the domain Environment while Efficiency, competitiveness and Economic viability, profitability in the domain Economy. The survey was carried out between 28 October 2014 and 6 January 2015. A total of 102 experts (including international experts), who have the expertise in sustainability of agriculture, received the questionnaire. During the research, 60 experts returned the questionnaire, representing a return rate of 59% (Table 21). 65% of the respondent experts held at least a PhD degree. The expert survey resulted in the weights for the indicators and the domains of the indicator system. The weights for the four domains are as follows: 30.9 for Environment, 28.3 for Food supply, 20.5 for Society and 20.3 for the domain Economy. When compiling a composite indicator system, a number of subjective decisions are to be made, which may even substantially influence the composite indicator values. Therefore, the robustness and the reliability of the composite indicators were measured using sensitivity analyses, which were carried out for the following areas: compilation of indicator system, type of weighting system and selection of experts. The values of the Sustainable Agricultural Index (key composite indicator for the sustainability of agriculture) calculated with modified conditions were compared with the results from the original method. Based on the results, only the selection of the type of weighting system influenced significantly the values of the composite indicators.

3. Results

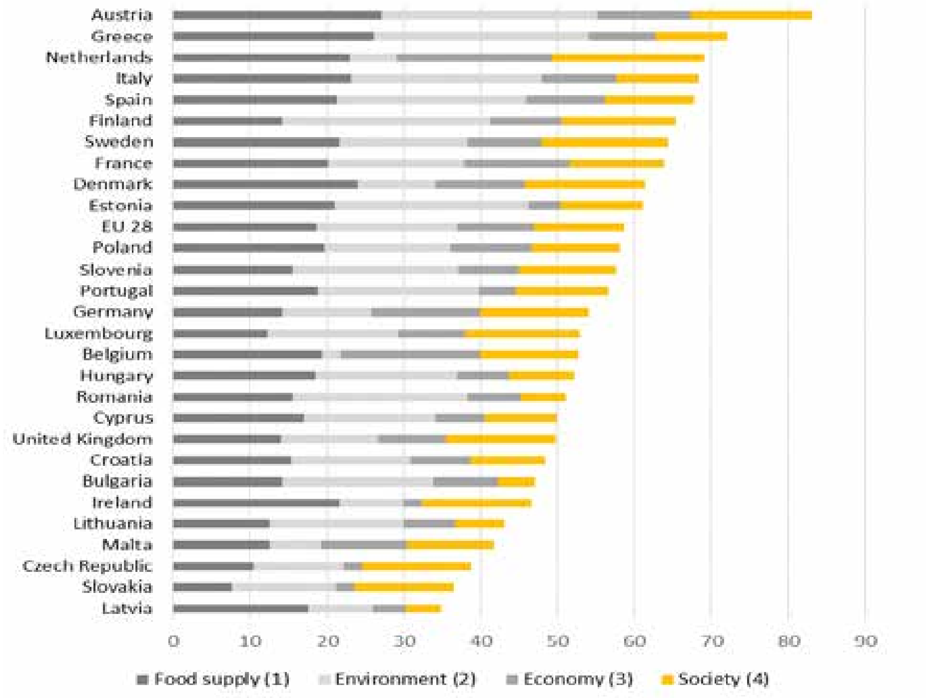
Sustainable Agricultural Index (values for 2010 are shown in the map of Figure 1) had the highest value in Austria in 2010 in the EU, followed by Greece and the Netherlands, while Latvia, Slovakia and the Czech Republic had the lowest values The contributions of components of the Sustainable Agricultural Index to the index values for 2010 are presented in Figure 2. The agriculture of Austria performed well in all major areas. The Austrian value of "Food supply" indicator is the highest in the EU, while second for that of the "Environment", and third for the indicator for the "Society". Greece showed an outstanding performance in the domains for environment and food supply, and the Netherlands achieved high values for the composite indicators of economy and society. At the other end of the country order, Latvia reached the lowest level in the EU in the domain "Society", while Slovakia had the lowest value in the domain "Food supply". 2010 values of the Sustainable Agricultural Index and the rate of change compared to the 2000 figures are presented in Figure 3. The Sustainable Agricultural Index of the Polish (94%), the Estonian (71%) and the Czech (63%) agriculture reached the strongest improvements between 2000 and 2010, while decrease in Ireland (24%), Denmark (8%) and Croatia (6%) can be detected.

Figure 1 - Values of the Sustainable Agricultural Index in the EU Member Countries, 2010



Source: own research

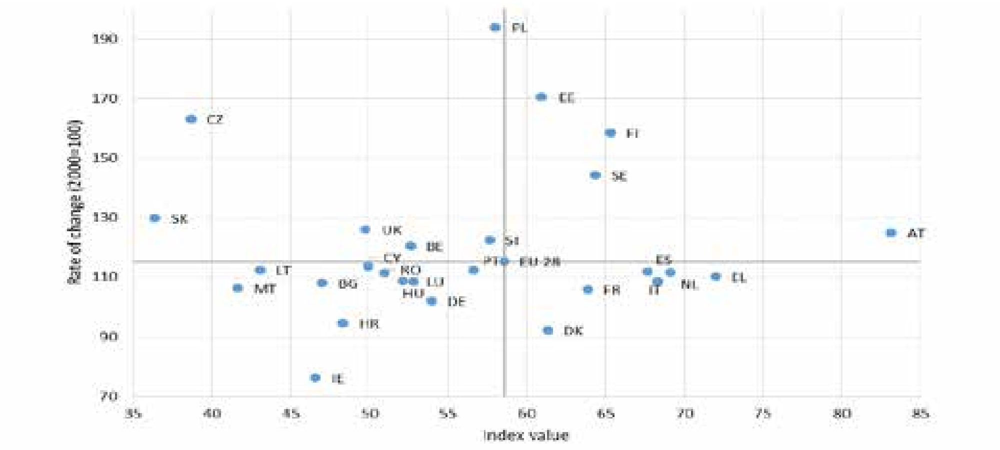
Figure 2 - Values of the components of Sustainable Agricultural Index in the EU Member Countries, 2010



Source: own research

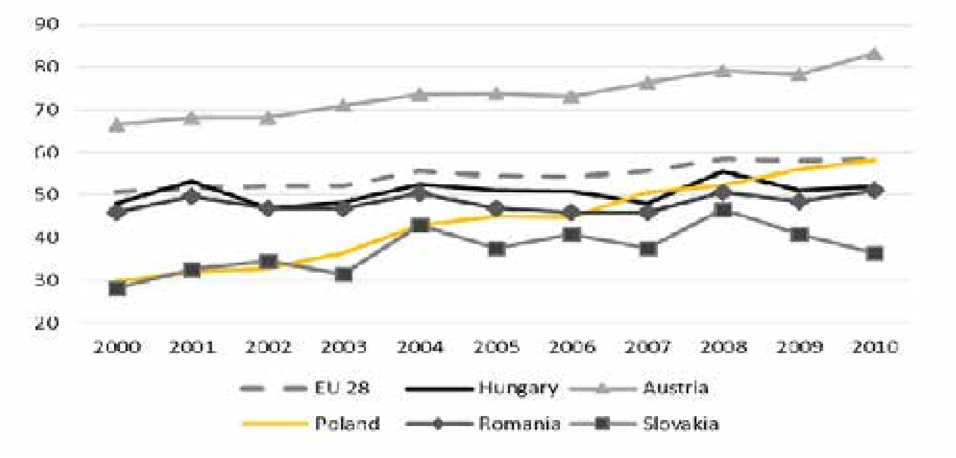
Figures 4 and 5 compare the values of Sustainable Agricultural Index in the region of Central and Eastern Europe. In the whole period, Austria had the highest index value, while Poland achieved a significant increase, and reached a higher value than that of Hungary and Romania in 2010. If we examine changes in the values of individual countries, we can conclude that Poland reached the most significant growth during the decade studied, while changes in the values of other countries were not significant apart from the minor growth in Slovakia.

Figure 3 - Values of Sustainable Agricultural Index and the rate of change compared to the 2000 figures in the EU Member Countries, 2010



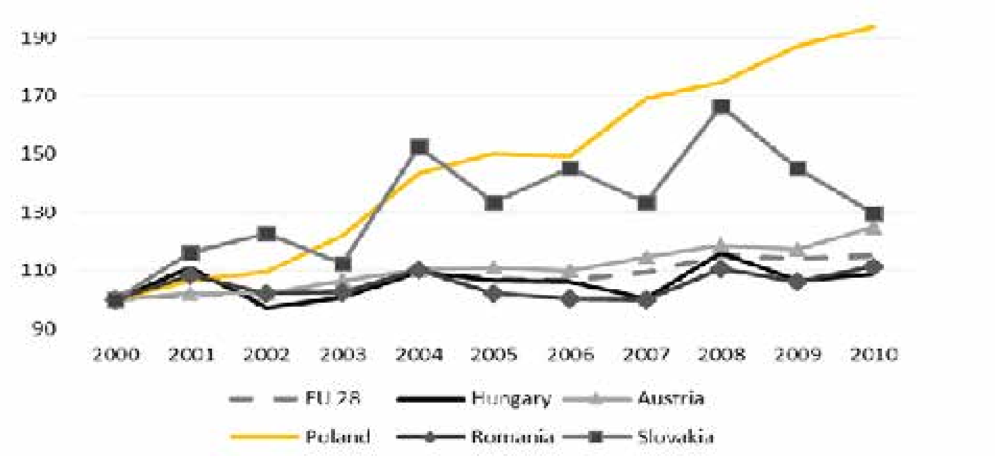
Source: own research

Figure 4 - Sustainable Agricultural Index in Central and Eastern Europe, 2000-2010



Source: own research

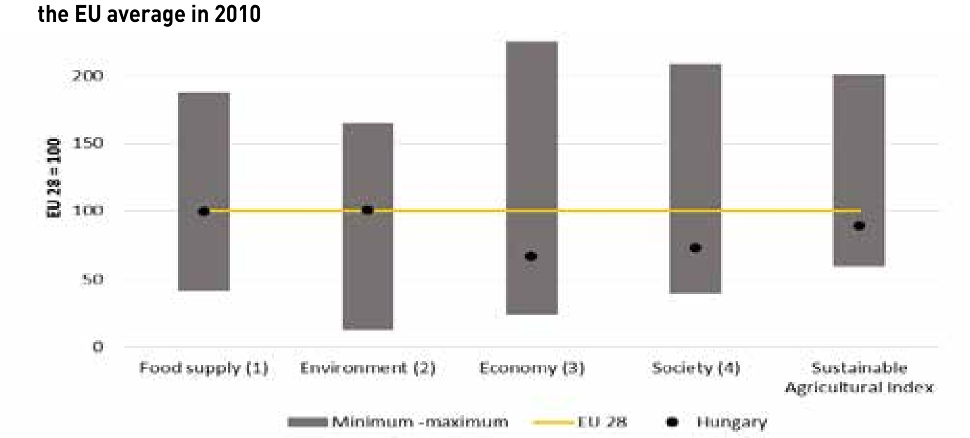
Figure 5 - Changes of Sustainable Agricultural Index in Central and Eastern Europe, 2000-2010 (2000=100)



Source: own research

The indicator system and the composite indices give an opportunity for detailed country analysis where the performance of a country can be analysed by components, against competitors and also temporal changes can be investigated. As an example for country analysis, the values of Sustainable Agricultural Index and its components in Hungary are shown in Figure 6. Sustainable Agricultural Index of Hungary was 11% lower than the EU average in 2010. The index for the environmental dimension showed a slightly higher value than the average, while the index for the "Food supply" domain was slightly lower than the average. The values of indices for the "Economy" and "Society" domains were significantly lower than the EU average.

Figures 6 - Sustainable Agricultural Index and the values of the indices for the domains in Hungary compared to the EU average in 2010



Source: own research

4. Conclusion

Numerous institutions and research teams have developed indicator systems for measuring the sustainability of agricultural production; however, none of these gave a summary assessment of the sustainability of the EU Member Countries' agriculture.

The average value of Sustainable Agriculture Index rose in the EU in the period between 2000 and 2010, according to which the EU agriculture moved towards sustainability. The index values showed the most significant increase in the domain "Economy" during the period under review, while the lowest growth rate was measured in the domain "Environment". There are significant differences between the sustainability performances of the Member Countries.

The compilation of the indicator system was difficult because of the lack of basic data or the inadequate quality of them in some areas. The quality of the composite indices is basically influenced by coverage of the specific areas in the theoretical framework by relevant indicators supported by basic data with adequate quality. For this reason, it is essential to improve the accessibility and quality of basic data. An additional problem in many areas is the long production time of data; timeliness needs to be improved. The production of indicators at a lower territorial level is currently not possible in many areas because raw data are not available, which deficiency could be eliminated by applying data collection methodologies or estimation procedures that could enable the dissemination of data at a lower territorial level.

A major difficulty related to the composite indicators is the lack of their widespread acceptance. The value of the indicators can be significantly affected by the theoretical framework, the scope of indicators in the indicator system and the methodology of the weight system that is needed for the calculation of the indicators. In many cases, subjective decisions are needed for the development. However, the communication value and the role of composite indicators in decision support are indisputable. It is necessary that the development methodology of a composite index should have the appropriate political support to become widely accepted. The system of indicators and the related composite indicators produced as a result of this research are capable of supporting the European and national agricultural policy decisions, as well as of the shaping of Common Agricultural Policy and its components. A distinct advantage of the indicator system is that it is suitable for the systemic tracking of changes in the main aspects of agricultural production both at national and at EU level.

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THEMATIC SET

MEASURING FOOD LOSES AND FOOD WASTE

B15

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ABSTRACT

The reduction of Food Losses and Waste (FLW) is a central topic in the current policy agenda. An FAO study of 2011[1] suggests that roughly one-third of food produced for human consumption is lost or wasted globally, which amounts to about 1.3 billion tons per year. Of this, potentially more than 40% is lost during post-harvest handling and processing in developing countries, while more than 40% is lost at retail and consumer levels in industrialized countries. Additional losses occur in non-food agricultural value chains such as animal feed or seeds. Taken together, these losses undermine economic, food security, nutrition, and other welfare outcomes; and they impact on the environment. Yet regional and national knowledge about FLW remains incomplete and unreliable. There is a poor understanding of, and limited accurate or comparable data on, the scale, nature, location, sources, and consequences of FLW across food systems. Without reliable information, countries and the global community are unable to assess the scale, causes and consequences of PHL; they hesitate to invest significant resources; and they are unable to design and target effective policies and investments. The challenge of measuring FLW is significant. There is methodological gap on a cost-effective and statistically sound approach to effectively assess FLW in support of measures for their reduction. FLW are a multi-dimensional phenomenon that affects the whole value chain from producer to consumer. Furthermore, problems and characteristics can be product-specific and require product-specific methods. Ultimately, measuring FLW in their entirety requires developing a conceptual framework to differentiate losses and waste, as well as the types of losses (quantitative, qualitative, and nutritional) and different actors or units of observation (farms, households, traders, food processors, distributors, warehouse owners, etc.), as food moves from food to fork. Compiling FLW statistics therefore implies establishing a multi-layered system consisting of different surveys each with its associated sampling and measurement challenges. The aim of this session is to discuss: statistical methods that can address the methodological challenges of measurement; options for designing integrated FLW measurement systems; and cost-reduction strategies such as use of small-scale case studies to identify main losses/waste points and focus sample surveys on those. Possible topics for papers include: integration of post-harvest losses into existing agricultural statistical surveys and systems;; survey design (two-phase sampling, indirect sampling for traders and distributors); estimates based on experimental design; commodity-specific methods (milk, horticultural products, fish); measurement issues; pre-harvest losses waste; modeling approaches.

1 FAO (2011), Global food losses and food waste – Extent, causes and prevention. Rome. ISBN 978-92-5-107205-9

LIST OF PAPERS

Dynamics of Losses in Tomato Commodity Chain (Estimates based on experimental design in Cameroon).

D. E. Tolly Lolo | Open Markets Ltd | Cameroon
P. Kamtchouing | Faculty of Agronomic Sciences of Dschang | Cameroon

DOI: 10.1481/icasVII.2016.b15

Post harvest food losses: a framework for horticulture sub sector analysis in sub-saharan Africa

M. R. Baha | The University of Dodoma | Dodoma | United Republic of Tanzania
M. Msafiri | The University of Dodoma | Dodoma | United Republic of Tanzania

DOI: 10.1481/icasVII.2016.b15b

THEMATIC SET

B15

Measurement Issues and Lessons Learned from Estimating Food Loss at the Retail and Consumer Levels in the USA

J. C. Buzby | Economic Research Service, U.S. Department of Agriculture | Washington, DC | USA
J. T. Bentley | Economic Research Service, U.S. Department of Agriculture | Washington, DC | USA

DOI: 10.1481/icasVII.2016.b15c

Developing cost-effective statistical methods for measuring post-harvest losses in developing countries

M. Kebe | FAO, ESSD | New York | USA

DOI: 10.1481/icasVII.2016.b15d

The FAO approach to food loss concepts and estimation in the context of Sustainable Development Goal 12 Target 3

S. Tayyib | Statistics Division, FAO | Rome | Italy
N. Golini | Statistics Division, FAO | Rome | Italy

DOI: 10.1481/icasVII.2016.b15e

B15

Dynamics of Losses in Tomato Commodity Chain (Estimates based on experimental design in Cameroon)

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DOI: 10.1481/icasVII.2016.b15

ABSTRACT

In order to improve food security in Cameroon, a diagnostic study for the reduction of Post-Harvest Losses (PHL) in tomato supply chain was carried out in 2013, by a team of two FAO consultants, for the Ministry of Agriculture and Rural Development (MINADER). The study was conducted in the West (main production area), and Littoral (urban markets) regions of the country. The methodology was based on four main stages: (i) preliminary diagnosis of the situation of PHL throughout the supply chain, (ii) field work with various actors of the sub-sector, (iii) synthesis of the results obtained, and finally (iv) the development a strategy and the relevant work plan and for a significant reduction of these losses over a period of 10 years.

With an average consumption of 30.05 kg/person/year and 35% of all vegetables consumed in the country, fresh tomato occupies a prominent place in the country's food security. About 329 033 small farmers are involved in the sub-sector with a potential of 1 645 165 jobs.Tomato produced locally is mainly marketed fresh, without any significant processing after harvest. For reasons related to logistics and time constraints, the western production area and urban market of Douala were selected for further analysis in the field. Moreover, we also considered financial resources available for the study and the following criteria, defined by the FAO guide: (i) be part of an organization of small farmers producers of tomato, (ii) final products are intended for human consumption, (iii) have their end markets in villages, urban areas or abroad, (iv) create value added by small and medium sized farms in the supply chain; (5i) to be integrated into a support program underway in the tomato subsector. Preliminary investigations revealed that Pre-harvest, Transport and Marketing were the highest Food Losses stages. Even though the production of fresh tomato was about 932 530 tons in 2012, and the consumption estimated at 605 054 tons, the country still faced huge deficit which were partly filled by concentrated tomato imports; This is due to high losses along the supply chain. Interviews with different actors of the supply chain, and a study conducted in markets, allowed us to compare the preliminary information obtained during the screening phase, with the results of measurements of losses at critical points. Hence, losses in tomato supply chain are both quantitative (reduction of mass) and qualitative (reduction of market and nutritional value). Causes of these losses depend on several factors: technological, managerial, infrastructural, etc. Origin of these losses is diverse and include among others: climate, soil, variety, physiology, mechanical damage, diseases, pests, and agricultural processing practices. Field analysis revealed the steps where tomato losses (quantitative and qualitative) were most significant: Pre-harvest/harvesting (28.30%; # %), Transport (7.70%; 5.15%), and Retail sale (#%; 25.85%) of production. The synthesis of results helped us to identify the following solutions: (i) improve access to agricultural inputs (quantity, cost, regulation, certification, etc.) and adequate knowledge of the usage; (ii) drive an inclusive research-development action to improve traditional containers used for tomato transportation; (iii) develop farmer's capacities in farm management practices, and market access; (iv) improve market infrastructure, (v) Facilitate access to innovative packaging and handling techniques. Finally, a strategy for the reduction of losses in the tomato sub-sector over a period of 10 years was proposed to Cameroonian Government.

Keywords: supply chain,critical stages, quantitative losses, qualitative losses

PAPER

1. Introduction

According to FAO statistics, the current energy consumption which is about 2300 kcal/ person/day in Cameroon remains below the average of developing countries (2600 Kcal/day/ person). The State of Cameroon in its strategy for growth and jobs (agriculture and rural development component) had set a goal to reach a level of 3100 Kcal/day/person in 2015. To achieve this objective, it was necessary to combine the growth of agricultural production initiatives, with the reduction PHL. These losses account for about 20 to 50% of production or more for some crops in Cameroon, including fruits and vegetables. Indeed, a significant reduction in losses is not only beneficial to all stakeholders of the various agricultural and food sectors but is also conducive to food security in its different dimensions (availability, accessibility, stability of market supplies, sanitary quality and nutritional food) and preservation of the environment. No previous study had been conducted for the assessment of post-harvest losses on the tomato supply chain in Cameroon.

Although these estimates come from the Ministry of Agriculture in Cameroon, they are not confirmed by reliable field analysis.

From the Ministry of Agriculture data in Cameroon (not confirmed by reliable field analysis), although estimates are available on the level of food losses, there is always the need to identify the most critical determinants at different points of the food supply chain in order to achieve profitable and sustainable socio-economic and environmental solutions. Studies are needed as a prerequisite for setting priorities for the implementation of specific interventions for reducing losses and obtaining a maximum desired effect. It is in this context that MINADER requested a diagnostic study for reducing PHL of three crops (cassava, potato and tomato) with FAO support. This was evidenced by project MINADER/FAO-TCP/CMR/3402: "Diagnostic study of post-harvest losses in cassava tomato and potato value chains in Cameroon". This report covers only the work done in the context of tomato in Cameroon. For FAO, the study is part of a series of case studies from the global initiative to reduce food losses and waste (Save Food).

The main objective of this study is to make an inventory of PHL and critical stages in the tomato supply chain in order to propose a strategy for better control of losses. The fieldwork was conducted in 2013 and was subject to a detailed report and validated during a national workshop held in Yaoundé in April 2014.

2. Intermediate sections

2.1 Methodological approach

The methodological approach used is that developed by FAO for the case studies as part of the Save Food initiative. It consists of the implementation of the main steps and actions summarized below:
- Preliminary diagnosis of the sub-sector. It brought out general situation of losses on the tomato sector in Cameroon, identify key critical steps and reveals the levels of qualitative and quantitative losses as perceived by experts and other resource-persons in the sector;
- Field surveys for evaluation of losses. In the production area (western region), they were made via field measurements in farms, and semi-structured interviews with groups of stakeholders (producers, processors), completed by field observations. In consumption areas(Douala markets), specific questionnaires were administrated to transporters, wholesalers and retailers.
- Monitoring of tomato shipments from the fields through the rural markets (or assembly markets), to urban consumer markets (wholesale and retail);
- Analysis of data collected in the production areas and markets in order to establish a detailed statement of the causes of food losses, estimate their size and the possibilities of their reduction to the different critical stages of the supply chain;
- Preparation of the study report and validation via a national workshop Based on the findings, interventions are proposed, aiming for a significant reduction in losses over a period of ten years in the tomato supply chain.

The fieldwork was made in 2013 in the following areas: (i) Production area and rural markets (West)and (ii) urban-consumption markets: Douala (Littoral). The choice of supply chains for the field work was done at the end of the preliminary phase, in regard of the following criteria: creation of added value, contribution to income generation, ability to generate non-family labor, importance of the export market (generation currency), and contribution to food security. It is also based on the following criteria: (i) size of the food chain operations; (ii) creating added value for small and medium farms in the supply chain; (iii) nature of the products obtained in the supply chain; (iv)existence of markets in villages, urban areas and opportunities to sell abroad; (5i) sector/ study is included in an ongoing program of support for the sector.
A team including two national experts (an economist and a food technologist) conducted the field study under the supervision of FAO.

2.2 Status and importance of the tomato subsector in Cameroon

With an estimated production of 889,800 tons and annual growth rate of 9.4% in 2012, tomato sector occupy about 329,000 producers in Cameroon. Based on FAO estimates, 150 000 hectares were planted in 2012, with an average yield of 11.3 tons/ha, still well below the value of 20 tons/ha referred. The production is still artisanal, largely carried out by small producers operating in a context of family farming, and organized into cooperatives. Moreover, tomato is grown mostly by men who typically exploit an area of 0.25 hectare each where they practice monoculture. An estimate conducted by MINADER between 2007 and 2008 shows that current consumption of tomato in Cameroon is about 30 kg per capita. Tomato is firstly produced for marketing and it contains a potential of 1,645,200 jobs. The tomato processing is almost non-existent in Cameroon yet. There is a significant demand for derivatives products such as concentrate and sauces, covered by imports. Moreover, this sector also has enormous export potential in the CEMAC sub-region unfortunately; this opportunity is not used because of the high volume of PHL recorded throughout the supply chain, aggravated by poor organization of the sector, the isolation of production areas and the instability of marketing channels.

Table 1 summarizes the essential information on the national tomato production. It shows that this production is greater than consumption of the country that would amount to 605 054 tons, valued at 148.5 billion CFA francs. However, it is only an apparent surplus because if one takes into account all the losses suffered by the product after its harvest, the supply of fresh tomato in Cameroon would be negative. This significant gap is filled in part by imports of tomato paste which constitutes an offer of 6,000 tons for a demandabout 60 390 tons.

Table1 - Information on production and by-products of the tomato sector

Item	Data	Observations
Annual volume of production (tons / year)	889 800	Data for 2012 (FAOSTAT, 2015)
Area (ha)	150 000	Data for 2012 (FAOSTAT, 2015)
Average yield (tons/ ha)	5,9	Production volume/area
Average rate of increase over the last 10 years (%)	9,4	Data for 2012 (FAOSTAT 2015)
Average production cost (FCFA /ton)	221 240 (434 USD/ ton)	Average production costs of tomato growers organizations in the targeted regions.
% Of production consumed	2	Almost all family farmers which cultivate tomato consume a small amount (less than 1 Kg/day), the rest going to the market
% Of production marketed	98	Interview with Experts
Estimate% sold wholesale / retail sold by producers	90 10	Interview with experts; Field confirmation
Output value (FCFA / year)	166 billion (325.5 million USD)	Turnover for 2012 (FAOSTAT 2015)
Number of producers	600 000	The majority of farms in the studied production areas have an area of 0.25 hectares. Number of producers/ 0.25 = area.
Market size of fresh tomatoes (request) (tons / year)	867 000	In 2007, the consumption of fresh tomatoes in Cameroon was 27.5 kg per capita (MINADER, 2009). It is assumed that it evolves with the same trend as production (average annual growth rate: 9.4%); so, it is of 43 kg per capita in 2012.
Market value of fresh tomatoes (FCFA / year)	213 billion (417 million USD)	Average price/kg = 245.5 FCFA ($ 0.48), value calculated from measurements of the market.
Size concentrated tomato market (tons/ year)	60 400	Tomato paste consumption is about 3 kg/person/year in some African countries, including Benin, Nigeria and Niger (LARES and IRAM 2002). The consumption of 3 kg/person/year is extrapolated to that of Cameroon's population has almost the same diet as that of Nigeria.
Market value of concentrated tomato (FCFA/ year)	69 billion (135 million USD)	minimum average price/kg = 1142 FCFA ($ 2.24) calculated from the imported brands on the market

Source: *Results of the study; 1 USD = 510 FCFA*

2.3 Description of studied areas, actors involved and stages along the supply chain

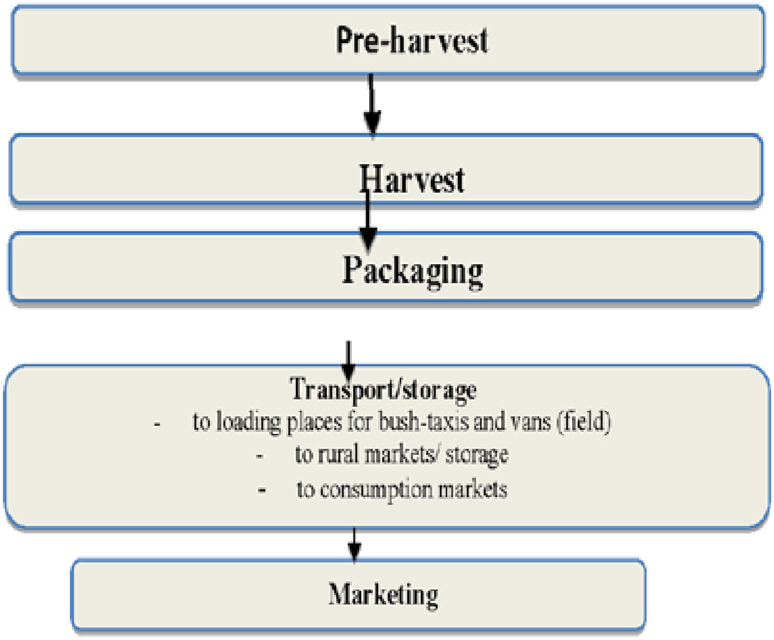
Two fresh tomato supply chains were selected for detailed study on PHL: Mbouda-Bafoussam-Douala and Foumbot-Bafoussam-Douala, with exports opportunities in neighboring countries namely Gabon and Equatorial Guinea. The following criteria were taken into consideration: (i) value added, (ii) contribution to revenue generation of each operator, (iii) ability to generate non-family jobs and ease to organize and track shipments and, (4i) ability to sell in the CEMAC zone.

The selected communities are located within a radius of about 70 km around the towns of Mbouda and Foumbot. The production of fresh tomato is done in two seasons: (i) dry (February-April) and (ii) rainy (August-October), where it reaches its peak. Women are almost absent in this sub-sector. There are carriers, wholesalers and retailers. Rio variety is the most cultivated in Cameroon and is characterized by its resistance to disease, its pear-shaped size of fruit, deep red, with a diameter of 4.9 ± 2 cm and an average weight of about 150g. The production cycle takes around 80 days. Several harvests take place on the same field of tomato (4-6) with one week interval between two successive harvests. The production facilities consist of rudimentary tools. Fresh tomatoes could be left non-cropped days after the maturity of fruit to meet the uncertainties of the market demand and lack of markets information.

Basic constraints such as (i) lack of electricity in rural areas, (ii) poor organization, (iii) limited volume of tomato per farmer, (iv) lack of maintenance, etc., cooling facilities seems not to be appropriate for the moment.

After harvest, the ripe or half-ripe fruit are packed in baskets (crates), made by local craftsmen from raffia bamboo. The full crate is covered by a bunch of grass or banana leaf. With a volume that varies between 20 to 25 liters, the average empty crate weighs 400 g and sold between 250 and 300 FCFA per unit is the most requested format. In the case of fresh tomatoes packed for export the conditioning is done in plastic boxes brought by the customer. Once packed in the field, crates are then transported on the heads, in wheelbarrows or on motorcycles to the nearest rural track where they can be stored by the roadside in full air (for maximum a day), until the arrival of the conveyance. A second storage takes place in the rural markets, in preparation of loading for high consumption areas. The transporters usually travel at night, with an average temperature of 20 to 25°C. Night trip reduces the perishability of the product that keeps certain level of freshness, while facilitating early arrival to consumption markets. Storage or exposure of the product to the sale is to put tomato in the open. Wholesalers and retailers do not have the means to create the ideal conditions for the conservation of fresh tomato for three days or more, in Douala where average temperature varies between 25 and 30 °c.

Figure1 - Flow Diagram of fresh tomato supply chain



2.4 Alleged losses in selected supply chains

With its high water content (about 90%), tomato is a particularly fragile vegetable. Should harvesting, transportation and marketing standards not achieved, they can cause huge PHL. Preliminary analysis revealed that pre-harvesting, transport and retail sales are the critical points where food losses (quantitative and qualitative) are the most significant. Qualitative losses appear at harvest and increase with process steps (transport, marketing). Quantitative loss is mainly expressed during the pre-harvest phase (because of the fruit growing or ripe rotting up especially when they are placed on the floor or fall), or during transport (as a result of mechanical factors such as shocks that cause the crushing of fruit and water loss). Thus in the first stream (Mbouda - Douala market), the level of fresh tomatoes loss was estimated at 27% during the pre-harvest phase, 5.3% at harvest, 8.8% in transport and 1.4% in marketing. The second stream (Foumbot - Douala market), gives an estimate of 31.7% during pre-harvest/harvest stage, 5.9% in transport and 0.65% for marketing.These low values of quantitative losses in marketing could be justified by poor practices observed on retail markets. Indeed, injured, crushed or sometimes even rotten tomatoes, are rarely disgarded; rather they are collected, crushed and re-sold to pig breeder or small restaurants. Hence, qualitative losses (25,85%) are important losses during marketing; and low quality tomatoes are even sold half price.

2.5 Post-Harvest Losses along the supply chain: Results of study

At each stage of the supply chain, detailed description considered the following aspects: location, time of the year, number of players involved, intermediates, quantities produced, location, facilities used, duration/distance, required inputs and services, cost of production and the cost of products at sale. Results of analysis show that losses of fresh tomatoes which are both quantitative (mass or volume reduction), and qualitative (reduced market value, nutritional value and food safety) have various origins: physiological, mechanical, microbiological and pests action. Furthermore, the identified critical points are pre-harvesting, transportation and marketing.

Table 2 - Critical points and levels of PHLalong fresh tomatosupply chains (average)

Supplychainsteps	Qualitative losses (%)	Quantitative losses (%)	
		Losses at critical point (% ingoing quantity)	Losses (% total harvested)
Pre-harvest		28.3	28.3
Transport	5.15	10.85	7.7
Marketing	25.85	-	-
Total	-	-	**36.0%**

Source: *Results of the study*

Qualitative losses are primarily valued as depreciation in the market value of the product at retail. Product quality decreases, it loses its economic value and is sold at a lower price. It will still be consumed. Monitoring of tomato shipments shows that most losses are obtained during transport.

A synthesis matrix of the results of semi-structured interviews, shipments tracking and market research on food has been developed. The main aspects taken into consideration were: (i) cause of losses, (ii) % of loss relative to the initial amount, (3i) affected people, (4i) impact of losses, (5i) loss of market value in FCFA (6i) trends, (7i) time / season (8i) perception of actors and, (9i) solutions suggested by stakeholders. All actors in the tomato supply chain are affected by PHL: producers, distributors, consumers and their families. Causes of losses appearing at all stages, potential solutions should therefore involve all actors in the supply chain. Summary tables allowed us to have an overview of interventions that can be performed at critical points to sustainably reduce the loss of fresh tomato. The economic feasibility, social acceptability, environmental impact and management of the practical implementation of these interventions should be carefully studied beforehand. Their formulation and implementation should be inclusive and involve stakeholders from the public and private sectors.

At each critical stage identified, the following aspects were considered: (i) extent of losses (qualitative and quantitative), (ii) economic loss, (iii) causes of losses, (iv) intervention proposed to reduce these losses, (5i) impact of reducing losses, (6i) intervention costs over 10 years and (7i) risks.

A rapid calculation of economic feasibility (cost-benefit analysis) of loss reduction interventions shows that the total cost of implementation is estimated at USD 10.4 million over 10 years. PHL can thus be reduced gradually to 50% over 10 years (5% per year) with a mid-term review. Quantitative losses in the supply chains amounted to 35%. After ten years, they are expected to be about 17.5%. If we assume that the losses are reduced by 5% a year, therefore the level of economic loss estimated at USD 110 809 000 per year will also be reduced by 5% per year (or USD 5 540 500 per year); yet the annual cost of interventions is only estimated about USD 1 million.

To achieve the objectives of reducing PHL it would be appropriate to develop an intervention program, which will be implemented at the national level through one or more institutional actors. During the implementation and monitoring/evaluation activities, other relevant partners such as Unions of Cooperatives, research organizations, NGOs and actors in the public and private sector should be involved. Hence, in order to reduce PHL in the tomato sector, three main axes should guide the implementation of an operational strategy:
a) Core axe effect: (i) organization of the supply of agricultural inputs through improvement of availability, accessibility and quality; (ii) capacity development in management and marketing, especially for producer organizations, to better manage marketssupply; (iii) facilitating access to rural financing (acquisition of transport and packaging equipment);(iv) implement a national network for tomato actor's chain;
b) Relay axe effect: inclusive Research and Development on packaging practices of fresh products for the improvement and/or substitution of traditional containers;
c) Result axe effect: strengthening of technical capacities of actors (producer organizations and other) on management (including logistics), marketing, hygiene and food safety.

A national strategy for the reduction of post-production losses was adopted in December 2015 by the Cameroonian government with FAO support, but the implementation of activities is still to be launch.

3. Conclusion

The quantitative and qualitative losses are present at all stages of the tomato supply chain with consequences on the income of actors and lower product availability in markets.

The critical stages where losses are most significant are: the pre-harvest, harvest, transport and marketing. The production stage, with at least 2/3 of losses identified on the entire supply chain, is the main critical point that should be a priority in loss reduction strategies. The losses represent approximately 39.5% in quantitative terms including: 28.3% for the pre-harvest stage and 10.9% during transport from the main production areas (Mbouda, Foumbot) to the marketing town (Douala); Qualitative losses are estimated at 31%, of which 5.2% for transport and 25.6% in marketing.

The poor chain organization impacts on transport (low professionalization), fragile packaging, lack of information on the product label, low mastery of conditioning techniques necessary for good conservation, etc. In addition, the poor state of roads prevents the product to arrive on time in the market, with a live effect on transport costs, increasing market prices. The level of losses for delayed shipments is reflected in its low price in the consumption market. Despite these constraints, there is a significant potential for the extension of production in different areas for the cultivation and development of marketing both at national and sub-regional level.

Reducing losses in the harvesting and processing greatly benefit from targeted actions such as: improving access to quality inputs, strengthening of technical and organizational capacities of stakeholders, the use of suitable agricultural and processing facilities, etc. To sustainably reduce product losses at the marketing stage, actions to be taken should have a direct effect on the transport, storage and display on retail. While the use of more robust and suitable packaging would greatly reduce mechanical losses, storage in the appropriate conditions would drastically drop the level of losses caused by the physiological deterioration of the product as a result of its conservation outdoors, under the sun or rain.

Control and reduction of losses throughout the tomato supply chain, and mainly at critical points will increase the income of the actors involved, increase the availability of goods and improve the level of professionalism in the sector. The results of this study recommend the development and implementation of an intervention program for reducing PHL, which would be implemented by the Government, in partnership with the Unions of Cooperatives, local councils, and other key stakeholders in the public and private sectors. At the level of the proposed measures, it will ensure that any implemented action benefits women, in particular actions facilitating access to finance and micro-finance structures will be relevant in this area.

Finally, the establishment of a sustainable system of monitoring/evaluation of PHL, especially in collaboration with relevant technical and financial partners, is important because it will measure, manage and know different performance of targeted value chains, through the levels of PHL performance indicators. It will also contribute to the evaluation of the implementation of PHL reduction solutions by 50% by 2025, target set in the Declaration of Heads of State and Governments of Africa in Malabo in June 2014.

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Post harvest food losses: a framework for horticulture sub sector analysis in sub-saharan Africa

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ABSTRACT

This paper contributes a framework for analyzing post-harvest food losses in horticultural crops in developing countries settings specifically Sub Saharan Africa. The review is based on estimation horticultural products at various critical stages of post-harvest supply chain. This was driven by the deficiency noted at both quantitative and qualitative studies which based on our understanding have failed to account for estimation of post-harvest losses specifically on horticultural crops.

Thus, this paper suggests a framework that generalize the understanding of horticultural sub – sector post-harvest losses. It also identifies some intervention points along the supply chain which if employed will be vital for reducing losses, improve nutritional aspects and enhancing food availability for domestic as well as for export. Yet, this is important given the recent macro

and sectoral – policies for most developing countries that emphasize on building a strong agriculture sector that is competitive at both domestically and at international level. It is also a means for more researches in the area given very few studies done and documented especially in developing countries so far.

Keywords: Post harvest losses, Horticultural crops, Sub Saharan Africa

PAPER

1. Introduction

Quantitative and qualitative losses of agricultural products are the main concerns in all stages of the post-harvest chain including; harvesting, handling, storage, processing, packaging, transportation and marketing until the crops are delivered to the final consumers all over the world. However, in developed countries losses in post harvest chain are generally small during processing, handling and storage because of availability and affordability of advanced technology, strictness in management of variables that may lead into losses and the high- quality standards set by retailers. (Hodges et al., 2010; Pedreschi et al., 2013). In developing countries post-harvest, losses are higher since most of the countries are characterized by lack or the use of old or poor equipment and lack of skilled managers for assisting in losses reduction in the food sector properly (FAO, 2005; Hodges et al., 2010).

Generally, fruit and vegetable production globally has recently experienced a remarkable increase. Evidence from the literature indicates production to increase at the the rate of 3% output during the previous decade. During 2011, nearly 640 million and more than one (1) billion tons' fruits and vegetables respectively got produced globally (FAOa, 2013). The growth rate noted globally is not unique given that food-in secured and developing countries of sub-Saharan Africa and Southern Asia have also witnessed a substantial increase in growth rate. Evidence from the literature indicates that, fruits and vegetables of developing countries are one of the fastest growing agricultural markets, with production increasing by 3.6% a year for fruits and 5.5% for vegetables over 1980 - 2004 (World Bank, 2008).

Horticulture crops (fruits and vegetables) have a number of economic importance such as creation of employment. On average it is pointed out that, they provide twice the amount of employment per hectare of production compared to cereal crop production (Ali and Abedullah, 2002). Thus, the move from cereal production towards horticulture crops is one of the important contributor to employment opportunities in developing countries (Joshi et al., 2003). They are also vital in improvement of diets by providing micro-nutrients rich diet, thereby impact the health status of the people. Low horticultural food intake as pointed by World Health Organization and cited by FAO (2014), accounts for about sixteen (16) million disability adjusted life and about 1.7 million of death globally.

Despite high production figures and the notable significances of these crops, horticulture post-harvest losses have continued to be a major challenge in developing countries agriculture. Further, the assessment of post – harvest losses of horticultural crops for these countries remain questionable. While some such as Asian Vegetable Research and Development Center (2012) have used the interview to establish their statistics on post-harvest losses, others have even used the historical statistics from other authors to generalize their results (Kasso & Bekele, 2016). Other emerging concern we found interesting was on whether the assessment should be cumulative along the whole horticultural crop value chain or for every stage along the chain. The other challenge rests on whether the assessment of the value chain should group all horticultural crops in an area or deal with a specific crop. These are important concerns that require prompt answers. Lack of quality and necessary data for post-harvest losses assessment in developing countries should also not be underestimated (Bureau of Economics and Business Affairs, US Department of state, 2013).

Thus, this paper contributes a framework for post harvest losses assessment from different literatures, explain the constraints faced by developing countries in developing a consistent methodology and then suggesting a consistent method of assessment of horticulture crops pertaining to our context.

2 Review of Assessment Procedures for Horticulture PHL

Currently, data on postharvest losses have been collected either via experiments, surveys/interviews or via sampling/direct measurements, and entomological storage studies essentially reporting physical and/or economic loss. Occasionally there are evidences provide on qualitative losses (due to damage, disease, pests, appearance changes, etc.).

The results from the studies that we are aware of were not comprehensive as they failed to provide the readers with sufficient information on the methods employed to enable a decision to be made about the reliability of the estimate. Also most studies were limited in scope considering the supply chain of the crops. However, some of the studies have proposed statistical estimations methodology for post harvest losses. Aulakh, and Regmi, (2013) proposed a method (by developing scales of damages in maize cob) in which a complete post harvest loss within a postharvest supply chain is computed by summing up all the food losses for established scales at all stages in the chain using controlled experiment surveys. They identified critical stages of food

supply chain (FSC) i.e. harvesting, storage, processing, packaging and sales and different measurable factors which contribute to these losses such as agro-climatic factors, farm and farmer related factors, credit availability and quality of management related factors. Then to estimate parameters, controlled experimental surveys are done to calculate post harvest losses at each node within a supply chain from harvesting to sales. Finally, a regressions are used establish drivers of losses within the supply chain that will have an impact on loss minimization, different indicators of loss are then often regressed. However, the experience and the literature shows that the method used is limited given that in most cases is confined only in the area under experiment hence difficult to generalize the results.

In 2010, a comprehensive study was done by Indian council of agricultural research "Harvest and Post harvest losses of major crops and livestock produce in India". The study used stratified multistage random sampling procedure to select 25 states in India, 100 districts within selected states and 1500 household farmers in the selected districts for estimating losses in different farm operations and storage. Data were collected through enquiry only. Data collected pertaining to losses during on farm operations (harvesting and other operations prior to storage) included method of operation, equipment's used, quantity handled and quantity lost. Each district selected data were then analyzed separately and the results pooled by assigning appropriate weights at higher levels. For estimating the losses at agro-climatic zone level, weightage was assigned based on the selection of specific crop/ commodity in all the sample districts. Similarly, PHL at the national level were estimated by assigning weightage on the basis of the production of a specific commodity in the agro-climatic zones. The challenge noted in the analysis is that the method used in the analysis is generalized to all crops regardless of the difference in rates of perishability between crops eg. grains versus fruits.

3 Challenges for Developing Countries Post Harvest Losses Assessment for Horticulture Crops

The stream of literature on Post harvest losses assessment studies in developing countries (Humble & Reneby, 2014; Léo et al, 2011) of which Sub – Saharan Africa is inclusive, shows that most of the studies are experimental oriented and therefore do not provide a macro level picture of the problem. Further most of the studies are crop specific and location specific which also limits their generalization. It has also been a problem for the specific nodes within a supply chain that are highly affected. Finally, for producers that are champions of horticultural crop production mostly do not consider changes in texture, color or tests as a loss therefore making them radical to postharvest management.

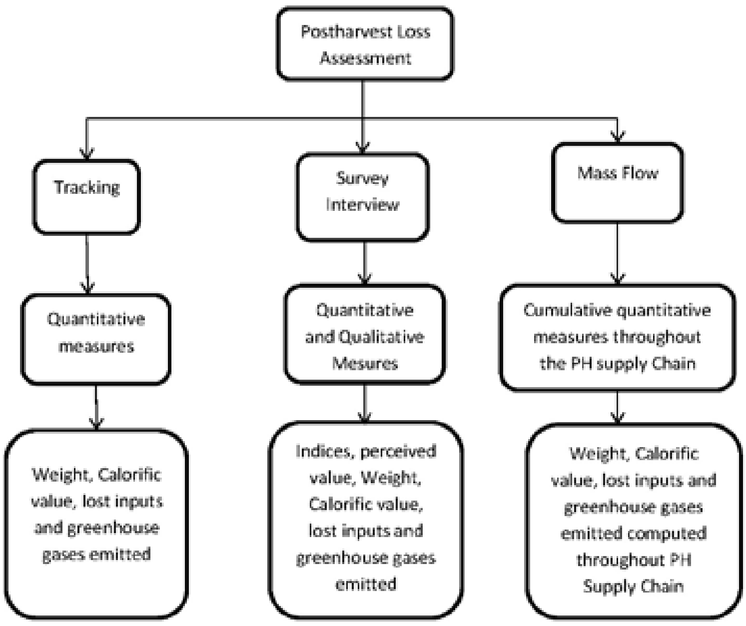
According to FAO (2014), post harvest losses in developing countries are highly pronounced during harvesting, transporting and and storing of horticultural crops creating a challenge throughout the whole supply chain. However, according to Kader, (2003), losses pronounced during processing, packaging, and marketing should not be undermined. Other losses are even a result changes in weather, pests and diseases at production level and physical environment and such as harvesting before time (Aulakh and Regmi, 2013). Losses in developing countries are pointed at texture, color and tastes of the product and it ranges from 15% to 50% (FAO, 2014).

4 Theoretical Approach to post harvest losses assessment

Trienekens (2011) provided a theoretical foundation based on value chain for developing countries such as those of Sub Saharan Africa on postharvest analysis in horticultural crops. The scope of the theoretical foundation provided by Trienekens touches different aspects in the agricultural value chain such as global value chain, supply chain management, new institutional economics and social network theory. In a mean time, this study will not consider all aspects rather it will consider the supply chain management and neglect the aspects. A working supply chain needs to have the value maximized within the chain, costs managed at different stages within the supply chain (Chopra & Meindl, 2010). If this is managed properly the losses will be avoided and output and nutritional aspects improved (Trienekens, 2011). It will also be easy to assess postharvest losses within different nodes within a supply chain which is essentially a major issue in food supply chain.

5 Post harvest Loss Assessment/ Analysis for horticulture crops

Complications in Measuring postharvest losses has been a common phenomenon in both developing and developed countries overtime (Hodges, et al, 2011). Evidences driven from previous studies indicates that commonly used approaches are firstly taking actual measurement for post harvest losses through tracking, secondly the use of questionnaire interview and thirdly the use of flow methods (Aulakh, and Regmi, 2013; Morris and Kamarulzaman, 2014). The developed nations apply approach one and two while developing countries use mostly the second. The third approach is commonly used by Food and Agricultural Organization of United nations based on regional data. The use of all the three approaches has the shortcomings given that it is difficult to practice them under different circumstance. Tracking method is tedious when the study is to be conducted in large area (Kader, 2005). Survey interview is also difficult as it might underestimate or overestimate the results if it is not conducted timely and the flow method is limited especially in developing countries due to data problems throughout the postharvest supply chain (Aulakh, and Regmi, 2013; Morris and Kamarulzaman, 2014). Further, evidence from the literature indicates that most of the studies are confined in a single area therefore generalizing the result is not plausible. The summary of commonly methods for postharvest losses assessment is summarized in the following diagram.



Source: Modified from Morris and Kamarulzaman, (2014).

According to Kader (2005), the context of post harvest losses assessment in fruits and vegetables between developing and developed countries also differs. While the former consider highly the quantitative loss due to food insecurity and nutritional problems noted in these countries the later focuses on qualitative losses due to high income prevailing to majority in these countries (Aulakh, and Regmi, 2013). It then recommends that developing countries assessment should invest on analyzing the quantitative loss. However, due to difference in income between people and between countries in developing countries this argument also remains controversial. Given that there are groups of people with preference on quality horticultural products and the other on quantitative products also resulting from income differences.

The analysis of post harvest losses regardless of the nature of the crops so far have involved post harvest chain level and production level analysis (Kader 2005, Buzby & Hyman 2012). Analyzed losses includes food waste, quantity loss (the amount produced minus the sum of sold and consumed products) and weighted measures, and qualitative losses (money). Commonly statistical methods used in post harvest losses assessment of horticulture crops includes descriptive statistics such means, variance and standard deviations and percentages and some econometric methods such as regressions which are commonly used to determine the drivers of postharvest losses at different nodes depending on the length of integration (Buzby & Hyman 2012; Gao, et al., 2008: Kader, 2005). However, it is important to group crops based on similarities eg. All citrus being grouped together and PHL assessed. For comparisons reasons before other analysis are conducted it vital to compare areas or countries with a common perception of post harvest losses.

6 Results of the Review

After conducting a review to the literature in developing and developed nation on postharvest losses, some few cases are shown that will guide the framework to be proposed by this study.

Table 1 - below provide some few reviewed studies as follows

Sn	Title of the study	Unit of Analysis	Data	Sampling design	Instruments for data collection	Method of analysis	Results
1	PHL and quality deterioration of horticultural crops in Dire Dawa Region, Ethiopia(Kasso & Bekele, 2016)	Farmers Associations, wholesalers, retailers and consumers	Primary	Two stage sampling design	Questionnaire , Key informants and FGDs &Checklist	Purchased/produced and quantity sold in relation to total quantity purchased /produced (Percentage)	PHL ranged from 20% to 50% in between market-ing and consumption
2	An Economic Analysis of Post-Harvest Losses in Vegetables (Onion and Potato) in Karnataka, India(Kumar et al, 2006)	Farmers, wholesalers and retailers)	Primary and Secondary	Multi-stage sampling design has been adopted for the selection of vegetable growing farmers	Time series Data and Questionnaire	Mean averages and percentages	PHL varies at different stages of supply chain in both crops, Onion (2.21 - 59.6) and Potato (1.16 - 56.59)
3	Post Harvest Economic Losses in Peach Production in District Swat, Pakistan (Khan et al, 2008)	Farmers	Primary data	Multi-stage sampling design. Strata of Peach farmers and random	Interview	Frequencies and means	PHL varies based on categories of varieties however the other stages of

Table 1 segue **- below provide some few reviewed studies as follows**

				sampling)			the supply chain was negleted without explanation
4	Post-harvest losses in fruit supply chains – A case study of mango and avocado in Ethiopia (Humble & Reneby, 2014)	Farmers, brokers, wholesalers, retailers and restaurants	Primary Data and Case Studies	expert judgment of local official and Universities in Ethiopia	Interview	Frequencies and means	The largest losses of avocado and mango in the supply chains occur during; harvest, transport and storage.
5	Assessment and management of post harvest losses of fresh mango under small-scale business in Morogoro, Tanzania(Msogoya and Kimaro, 2011)	Mango Fruits	Primary	Completely randomized design	Experiments (1 - 3)	Frequencies and Analysis of Variances	Mango fruit total postharvest losses were 43.8 % with the wholesale market, transport and harvest stages accounting for 30.6 %, 10.6 and 2.6 % of the total losses, respectively
6	FAO's Food Balance Sheet provides data for most food security and consumption analyses across the world (http://faostat.fao.org/site/354/default.aspx)	Different crops	Country level Data	Varies based on National Statistical offices	Varies based on National Statistical offices but mostly questionnaire	Deductions	Varies across countries. However the tool is used for different purpose

Table 1 segue **- below provide some few reviewed studies as follows**

7	Post-Harvest Food Losses Estimation-Development of Consistent Methodology, http://www.fao.org/fileadmin/templates/ess/documents/meetings_and_workshops/GS_SAC_2013/Improving_methods_for_estimating_post_harvest_losses/Final_PHLs_Estimation_6-13-13	harvesting, storage, processing, packaging and sales/agro-climatic factors, farm and farmer related factors, credit availability and quality of management	Developed & Developing countries	Varies based on National Statistical offices	Controlled experimental surveys are done to calculate post harvest losses at each node within a supply chain from harvesting to sales	Regressions are used establish drivers of losses	Econometric models can be used for selected commodities and countries to estimate the losses.

7 Application of Postharvest Harvest Losses Framework

From the literature reviewed, it has been noted that postharvest losses differ between horticultural crops (Morris and Kamarulzaman, 2014). There are variations of losses between technology accessing regions and regions with little or lack of technologies such as cold rooms (Beretta et al, 2013). There are also horizontal integration and vertical integration variations of losses within a supply chain of a crop and finally post harvest losses may vary also vary based on market development for example in a situation where low quality goods are restricted from high income people (Trienekens, 2011). Post harvest losses may also vary based on the season of production especially in developing countries which in most cases depends on rain for production activities.

Given that postharvest losses in developing countries are mostly pronounced from the field to the market stages of the supply chain any study that aims at analyzing the losses should consider the following;

...a) Whether the assessment should analyze losses by grouping all horticultural crops in an area in a single basket or deal with a specific crop, we suggest analysis should be independent due to the existing differences in losses and crops agronomic characteristics, however it is rational in the end to have cumulative results obtained by combining similar crop studies results within a country to avoid statistical biases.

...b) In case of limited resources, it is vital to group crops of similar characteristics e.g. citrus and establish the level of losses in group.

...c) There is also a need to include economic losses specifically at the farm level during the analysis of postharvest losses, given that it has the implication on farmers' decision of whether to grow a particular crop next season or not. Economic losses will also assist in qualitative postharvest losses assessment.

...d) In order to determine the drivers of post harvest losses one should consider demographic, agro ecological difference between areas in a country and between regions, market environment, technologies available and the level of income.

8 Conclusion

Regarding the objective set by this paper, we have attempted to re visit body of knowledge on post harvest loss assessment and establish the gap within the aspects of supply chain of horticultural crops in developing countries set up. The review of literature indicates some deficit on the context, quantitative, qualitative, mass flow and economic assessment of post harvest not only in horticultural crops but also to other crops. It is therefore important that, for any study that aims at assessment of postharvest losses in horticultural crops to analyze crop specific loss and where resources are limited to categorize crops with similar characteristics such as fruits or spices and assess the losses in group throughout the chain from the field to the market. In case of countries' comparison, we recommend a comparison that use a similar definition of postharvest losses. Include number of harvest within a season in the analysis given most horticultural crops are not harvested once and involvement of Economic Assessment - Value. For generalizing the results in large geographical area a focus should be in compiling the results from different locations and generalize the results.

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Measurement Issues and Lessons Learned from Estimating Food Loss at the Retail and Consumer Levels in the USA

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ABSTRACT

In the United States, 31%—or 133 billion pounds—of the 430 billion pounds of the available food supply at the retail and consumer levels in 2010 went uneaten according to the Loss-Adjusted Food Availability (LAFA) data series from the U.S. Department of Agriculture's Economic Research Service (USDA/ERS). The estimated retail value of this food loss was $161.6 billion.ERS has undertaken a series of initiatives to improve the technical and measurement assumptions underlying the LAFA loss estimates, including sponsoring a workshop to inform its data and research planning on food availability and food loss. This paper shares lessons learned from these efforts and provides valuable information for researchers interested in measuring food loss. Key lessons learned include the difficulty of obtaining food loss data from the private sector and measuring the loss of raw commodities embedded in multi-ingredient foods.

Keywords: Food availability, Food Availability Data System (FADS), food waste, Loss-Adjusted Food Availability (LAFA) data series.

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1 Intoduction

The Economic Research Service (ERS) of the U.S. Department of Agriculture (USDA) maintains the Loss-Adjusted Food Availability (LAFA) data series. The primary purpose of this series is to estimate the per capita daily calories and food pattern equivalents (i.e., "servings") for five major food groups (fruit, vegetables, grains, meat, and dairy) plus added sugars and sweeteners and added fats and oils. These estimates represent the food available for consumption as a proxy for actual intake.

ERS also uses the underlying loss assumptions in the LAFA data series to estimate the amount, value, and calories of food loss at the retail and consumer levels in the United States for around 215 commodities(e.g., beef, eggs, fresh apples, canned corn). Here, food loss represents the amount of food, post-farm-gate that is available for human consumption (i.e., does not include animal feed) but is not eaten for any reason. It includes cooking loss and natural shrinkage (e.g., moisture loss); loss from mold, pests, or inadequate climate control; and food waste. Consumer level loss estimates do not include inedible portions. The denominator for retail level food loss is the amount of food availability at the retail level and the denominator for consumer level food loss is the amount of food availability at the consumer level.

ERS estimates that in the United States, 31%—or 133 billion pounds—of the 430 billion pounds of the available food supply at the retail and consumer levels in 2010 went uneaten (Table 1)(Buzby et al., 2014). The food loss had an estimated retail value of $161.6 billion and equaled 141 trillion calories annually, or 1,249 calories per capita per day. One-third of these losses, or 43 billion pounds, were in grocery stores and other retailers, and two-thirds, or almost 90 billion pounds, occurred in homes, restaurants, and other away-from home eating places. Had losses on-farm and between the farm gate and retail level been included, total food loss nationally would have been greater.

Measuring food loss in the United States has recently gained new importance following the September 16, 2015 announcement of a new Food Waste Reduction Goal by USDA and the U.S. Environmental Protection Agency (EPA), which aims to reduce total food waste in the U.S. by 50% by 2030(USDA, 2015). This paper advances knowledge and understanding of the measurement and technical challenges of estimating food loss with a focus on loss at the retail and consumer levels. In recent years, ERS has undertaken a series of initiatives to improve the technical and measurement assumptions underlying the LAFA loss estimates, and in 2014 sponsored a workshop to inform its data and research planning on food availability and food loss (NRC and IOM, 2015). This paper shares lessons learned from these efforts and provides valuable information for researchers interested in measuring food loss and its food waste subcomponent. The LAFA data series is considered preliminary because ERS has initiatives underway to further refine the data series.

Table 1 - Estimated Food Loss in the United States, 2010

Commodity	Food Supply[a]	Retail Level Losses	Losses	Consumer Level Loss		Total	
	Billion Pounds	*Billion Pounds*	*Percent*	*Billion Pounds*	*Percent*	*Billion Pounds*	*Percent*
Grain products	60.4	7.2	12	11.3	19	18.5	31
Fruit	64.3	6.0	9	12.5	19	18.4	29
Vegetables	83.9	7.0	8	18.2	22	25.2	30
Dairy products	83.0	9.3	11	16.2	20	25.4	31
Meat, poultry, and fish	58.4	2.7	5	12.7	22	15.3	26
Eggs	9.8	0.7	7	2.1	21	2.8	28
Tree nuts and peanuts	3.5	0.2	6	0.3	9	0.5	15
Added sugar and sweeteners	40.8	4.5	11	12.3	30	16.7	41
Added fats and oils	26.0	5.4	21	4.5	17	9.9	38
Total	430.0	43.0	10	89.9	21	132.9	31

[a] Food supply at the retail level, which is the foundation for the retail- and consumer-level loss stages in the LAFA data series. Totals may not add due to rounding. Source: Buzby et al.(2014).

2. FOOD AVAILABILITYDATA SYSTEM

The ERS' Food Availability Data System (FADS)is an important and useful resource for assessing the country's ability to provide healthy diets, and for evaluating policy changes and interventions aimed at improving diets (Krebs-Smith in NRC and IOM(2015), p. 61).The core series in the system, the Food Availability (FA) data series is based on supply and use balance sheets, which provide estimates of the supply of around 215 commodities or foods available for consumption in the United States. For a given year and commodity, the supply of that commodity is the sum of production, imports, and beginning stocks (i.e., inventories). From this amount, ERS subtracts out exports, farm and industrial uses, and ending stocks to estimate the amount available for consumption. Per capita estimates for a commodity are calculated by dividing the total annual availability by the U.S. population for that year. The data system relies on annual measures of U.S. agricultural production and stocks at the farm level from the USDA's National Agricultural Statistics Service (NASS) and on estimates of U.S. imports and exports from the U.S. Census Bureau' trade data. The data to estimate farm and industrial (non-food) use, if available, come from a variety of sources depending on the commodity, and include products used on the farm for feed, seed, or industrial uses, such as ethanol or biofuels.

Because the FA data series overstates the amount of food actually eaten by capturing substantial quantities of food lost to human consumption(e.g., spoilage, plate waste) beyond the farm gate in the marketing system, in foodservice outlets and restaurants, and in the home, ERS created the LAFA series, which adjusts the FA data for loss at three levels:

- 1) Primary: Farm gate to retail (e.g., during transport, processing, and wholesaling);
- 2) Retail: Supermarket losses (e.g., dented cans, unpurchased holiday foods, spoilage, and the culling of blemished or misshaped foods);
- 3) Consumer: Losses of food consumed at home and away from home (e.g., in restaurants, fast-food outlets, schools and other institutions). This loss includes cooking loss and uneaten food, such as plate waste from the edible share.[For selected commodities (e.g., produce), the series also removes the non edible share of a food (e.g., apple cores, asparagus stalks) at this stage. Other commodities have inedible portions removed at the primary level (e.g., boneless meat, poultry, and seafood)].

For each LAFA commodity, retail and consumer level food losses are measured by multiplying the per capita quantity of that commodity available for consumption by a loss factor. Per capita loss estimates are multiplied by the U.S. population and summed by food group.

3. LESSONS LEARNED FROM INITIATIVES TO UPDATE ERS'S FOOD LOSS ASSUMPTIONS

ERS's long-run goal is to provide the best estimates of food availability (as a proxy for actual consumption) possible given available resources. A key component of that goal has been to increase the rigor and reliability of the LAFA data series through a series of initiatives to improve the technical and measurement assumptions underlying the LAFA loss estimates. This has been challenging due to resource limitations, the diverse nature of the three types of food loss assumptions in LAFA, and the complexity of the U.S. food system. To date, ERS has completed several initiatives to update the three types of loss assumptions for many of the 200 plus commodities in the LAFA data series. Data from two of the initiatives, which measured losses at the retail and consumer levels, are now used directly in the LAFA data series. Select data from a third initiative, which measured farm-gate to retail losses, are used by ERS commodity analysts in the FADS supply and use balance sheets.

3.1 Losses at the primary level (farm gate to retail)

In 2003, ERS and the University of Minnesota's Food Industry Center (TFIC) compiled revised agricultural conversion factors from the farm gate to the retail level, which described how a farm commodity (e.g., fresh chicken) is transformed into a consumer-ready product (e.g., boneless fresh chicken). Using information from a series of industry interviews, TFIC updated conversion factors for major meats and poultry commodities, and for several fruits and vegetables.In 2007, researchers from Pennsylvania State University and the International Life Sciences Institute (ILSI) built on the TFIC work under a new cooperative agreement with ERS. They reviewed the TFIC estimates, collected data on the remaining commodities not covered by TFIC (e.g., grains, fats, and dairy products), and explored additional areas of concern.

Lessons learned:

- One identified area of concern is how well the FA supply and balance sheets account for the increased amount of some commodities (e.g., chicken) going to pet food use.
- It is very difficult to produce reliable national farm to retail conversion factors or food loss estimates for individual commodities given the size and diversity of the U.S. farm and food processing sector, the wide range of commodities, and diverse growing regions, as well as year-to-year variation in weather (e.g., drought, floods), pest infestation, and farm animal and plant diseases. Some of these may affect the quality of the commodities and hence, ultimately, the post-farm gate shelf life of individual products.
- Even if farmers, processors, and others collected this information, concerns about losing competitive advantage may preclude them from publically releasing the data;
- For some commodities, like baby carrots, production is too concentrated in a small number of firms to report data without disclosing information on individual firms.

3.2 Losses at the retail level

In September 2007, ERS obtained 2005-06 food loss estimate sat the retail level (e.g., from supermarkets) for fresh fruits, vegetables, meat, poultry, and seafood through a competitive grant with the Perishables Group, Inc. (PG). For individual fresh fruits and vegetables, PG compared supplier shipment data with corresponding point-of-sale data (with both types of data aggregated across all stores and retailers in the sample) from stores in supermarket retail chains to identify shrink, which was later used as a proxy for food loss in LAFA. The sample provided estimates for over 600 retail stores from 6 national or regional chains in all 4 U.S. regions (East, South, Central, and West). Supermarket shrink for fresh meat, poultry, and seafood was estimated via interviews with a small sample of retail executives due to a lack of reliable supplier shipment data for these foods. The updated loss estimates were incorporated into LAFA in February 2009 and are documented in Buzby et al.(2009).PG did not have appropriate data to update the retail-level loss assumptions for other LAFA commodities, including added fats and oils, added sugars and sweeteners, dairy products, grain products, and processed fruits and vegetables (e.g., canned, frozen, dried/dehydrated, and juice).

More recently, ERS repeated the study for the same commodities with PG, now known as the Nielsen Perishables Group (NPG), and obtained 2011 and 2012 shrink estimates for the same individual fresh foods(Buzby et al., 2015, Buzby et al., Forthcoming). This study had greater coverage: roughly 2,900 stores from 5 retail chains (one large national and four regional supermarket retailers). These stores were located in 45 states plus the District of Columbia (DC). The same method was used for individual fresh fruits and vegetables (i.e., supplier shipment data was compared with point-of-sale data to estimate shrink). Unlike the previous study, shrink was estimated directly for fresh meat, poultry, and seafood, but only for case-ready, Universal Product Code (UPC)-coded items. Data were not available for random-weight items.For perspective, a National Meat Case Study found that the estimated share of case ready, UPC-coded fresh meat and poultry was 66% of the market in 2010 (SealedAir/BCP/NPB, 2010).

Lessons learned:

- Supermarket shrink for fresh meat, poultry, and seafood is difficult to estimate due to a lack of reliable supplier shipment data. In the United States, a significant share of fresh meat is delivered to grocery stores in carcass portions, which are later butchered in-store into retail-size cuts and sold as random weight;
- Using UPC-coded data alone to estimate shrink for fresh meat, poultry, and seafood is not appropriate due to a lack of data on random weight items, which account for a significant share of total product sales;
- Comparing shipment to point-of-sale data to estimate shrink is not appropriate for many FADS commodities (e.g. flour) that are primarily consumed as multi-ingredient foods (e.g. bread, cookies). As most foods that people eat are mixtures (Moshfegh in NRC and IOM(2015), p. 83), a method that starts with foods as eaten and works backwards (i.e., fork to farm) would require the use of recipes to break down these foods into commodity ingredients to estimate food loss;
- Further retail-level research is needed to:

- estimate shrink for the other commodities in LAFA;
- determine the extent to which shrink captures an unknown amount of theft, accounting errors, and other factors;
- determine if shrink is dependent on the assortment offered for sale, including the variety of products of a particular commodity at different value levels (e.g., lower-, average-, and higher-priced bagged spinach or salad greens) (Buzby et al., 2015)(p. 644); and
- determine if shrink varies by store type (e.g., megastores, convenience stores, supermarkets).

3.3 Losses at the consumer level

Under a grant with ERS, RTI International (henceforth RTI) generated new consumer-level loss factors for the majority of the LAFA commodities (Muth et al., 2011).First, RTI reviewed existing studies on consumer-level food loss and interviewed a small sample of restaurant managers(Muth et al., 2007). Next, they calculated household food loss by comparing household food purchase data (Nielsen Homescan data) with at home dietary intake data from the National Health and Nutrition Examination Survey (NHANES). ERS then analyzed the impact of the proposed RTI loss factors on the LAFA data series(Muth et al., 2011). In August 2012, ERS incorporated most of RTI's „best estimates" of consumer-level food loss (where available) in the LAFA data series.

Lessons Learned:

- Comparing food purchase with intake data is challenging for LAFA commodities typically consumed as multi-ingredient foods (e.g., wheat and rye flour consumed as breads, cookies, rolls, and pasta).
- Sample sizes were too small for some commodities (e.g., rye flour, corn starch, and select fruit juices) to calculate accurate loss factors.
- Methods are needed to estimate food loss for individual foods consumed away from home (i.e., in restaurants, fast-food outlets, and schools).Currently, the LAFA data do not distinguish food loss (or food availability) at home versus away from home. Some food loss is likely greater in away from home settings (e.g., plate waste in restaurants due to larger portion sizes)(Muth et al., 2011).
- Nationally representative data are not available to analyze consumer-level food loss patterns by demographic or regional groups (e.g., level of education; rural vs. urban; age).

4. OTHER MEASUREMENT ISSUES AND CHALLENGES

In 2013, ERS contracted with the National Research Council (NRC) and the Institute of Medicine (IOM) of the National Academies to organize a workshop to advance knowledge and understanding of the technical and measurement issues of the Food Availability data series, the LAFA data series, and the LAFA food loss factors so that the data can be maintained and improved (NRC and IOM, 2015). As a result, a day-and-a-half workshop was held April 8-9, 2014 in Washington DC. Some of the measurement issues and challenges discussed include:

- **FADS relies on continuous, high-quality national, annual data at different points of the farm gate to fork chain**. Most time-series data rely on a steady stream of high-quality, national, and annual data. However, researchers cannot always anticipate, or control, data shortfalls. For example, in 2011, the Census Bureau discontinued select Current Industrial Reports (CIR), which provided FADS data for added fats and oils (except butter), durum flour, and candy and other confectionery products. Therefore, 2010 is the last year that FADS data are available for these commodities. Subsequently, NASS developed the Current Agricultural Industrial Reports (CAIR) data series to collect data on specific manufactured products in key agricultural industries. ERS plans to incorporate the CAIR estimates in FADS.
- **Food loss factors are not refined enough to vary over time (in most cases)**. In LAFA, the food loss factors for individual foods and levels are the same for the entire data series range (i.e., 1970 to the most recent year), with few exceptions. For example, one exception is that beef conversion factors have changed over time to reflect greater trimming of fat when transforming meat from carcass to boneless weight.
- **Food donations are not directly measured**. FADS doesn"t adequately reflect food donations (e.g., at the retail level to food banks and other charitable organizations) or the transfers of unsold food in retail stores to thrift shops for sale at lower prices. Donated food ultimately eaten by people should not be counted as food loss.
- **FADS import and export data do not reflect the growth of multi-ingredient foods**. An increasing share of U.S. food trade is in the form of multi-ingredient or processed foods (e.g., vegetable beef soup). However, trade data in the FADS is mainly commodity-based (e.g., beef). This is an increasingly important issue to address. The Food and Agriculture Organization (FAO) is also confronted with this problem in

their food balance sheet system, which has data for around 185 countries or territories for more than 80 primary commodities plus 10 commodity groups, though not all commodities are produced or consumed in every country (Schmidhuber in NRC and IOM(2015), pgs. 68, 71). Methods need to be developed to account for the commodity portion of multi-ingredient foods in trade data.

- **Various definitions complicate comparisons of studies worldwide and the estimation of new loss factors**. Definitions of food loss and waste differ widely across studies worldwide, complicating the comparison of estimates and the identification of trends across the supply chain, U.S. localities, and internationally(Buzby & Hyman, 2012). Not only are there different definitions of the measured variable (e.g., shrink, food loss, and food waste) but studies may also use different points of reference and different areas of coverage in the analyses (Buzby et al., 2015).

5. CONCLUSION

To date, ERS has updated and explored food loss estimates with an ad hoc approach for various commodities and marketing levels (i.e., primary, retail, and consumer), rather than updating the data simultaneously. The underlying estimates are derived from several sources (e.g., NASS, Census, and the aforementioned food loss initiatives). Currently, probability distributions or other measures of variation are not reported. ERS plans to obtain such measures in future food loss research initiatives. For example, in April 2016, ERS contracted with RTI to update food loss factors for the consumer level.

Moving forward, ERS will have many decisions to make about whether and how to integrate any new loss factors into the LAFA data series (e.g., whether to adopt them for the entire time span of 1970 to the most recent year available). Currently, the FADS data are a valuable resource for assessing the country's ability to provide healthy diets to the population, and for evaluating policy changes and interventions meant to improve nutrition and health. Improved accuracy and precision of the food loss assumptions underlying the LAFA data will improve the data's usefulness to researchers and policymakers. Once further improvements are made, the LAFA data series can be used as an important foundation for analyzing the national „food loss foodprint," such as the amounts of CO_2, water, and energy equivalents embedded in the food lost to human consumption in the United States in a given year. To date, Venkat(2012) has used the LAFA data to analyze the climate change and economic impacts of food waste in the United States. However, other measures of the societal burden of food loss could help target private and public sector actions to address food loss.

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B15

Developing cost-effective statistical methods for measuring post-harvest losses in developing countries

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ABSTRACT

In line with the current policy debate on agriculture and rural development, the improvement of methods for estimating post-harvest losses was identified by FAO member countries as a priority research topic to be included in the Research Programme of the FAO Global Strategy to Improve Agriculture and Rural Statistics (GS). The objective of this research is to develop cost-effective statistical methods for measuring post-harvest losses.

Keywords: post-harvest losses, statistical methods, cost-effective.

PAPER

1. Introduction and background

Historically, loss assessment studies have been associated with loss reduction/prevention programmes. The Seventh Session of the United Nations General Assembly, meeting in 1975, set the goal of 50% reduction of post-harvest losses by 1985.

In 1976, FAO formulated a Special Action Programme that identified three major constraints on post-harvest loss prevention in the developing countries. They were as follow:

1. lack of information about the amplitude of the losses, the nature of the losses, their causes and the most effective techniques for reducing or preventing them;
2. lack of infrastructure for implementing loss prevention measures;
3. lack of investment in food loss prevention.

These events highlighted the need to develop standard and suitable terminology and methodology for the measurement of losses.

The manual "Postharvest grain loss assessment methods. A manual of methods for the evaluation of postharvest losses" was then developed by Kenton L. Harris and Carl J. Lindblad published in 1978.

Some methods and techniques compiled by Harris and Lindblad (quite accurate and detailed) were first reviewed by R. A. Boxall in the period 1980-1986, in an attempt to simplify them.

During that same period, FAO also published a manual "assessment and collection of data on post-harvest food-grain losses", manual intended to serve as a guide to the statistical methodology for assessing and collecting data on post-harvest food-grain losses, using objective measurements coupled with statistical survey sampling techniques.

During the period 1990-2000 researchers improved on the previous methods and kept on more and more using the rapid methods (visual scales, standard chart for instance, described above). J.A.F. Compton and J. Sherington, for instance, devised rapid assessment methods for stored maize cobs where weight losses were due to insect pests. From 2000 onward, additional methodological improvements have been brought about by the APHLIS team project and other researchers by making the rapid methods work with more modern sampling-based field surveys to provide the data necessary for loss estimations.

Most of the time, loss prevention and reduction efforts are undertaken within only part of the post-harvest system. Basically this is done by identifying the most obvious and serious grain loss points in a country's post-harvest food system and concentrate the loss prevention and reduction efforts on those points. Methodologies for measuring post-harvest losses, aim at providing outcomes that allow the determination of priorities for loss prevention and reduction efforts.

Assessments may be made by surveys (traditional or improved), or by experimental design studies (field studies, trials), and more recently by using econometric modelling (special cases of machine learning algorithms).

Because of the need to obtain reliable estimates of loss, FAO and other organizations conducted literature reviews in the seventies to map the extent of available quantitative information on post-harvest losses in cereals. A number of examples of very high estimates of unsubstantiated losses were found, most of it due to the ambiguity of the terminology used by their authors. Quoted figures of the type "39% for grain losses in Sub-Saharan Africa, or 45% for pearl millet losses in Namibia" may not provide an objective view of the real situation. In certain situations, figures provided for certain stages of a stated post-harvest chain have simply been totalled, leading to over-estimates. Boxall, in 1986 gave an illustration along the following example:

Table 1 - How post-harvest losses may be over-estimated (Boxall, 1986)

Chain level	% loss	Weight loss (kg)	Balance (kg)
Start	----	----	1,000.00
Harvesting	15	150.00	850.00
Threshing	10	85.00	765.00
Drying	5	38.25	726.75
Transport	5	36.34	690.41
Storage	10	69.04	621.37
Processing	10	62.14	559.23
	-----	--------	
	55%	440.77	

If it is wrongly assumed that each loss figure is a percentage of the initial weight of product, over-estimation will ensure. In fact, here, each loss figure is a percentage of the amount remaining in the preceding level of the chain. Hence, the total loss 55%, a simple addition of the losses at different levels, is an obvious over-estimate. The proper loss is shown on the weights in the right-most two columns, namely 440.77 kg loss from the potential 1,000 kg or 44.077%.

Over-estimation can also happen during farm level storage loss studies, when grains are being withdrawn at certain intervals during the storage period. In that case it is not enough to record only one loss figure at one point in time during the season and use it as an indication of the overall loss for the year.

2. Types of loss assessment studies

General baseline surveys

These are for preliminary examination of specific problem points and are conducted first to expose the most serious grain loss points. They may or may not be randomized, and may include elements of purposive sampling. Properly conducted, they allow the post-harvest system to be better understood, and the causes of losses to be revealed. At the same time they are conducted, additional relevant available data from other sources like administrative records (rainfall, temperature, etc.) should be collected. These surveys always preceding the main loss assessment survey, should also try to provide initial rough expected values for losses.

Probability sample surveys

They are used for the main loss assessment exercise, with the aim is to obtain statistically reliable quantitative data at different administrative and agro-ecological units (village, regional, national, etc.). Procedures like random sampling (simple, stratified, clustered) with possibly sampling stages, are used. In cases where the primary sampling units differ widely in size, sampling with probability proportional to size can be used. These operations are of course quite expensive and require specially trained personnel. Probability sample surveys (both traditional and modern) are best suited for value chain processes like harvesting, threshing, drying, and processing. They tend to be less suitable for estimating losses during the storage stages of the value chain, where processes of biological degradation occur.

Experimental designs – Field trials

These are also used for loss assessment studies; moreover they can handle loss comparisons between traditional and improved practices. Storage simulation trials can be conducted at research stations with a high degree of control over the conditions of the experiment; alternative post-harvest production practices can be evaluated for their effect on the level of losses, and multivariate analysis is performed using regression models.

Appiah F, Guisse R, and Dartey P.K.A 2009/2010, have used this technique in a study of post-harvest losses of rice from harvesting to milling in Ghana (Ejisu Juabeng District) to provide basic important information regarding the losses.

Multivariate Linear Regression Fitting

Strictly speaking, this is more of an estimation technique than a type of study; data are collected from surveys and administrative records to create a database that is then used to estimate model parameters. At different stages of the food loss value chain, some of the factors causing quantitative and qualitative losses are inter-related. For example at the storage stage, variables like storage structure, moisture content, temperature, relative humidity, insects, mites, rodents, micro-organisms attacks, respiration, and other biological processes (independent variables), all act together at the same place to impact loss variables (dependent variables). Hence, regression equations can easily be fitted to quantify the relationships between dependent and independent variables. The big advantage of doing this is the ability to predict losses in advance so that planners and decision makers can take appropriate measures as early as possible in their decision cycles.

Some of these techniques have been used with some success in studying the factors affecting post-harvest losses in rice and wheat at farm level in India. See H. Basavaraja, S.B. Mahajanashetti and Naveen C. Udagatti. 2007. AbdollahTaherzadeh, Seyed Saeid Hojjat. 2013 also used a regression model in Iran for the study of Post-Harvest Losses of Wheat in North Western Iran, combining post-harvest loss survey data and administrative records data.

3. General Principles of loss assessment studies

In the literature, measurement techniques and methodologies are most often presented at each of the main stages of the food loss chain. For food grain losses to be assessed at any of those stages, statisticians have developed a number of techniques, based on the following principles:

1. definition of the population for which loss estimates are to be produced;
2. construction of a proper sampling frame;
3. design of proper sampling procedure and measurement technique;
4. design of the field work organization, data collection tools, data processing and analysis tools;
5. production and publication of standard errors of the estimated variables to evaluate the quality of the information thus obtained;
6. breakdown the loss estimation at various stages into at least three levels: (a) losses at farm level; (b) losses at the level of the intermediaries (grain merchants, etc.); (c) losses at the level of government agencies (warehouses, etc).

Once the sampling issues have been sorted, the data collection techniques as briefly described below are then implemented, and appropriate estimation procedures devised to obtain average loss figures for the desired level (region, national, etc.).

As a general observation, during harvesting, in-field drying, stacking, transport, threshing, drying and cleaning, all losses caused by biological agents, should be adjusted to a dry-weight basis. Other losses are usually expressed in terms of weight of material at 14-percent moisture content (Boxall R.A. 1986). It has been found (Boxall R.A. 1986), that it was more convenient to work on the basis of the dry weight of grain which can then be simply calculated from the formula:

$$Dry\ wt.of\ grain = wt.of\ grain * \frac{(100 - m.c.of\ grain)}{100}$$

$m.c.$ is moisture content

To also be able to compare with other-loss assessment figures, losses can be expressed as percentages (rather than adjusted weights) with a clear statement of the basis of the presentation (the denominator of the percentage). Losses in harvesting, in-field drying, and stacking operations, are expressed as percentage of yield, with yield defined as obtained yield (maximum quantity of clean grain less the losses being assessed. For threshing and cleaning, losses are expressed as a percentage of the grain input to the operation. It should also be noted that farmers' practices in time of harvesting (and rainfall), duration of in-field drying, and stacking, have a marked effect on the level of losses.

4. Data collection and measurement in loss assessment studies

Building a suitable sampling frame is normally the very first stage when planning a main loss assessment survey. First and ultimate sampling units will vary depending on the level/stage of the post harvest process where losses are being measured. Lists of all these units should be prepared to allow proper selection of sampling units.

At the *harvesting level* of the chain, villages (or their groupings) are commonly the primary sampling units (PSU); holders are the secondary sampling units (SSU), and fields the ultimate (tertiary) sampling units.

PSUs may be clustered prior to sampling. Simple or stratified random sampling may be used to select the holders; for each chosen holder, a simple random sample of subplots within fields can then be selected.

For *threshing, cleaning, drying, transportation, and processing*, villages are PSUs and holders the secondary units.

For these levels, additional sampling stages will be necessary; for instance selecting a random sample of produce (maize cobs, etc.) to be threshed and observed for lost or damaged grain.

For *storage*, villages are PSUs, holders are the SSUs, and the storage units (if there are more than one) within the holding are the ultimate sampling units.

The villages (PSUs) may be selected via simple random sampling, stratified random sampling, or may be sampled with probability proportional to size. FAO has produced a number of useful guidelines and manuals on these procedures, to be consulted by the interested readers.

Grain losses at farm level

Losses during harvesting

Strictly speaking, these are post-production rather than post-harvest losses. In fact, they were not considered by Harris and Lindblad in 1978.

Ideally, this stage of the value chain should benefit from a linkage with an annual production survey that has a crop-cutting component. The crop cutting plot is selected at random within the field before harvesting by the holder. The crop inside a crop-cutting plot (usually 10 meters x 5 meters, or 5 meters x meters depending on the type of crop) is harvested according to the usual farmer practices and the yield is weighted and recorded. After the harvested produce is removed from the plot, all grains shed or missed are then carefully picked up for estimating harvest loss.

If a stratified two-stage random sampling design has been used with village as PSU and holder as SSU, *estimates of production and loss* per hectare can be produced as follows (assessment and collection of data on post-harvest food grain losses, FAO Rome 1980):

p_{ij} is production per hectare for holder j in village i

a_{ij} is the area under the crop for holder j in village i

A_i is the area under the crop for village i

l_{ij} is loss per hectare for holder j in village i

m is the number of sampled holders

n is the number of sampled villages for the given stratum

$$\mathrm{P_i} = \frac{\sum_{j=1}^{j=m} a_{ij} p_{ij}}{\sum_{j=1}^{j=m} a_{ij}}$$ is the estimate of production for village i

$$\mathrm{P} = \frac{\sum_{i=1}^{i=n} A_i P_i}{\sum_{i=1}^{i=n} A_i}$$ is the estimate of production per hectare for the given stratum

$$\mathrm{L_i} = \frac{\sum_{j=1}^{j=m} a_{ij} l_{ij}}{\sum_{j=1}^{j=m} a_{ij}}$$ is the estimate of loss for village i

$$\mathrm{L} = \frac{\sum_{i=1}^{i=n} A_i L_i}{\sum_{i=1}^{i=n} A_i}$$ is the estimate of loss per hectare for the given stratum

Hence the percentage loss in this harvesting stage is given by

$$\mathrm{PCL} = \frac{\mathrm{L}}{\mathrm{P}}$$

Estimates of variances for P and L can easily be derived as well as for their ratio PCL.

Tremendous difficulties are associated with the usage of crop-cutting techniques to assess yields in normal annual agriculture production surveys as conducted in developing countries. Therefore the use of these techniques for loss assessment should be carefully evaluated for the situation at hand. In fact, there is still no best single ideal method for crop-cutting.

Losses during stacking/stooking

In the literature, it has been suggested to measure these losses when the operation is being carried out normally by ensuring the stacks or stooks are built on a plastic sheet or tarpaulin to collect all scattered grains when the bundles are later removed. This approach might be a problem if the labourers perceive the situation as a not 'normal' situation and hence try to handle the bundles (carefully or roughly) differently from the usual situation.

Sometimes, loss of quality may occur for newly harvested grain stacked for threshing during a wet season. Grain may become mould or discoloured, when exposed to humidity for relatively long period. In case of severe deterioration of grain leading to grain rejection as unfit for human consumption, then reduction of quality may be expressed on a quantitative basis. In case the grain is not rejected, some sort of estimate of the reduction in quality can be provided by contrasting the condition of a carefully processed sample of grain from a stack/stook at threshing time with that of a sample drawn at time of stacking/stooking.

If grain remains stacked or stooked for many months, this can be regarded as a means of storage during which losses to rodents, birds, insects and microorganisms may occur. Hence, the standard techniques for estimating losses due to insects during storage can still be applied, though it might be difficult to estimate losses due to birds and rodents. Using the standard technique, grain samples are collected at stacking time and also before threshing; they are then carefully threshed and analysed for insect loss. There was no substantial account in the literature of such technique being used.

Losses during threshing/shelling

Data on grain loss at this stage of the chain will be collected from a sample of produce from the sampled holders.

Losses during threshing may occur following (i) incomplete threshing (grain remains on the straw) or (ii) damage through the grain or (iii) spillage and scattering during the process.

In case of incomplete threshing, random samples of bundles of harvested crops are threshed by farmers' methods, and the grain obtained weighed and recorded. After that the remaining straw is carefully examined for grain which has escaped the threshing process. Hand-winnowing is done next to bring the two samples to the same quality level. Moisture content measurement is conducted for both samples and weights converted to standard moisture content.

Assessing grain damage during threshing is similar to with any other processing stage. Basically, all processing steps leading to the final products are standardized; then grains are threshed by the farmers' methods and by an optimal method which provides the optimal yield of the undamaged grain.

For losses due to scattering and spillage, there is little guidance in the literature on ways to assess these losses. Some researchers suggested using a large sheet to be spread on the threshing floor to capture all possible scattered grains. This however might be difficult to achieve in practice especially is the area to cover is quite big (grains can be scattered several meters from the point of threshing.

In the case of maize shelling, losses may be due to grains remaining on the cob or damage caused to the grain by the shelling method. The technique for assessing the loss of maize on the cob is similar to assessing threshing losses as shown above. Usually the loss is expressed as a percentage of the total weight of grain; some researchers however, have elected to express it as a percentage of the weight of shelled grain.

There might be an interest in examining grain damage caused by the shelling process, possibly to provide an indication of the efficiency of the shelling instead of an estimate of food loss. In that case shelled grain are grouped as a representative sample of a minimum of 200 grains and examined for damage in order to express the number of damaged grains as a percentage. Then a second sample of cobs is hand-striped and a sample of 200 grains observed as previously to constitute a check of shelling damage.

Estimates of average losses for the given stratum can be computed as follows (assessment and collection of data on post-harvest food grain losses, FAO Rome 1980):

P_i is the estimated grain production for village i

p_{ij} is grain production for holder j in village i

x_{ij} is the percentage loss of any kind for holder j in village i

m is the number of sampled holders

n is the number of sampled villages for the given stratum?

$$X_i = \frac{\sum_{j=1}^{j=m} p_{ij} x_{ij}}{\sum_{j=1}^{j=m} p_{ij}}$$ is the estimate of percentage loss of grain for village i

$$X = \frac{\sum_{i=1}^{i=n} P_i X_i}{\sum_{i=1}^{i=n} P_i}$$ is the estimate of percentage loss of grain for the given stratum

Variances and hence standard errors can also be worked for X.

Losses during cleaning/winnowing

Losses occur because part of the edible grain passes into the chaff. For the estimation, a sample of grain in a single batch is taken and the quantity of chaff and grain obtained in the operation are recorded.

Lost grain isolated from a sample of chaff has to be grossed up to give the total quantity. Percentage is calculated on the basis of grain obtained by normal cleaning. In the case where two or more samples were taken, they will be averaged to get the percentage loss in the winnowing process. Stratum and regional levels of percentages are then computed from holder percentage level using the same technique as in threshing/shelling stage

Losses during drying

To estimate losses at this stage, it is required to know the quantity of grain initially spread out for drying, along with its moisture content (reduction in weight resulting from loss of moisture is not counted as loss), and also the quantity of dried grain collected (with its moisture content) by the farmer after drying. Methods for determining moisture content are many and therefore care should be exercised to ensure methods are uniform in any given region.

For estimating losses at this stage, a stratified two-stage random sampling design is assumed. The difference between initial quantity of grain spread out for drying, and the quantity of grain collected after drying is divided by the initial quantity of grain spread out to obtain the percentage loss. For getting the obtained percentage at stratum and regional levels, the formulae used for the threshing/shelling stage apply.

Losses during storage

Storage losses are investigated at different levels of farmer, trade, and government distribution agency. Hence, the losses will be estimated differently. Again, in countries where crop-cutting surveys are being conducted annually, a sample of farmers can easily be obtained from the annual production survey; otherwise, multistage stratified sampling of farmers can be used, as already described. Loss data may be collected at different frequent intervals, depending on the prevailing period and mode of storage.

Loss in weight during storage (due to insects and moulds, rodents, and birds at farm and village level) must always be related to the quantity in store at the time of assessment. A number of methods have been devised for assessing losses during storage; most original methods are found in the manual of methods compiled by Kenton L. Harris and Carl J. Lindblad; these methods were then reviewed by Boxall et al. in the eighties and later on also by Compton A. J. and other researchers (in the nineties) to make them more "rapid"(hence also less reliable); for the purpose of illustration, the original methods (compiled by Kenton L. Harris and Carl J. Lindblad) are quickly reviewed here. The reference section of this report contains the essentials of the other methods; in addition, new methods are also being devised by researchers in other countries around the world.

As reported in the manual of Harris and Lindblad, J.M. Adams and G.G.M. Schulten (1978), suggested three methods of determining losses in grains due to insects, and microorganisms.

Losses due to insects

Determination of the weight of a measured volume of grain: in this **Standard Volume/Weight method (SVM)**, also known as **Volumetric/Bulk density**, dry weight of a standard volume of grain is measured by a standard method at the beginning of the storage period and is compared with the dry weight of the same volume of grain after a certain storage period (depending on farmers practices in the study region - 6 to 9 months – in some African countries). The dry weight of a standard volume of grain depends on moisture content and variety. This is probably the most reliable method of loss determination. A variation of the technique exists when baseline samples cannot be obtained (Boxall R.A.1986). The modified standard volume/weight method uses an artificial baseline prepared by selecting undamaged samples from the grain present in the store at the time of loss determination. The loss is then the difference in weight (expressed as a percentage) between the undamaged and the damaged sample. Moisture content being approximately the same, there is no need for conversion for moisture.

The Count and Weight or Gravimetric method: The count and weight method provides an estimate of loss where a baseline cannot be determined at the beginning of the storage period and requires only minimal equipment. The method, which is applied to a single sample, requires the computation of (a) the proportion by weight of grains damaged by insects, and

(b) the percentage of damaged grains. Damaged and undamaged grains in a sample of 100-1000 grains are counted and weighted. The weight of the sample is compared with the weight it would have registered in the absence of damage. The base equation (FAO. 1985 "Prevention of post-harvest food losses") reads as follows:

$$\% \; weight \; loss = \frac{[UaN - (U + D)] * 100}{UaN}$$

With U = weight of undamaged fraction in sample
N = total number of grains in sample
Ua = average weight of one undamaged kernel
D = weight of damaged fraction in sample

With this formula, the percentage weight loss has to be adjusted to 14-percent mcwb, or moisture content should be stated. Percentage weight loss can also be computed using a formula that does not require the value of the mean weight of undamaged grain. This method has some sources of error, which may give negative weight-loss figures at low infestation levels. Other variations of the formula have been reported as follows: (Harris & Lindblad)

$$\% \text{ weight loss} = \frac{(UNd) - (DNu)}{U(Nd + Nu)} * 100$$

Where U = weight of undamaged grain,
Nu = number of undamaged grains,
D = weight of damaged grains,
Nd = number of damaged grains.

This formula does not require knowing the value of the mean weight of undamaged grain.

There is a variation of this traditional count and weigh method, in case maize grain kernels are destroyed or lost, as opposed to damaged by pests. In those cases, the traditional count and weigh method, grossly underestimates the losses. The modified count and weigh method was proposed by J.A.F. Compton in 1998 for assessing losses due to insect pests in stored maize cobs. In essence, the method is applied by counting the destroyed grains in each cob and applying an adjusted calculation through an 8-step process. After performing the 8 steps, the formula as given by Compton is as follows:

$$\text{Percentage weight loss} = 100 \times \frac{TND(W_d + W_u)W_u + FW(N_d W_u - N_u W_d)}{TND(W_d + W_u)W_u + FW(N_d + N_u)W_u}$$

Where TND = total number of destroyed and missing grains,
FW = the final weight after the 8-step process,
Nd = number damaged grains in subsample,
Wd = weight damaged grains in subsample,
Wu = weight undamaged grains in subsample.

This method is an improvement on the traditional one when maize grain kernels are destroyed or lost during storage.

The Converted Percentage Damage Method relies on the determination of the percentage insect-damaged grain in a sample and its conversion to a weight loss using a predetermined factor; it is a method suitable only for insect damage that provides a useful estimate for quick appraisal of losses. Although the method is liable to the same sources of error as the modified standard volume/weight method and the count and weighs method, it has apparently given good results in practice. Hence, it is recommended to use it rather than guessing when these two earlier mentioned methods cannot be used. Boxall R.A. suggests that once the relationship between percentage damage has been established by laboratory experiment, a conversion factor could be calculated and subsequently used to determine the weight losses in other samples of the same type of grain. Adams and Schulten (1978) recommended that the percentage damage/weight loss relationship be established from the count and weight method. This obviously, is the reason why this method is subject to the same sources of errors as the count and weight method. The conversion factor is calculated from the formula by using the figures from the count and weigh technique:

Most of these techniques that were compiled by Harris and Lindblad involved collecting grain samples from the farmers and sending them to distant laboratories for further analysis and returning them afterwards; this back and forth movement of grain samples created of lot of delays for getting the results of the surveys. Hence the attempt by J.A.F. Compton and other researchers to devise rapid and improved methods, avoiding sending sampling grains to the lab. Instead, they devised visual scales (maize cobs) and standard charts (maize grains) to be used directly in the field during enumeration. Using visual impression, the enumerator is able to match the farmers' sample cobs with various classes of infested cob portrayed in the pictures handed over to them. The percentage weight loss assigned to the picture with corresponding appearance can later be entered as the weight loss for the cob. The enumerator can then sum up the number of cobs assigned to each class; the percentage weight loss for the maize stored in cob form is determined by using the following formula (J.A.F. Compton, A. Sherington 1998).

$$Vissloss = \frac{aN_1 + bN_2 + cN_3 + \dots\dots\dots + nN_i}{N_T}$$

Where
$Vissloss$ = weight loss estimated using the visual scale
a to n = damage coefficients for each class
N_1 to N_i = Number of cobs in each class
N_T = Total number of cobs in sample

In order to estimate the weight loss for maize stored in grain form, the enumerator uses a standard chart. The enumerator randomly selects separate samples of say 100 grains each from the farmers' maize. The enumerator then places the grains in a litre plate to physically count the damaged grain. The process is repeated for the samples and an average number of damaged grains per 100 grains is established. The number of damaged grains is read off against a predetermined regression chart to find the percentage weight loss.

With these new technologies the techniques have become faster and less cumbersome; in addition, they clearly demonstrate, once again that the sampling statistician (who might not know about biological laboratory calibration of experiments), has to work very closely with the biometrician and other food loss specialists to make these techniques successful.

The Thousand Grain Mass Method (TGM) is another method (Boxall 1986) that was advocated as capable of determining insect losses, and which can overcome the problems encountered with both the volumetric and the count and weigh method. It is a technique modified from a standard procedure of determining the weight of one thousand grains and is known as the thousand grain mass method (TGM). The multiple TGM technique, a variation of the TGM has also been proposed to take into account the variations in grain size and the difficulties in obtaining representative samples when using the traditional TGM.

The TGM is the mean grain weight multiplied by 1000, corrected to a dry weight; it is calculated by counting and weighing the number of grains in a sample; to avoid possible sources of error and bias, the sample is not adjusted to a specific weight or number of grains; a reference TGM is determined from a sample of grain collected at the beginning of the storage season and compared with subsequent measurement throughout the season. The weight loss in a sample of grains is given by the formula (Boxall, 1986):

$$\frac{Initial\ TGM - Sample\ TGM}{Initial\ TGM} \times 100$$

Dry weight TGM can be derived from the following formula:

$$M_D = \frac{10m(100 - H)}{N}$$

Where M_D = TGM (dry basis)
m = mass (weight) of grains in the sample
N = number of grains in sample
H = moisture content in sample

However, there was no account in the literature of a practical application of these TGM techniques in loss assessment studies.

Losses due to microorganisms (moulds)

Grains infected by microorganisms will lose weight at a rate which varies according to the grain moisture content, temperature, and the amount of physical damage to the grain. There does not seem to be much work done on the quantification of losses due to moulds at the farm level through the literature. The methods used to assess weight losses caused by insects can be used for assessing losses due to microorganisms. The loss in weight caused by microorganisms in a sample of grain can be calculated by a comparison of the damaged (infected) sample with a baseline (undamaged) sample. As in the case of insect losses assessment, the baseline sample should ideally be collected at the time the grain is stored.

Losses due to vertebrate pests (rodents, birds)

There is a lack of data and appropriate studies and techniques to assess losses due to rodents and birds in the literature. There have been proposals that in order to measure loss of grain cobs or heads caused by rodents, an estimate of percentage of grain removed has to be calculated first; second, undamaged cobs or heads of the same size as the damaged ones should be shelled or threshed and the grain weighed; last, the loss is calculated by multiplying the weight by the percentage of grain removed. It is not clear however, how this method should be used.

It has also been proposed in the literature that losses of threshed grain to rodents can be estimated by comparing weights of grain stored and removed, provided allowance is made for other losses, for example, losses due to insects. This can be really challenging with in farm-level studies because of the difficulty of monitoring all grain movements in and out of farmer store (unless the study is conducted in the experimental way under more controlled conditions).

There is no generally accepted methodology for assessing bird losses after harvest, though losses before harvest are known to be serious. The little guidance that exists revolves around estimating losses in the field. At some other stages of the post-harvest system, one can compare weights of grain entering and leaving the stage (correcting by moisture content) in order to estimate losses caused by birds. However, estimating losses caused by birds during storage still remains a difficult task.

Calculating total storage losses

When performing assessments of total storage losses at the farm level, losses calculated from samples should be related to the quantity of grains originally stored and to the pattern of grain consumption.

When grain is being removed at regular intervals during the storage season, total loss due to insects can be gauged by calculating the loss in each quantity of grain removed by comparing samples of grains collected from the removals with a sample of grains collected at the beginning of the season. Boxall (1986) gives the example as illustrated in the following table.

Table 2 - Relationship between weight loss and grain consumption

	Months during which grain is removed					
	1	2	3	4	5	6
Quantity (volume) of grain removed (%)	10	10	15	15	20	30
Weight loss in sample (%)	1	2	3	5	7	10
Weight loss (as percentage of total stored)	0.1	0.2	0.45	0.75	1.4	3.0
Cumulative weight loss (as percentage of total stored)	0.1	0.3	0.75	1.5	2.9	5.9

Ideally quantities of grain stored put into and removed from store should be weighed. In practice, this might be extremely difficult to achieve. Hence some sort of estimation of grain quantities has to be made.

In some studies, volume occupied by the produce in store was measured and transformed into a standard weight using some predetermined factor and quantities of grain removed calculated by reference to standard baskets. Grain removed was first placed in the basket; with prior knowledge of the dimensions of the basket used, the volume and weight of grain removed could be calculated. In other studies researchers had to rely upon the use of traditional/local volume measures to obtain estimates of quantities of grain stored and removed. Once the proper figures of average quantity of grain stored, aggregate loss of grain during the storage period and its break-down by causes of loss (insects, moulds, etc.) are obtained for the holding, stratum and regional estimates of the same indicators can be obtained using the estimation formulae similar to those derived at the threshing/shelling stage.

Losses during transport

Losses in transport at the farm level may occur in (a) transport from field to the threshing floor; (b) from threshing floor to the storage; and (c) from storage to the market, with different modes of transport being used at different stages. Losses are normally estimated as difference of weights between the quantity loaded and the quantity unloaded. When transport operations might take days, samples will be taken at the loading stage and at the unloading stage, and then examined for change in moisture content and qualitative damage during transit. Based on the percentages obtained, percentage losses for any given stratum/region can be derived using the procedure described in the threshing/shelling stage. Estimating percentage losses at the stratum/regional levels (based on percentages obtained at holding level follows the same procedure as indicated in the threshing/shelling stage.

Losses during processing

Traditional hand processing or mechanical processing is used to process grain through de-husking, milling and grinding of grains. At this stage, grain loss is normally expressed as a reduction in quality of finished product, although there may be some physical loss of grain through spillage. In large-scale, commercial mills, grain is usually processed in a continuous operation; grain can also be processed in small batches (hand pounding for instance), using querns or village custom mills. Loss assessment studies at farm level are mostly concerned with the latter mode of processing. In that case, it should be possible to weigh the grain before processing, and after to obtain a measure of physical loss. In addition, a comparison between the products of the process with that of a sample of grain carefully processed in the laboratory will provide an indication of the loss of quality.

Estimating percentage losses at the stratum/regional levels (based on percentages obtained at holding level follows the same procedure as indicated in the threshing/shelling stage.

Losses during packaging

Losses occurring due to defects in the methods of packaging and handling of grains can also be estimated. Data on different types of packaging could be collected for a selected sample of farmers to study the efficiency of alternative methods of packaging. However, within the context of the post-harvest value chain, the losses at this stage do not seem important.

Estimating percentage losses at the stratum/regional levels (based on percentages obtained at holding level follows the same procedure as indicated in the threshing/shelling stage.

Grain losses at intermediary level

In this category, reference is made to government distribution agencies, mills, marketing cooperatives, wholesale and retail traders. At this level, losses are to be estimated at the stage of transport, storage, processing, packing and distribution. For transport, storage and handling by market handlers, a sample of such handlers is to be selected and the required information collected. In the same way, random sample of mills/processing factories, may be chosen and the data collected. The design used for this stage calls for a two-stage stratified random sampling with the market of some sort as the primary sampling unit, and the intermediary as the secondary sampling unit. Then for each sampled intermediary, different kinds of percentage losses are computed and then grossed-up to stratum/regional levels using the same techniques as in the threshing/shelling stage. In the case of mills and similar units, a single stage sampling design will suffice and the estimation will get even simpler.

Grain losses at Government warehouses

These agencies and other public distribution agencies should maintain detailed administrative records of grains received and dispatched. Food technology specialists working in these agencies are expected to collect samples of grains periodically, and record pertinent information, such as moisture content, insect and pest infestation and other causes of damage. Hence these agencies should therefore have readily available comprehensive data on levels of losses and their causes. A number of these surveys have been conducted in various countries around the world mostly in India for food grains (maize, rice, sorghum, wheat, etc.). APHLIS has been very active in Southern and Eastern Africa regions concentrating on the maize crop. Selection of warehouses may be done by a single stage random sampling if they are many or all of them selected if they are only a few. Estimation of average and percentage loss can be worked out as in the case of mills.

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B15

The FAO approach to food loss concepts and estimation in the context of Sustainable Development Goal 12 Target 3

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ABSTRACT

FAO is undertaking a two-pronged approach to building a dedicated global database on post-harvest/slaughter food losses (up to the retail level), and providing country level support to measure, estimate or impute the pertinent data. Country-specific food loss indices will then be calculated, and geo-aggregated up to a global level index. These indices will measure and monitor progress against one of the two components of Sustainable Development Goal 12 Target 3 (denoted as SDG 12.3).

Keywords: Food Balance Sheets, Food loss estimates, Food production/supply chain, Post-harvest/slaughter losses, SDG target indicators.

PAPER

1. Introduction

Due to the notorious acute lack of reliable data, assessing the magnitude and the economic, food security and environmental impacts of food losses and waste is an extremely challenging task. Nevertheless, basic data and observations clearly point to the large obstacles these two phenomena pose to global sustainable development. Some estimates indicate that the equivalent of some 24 percent of all calories produced for human consumption per year[1] are lost or wasted. Reducing food losses and waste is, therefore, a combined opportunity to mitigate environmental impacts (particularly greenhouse gas emissions), manage resources (energy and water) and better meet the challenge of improving global food security by means of increasing food availability[2] and smallholder incomes. All this is even more evident when considering the ever-increasing stresses on our planet's ecosystems, and the rising world population requiring more and more food.

The recently adopted SDGs[3], reflecting the importance of food loss and waste, have included the specific target 12.3 which aims to halve per capita global food waste and reduce food losses (see the section on the SDG further down). To monitor progress against this target, a country and then global Food Loss Index will be calculated by FAO.

Generally speaking, loss is the result of unintended actions, decisions or situations; while waste results from some elements of a discretionary process. That said, food losses and waste both occur, to different extents, along the whole food production and supply chain[4]. Consequently, it is understood that the labelling of the "loss" and "waste" parts of the food production and supply chain in this paper, while mainly for convenience, does tend to denote where one or the other is more likely to occur, and is in line with the terminology of the indicator of SDG 12.3.

In less advanced food systems, food loss is the largest component and generally occurs along the production chain as a result of wide-ranging managerial and technical limitations in harvesting, storage/cooling, transportation, processing, and infrastructure. By contrast, and mostly in advanced food systems, waste is the largest component and generally occurs along the supply chain as a result of retailer/consumer decisions to discard food that still has value[5].

[1] Global food losses and food waste. FAO (2011).

[2] One counter argument, however, states that the more food is available the lower its price and therefore the more likely it is to be wasted.

[3] September 2015 (http://www.un.org/sustainabledevelopment/development-agenda/).

[4] The production chain in this paper is considered to be from the post-harvest/slaughter stage till, and excluding, the warehouse. While the supply chain is considered to be from, and including, the warehouse, to retail, then to point of consumption and, ultimately, to the consumer.

[5] Global food losses and food waste. FAO (2011)

This paper will focus on FAO's work on food loss data, in the context of SDG 12.3, with emphasis on the model-based estimations within the context of the compilation of the FAO Food Balance Sheets (FBS). The FBS is a framework where the central concept is that the supply of food items in quantities equals its utilization. Within this context, food loss is treated as one of the utilization components, and includes all the losses incurred in all the other FBS utilizations (such as animal feed, industrial uses, the seeding process)[6]. The data aggregated to build the food loss index, to monitor SDG 12.3, are those loss numbers (official or imputed) in the FAO FBS database. Consequently, food waste from retail to consumer (the first component of the SDG 12.3) is beyond the scope of this paper. Furthermore, it should be noted that the term "food loss" in this paper refers to the primary quantities of crop and livestock commodities that can potentially be consumed by humans, either directly or after processing, and not to specific amounts of directly edible processed/derived products.

2. The two-pronged FAO approach to food loss data

Given the lack of reliable and nationally representative data on food loss as well as of an internationally agreed methodology for its measurement, FAO - in its role of custodian of the indicator(s) for measuring country and global progress towards reducing food losses and waste related to SDG 12.3 - is currently undertaking a two-pronged approach:

1) Assist countries in **collecting food loss data** along the production/supply chain (up to and excluding the retail level) by producing guidelines on cost-effective data collection methods and testing them in some pilot countries. This is an endeavour that will ensure global data coverage only in the long-term,

2) Assist countries in **estimating losses** of food-related crop and livestock commodities, within the framework of the Food Balance Sheets (FBS), using a hierarchical linear model, as an interim solution to filling data gaps.

Both „prongs" involve post-harvest/slaughter food commodity quantity loss data (e.g. tonnes of wheat, apples, meat, milk) up to and excluding the retail level of the production/supply chain. Such data contribute to monitoring the second component of the SDG 12.3.

Work related to the first of the two-pronged approach, development of a methodology for food loss measurement in developing countries (based mainly on sample-derived estimations), is being undertaken under the research programme of the **Global Strategy to Improve Agricultural and Rural Statistics** (GS). It will suffice here to mention that measurement of post-harvest food losses proposed by the GS is aimed at identifying the most cost-effective methodological options to measuring losses at different stages of the food production/supply chain (farm, intermediary, and warehouse levels), distinctively for the main food items.

Furthermore, the **Nutrition Division** of FAO (ESN) is conducting case studies in a number of countries to identify critical points along the value chain which have the highest impact on the extent of food losses and to design the appropriate mitigation measures. These food supply chain analyses are an important pre-requisite in deciding the scope and focus of the sample surveys.

Work related to food loss estimation, the second of the two-pronged approach, using a heirarchical linear model, and in the context of the FBS, is being undertaken by the **Statistics Division** of FAO (ESS). As the SDG process is intrinsically country-driven, this work will ultimately involve the countries through direct collaboration.

3. The FAO proposal to modify the SDG 12.3 indicator

Target SDG 12.3 states that "By 2030, *halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses."*

To monitor progress against this target, the current proposed indicator, the Food Loss Index (FLI), only partially achieves this. This index is a quantity-based price-weighted aggregation of any available and reliable country-generated food loss data and, in their absence, of the model-based estimations. It is categorised as a Tier III indicator, meaning that the methodology, mechanisms and baseline involved have yet to be fully developed, tested and adopted.

Moreover, at a closer look, the food waste component of target SDG 12.3 is not covered at all by this indicator. The nature of the target with its two distinctly worded components, waste and loss, implies the identification of two separate indicators. While the two concepts are related and the precise boundaries between them may be blurred, differentiating between the two, however and as mentioned above, is important as they principally occur along different parts of the production/supply chain and are triggered by different dynamics which neccessitate different methodologies for measurement and estimation.

In this context, and for the above reasons, FAO would like to highlight the need to have an additional indicator for the SDG 12.3 that will focus on monitoring the food waste component.

6 http://www.fao.org/docrep/003/X9892E/X9892E00.HTM

Each of these two indicators will measure progress against their respective SDG target component by generating country level indices, and ultimately two global ones. A method of combining the two indicators, if feasible and significant, will be investigated at a later stage.

Furthermore, because these two proposed indicators require the introduction of new data measurement, estimation and collection methods, and potentially the establishment of new statistical programs of work at the country level, the close coordination of the FAO Statistics Division (ESS) with member countries will be essential to the success of this endeavour. National focal points and relevant national agencies charged with measuring progress on food loss and waste will be identified by coordinating with national SDG committees. Coordination and collaboration with other supranational and regional organizations (EU, World Resources Institute, UNEP, etc.) as well as with relevant private institutions will also be essential.

4. Challenges to the measurement or estimation of food loss data:

The challenge to measure or estimate internationally comparable food loss statistics is made all the more acute for the following reasons:

- No internationally endorsed food loss standard concepts and definitions exist. Several imprecise concepts and definitions, that differ in some key aspects (e.g. inclusion or not of non-edible parts; inclusion or not of food items destined to feed), are currently used and promoted by different key organizations. As a result non-comparable data across countries are generated, hindering any effective analysis.
- Current methods for measurement of food losses have not proved effective in generating data. The approaches proposed in these guidelines may be not so cost-effective and therefore are not being implemented by countries.
- Nationally generated reliable food loss statistics are extremely scarce. The proportion of official food loss data in the FAO FBS detailed database (the commodity-specific Supply and Utilization Accounts), over the last 25 years, amounts to only a mere 4% of total, the rest of the data cells (about 200,000) are all estimations. Considering that the FBS is a unique global database of time-series food loss data by country and commodity, the magnitude of the scarcity of reliable data is even more evident.

This lack of data is due to several factors which include the complexity of measurement along different stages of the production/supply chain; different distribution processes along the value chain for different commodities (e.g. pineapples follow a simpler chain than wheat); quality of the infrastructure (such as storage, transportation); the variation of weather/temperature patterns; and lastly, the actual investment (financial and human) that many countries do not appropriately make to measure and collect food loss data.

5. The concept of food loss in FAO agricultural statistics:

The food loss concept that should be reflected in FAO's statistical data[7], and the basis of which it would like to propose for international consideration is:

Food losses are all the crop and livestock human-edible commodity quantities that, directly or indirectly, completely exit the post-harvest/slaughter production/supply chain by being discarded, incinerated or otherwise, and do not re-enter in any other utilization (such as animal feed, industrial use, etc.), up to, and excluding, the retail level. Losses that occur during storage, transportation and processing, also of imported quantities, are therefore all included.

FBS data for food availability and for food losses include the commodity as a whole with its non-edible parts.

Out-graded quantities (not meeting certain specifications in terms of quality and/or appearance) that re-enter the supply chain (as feed or any other utilization) are not considered losses. Pre-harvest and harvest losses are a priori excluded since agricultural production data provided by countries to FAO refer to quantities net of harvest losses. Waste/loss that occurs at the retail level and all along the supply chain till the consumer is also excluded.

Food, in the above concept of "food loss", therefore refers to any substance, whether raw, processed or semi-processed (including drinks), that can be consumed by humans.

6. The Food Balance Sheets (FBS) and the food loss estimation model

The noted food loss data scarcity emphasises the necessity to have a robust statistical model that can generate estimations to fill in the many data gaps, with as much reliability as possible.

[7] As there is no internationally adopted definition of food loss, FAO cannot, therefore, be certain that the few countries that do report data on losses are doing so according to the FAO concept.

This is done in the FAO Statistics Division (ESS) within the framework of the FBS using a newly developed hierarchical linear model.

Very briefly, the FBS is a time-referenced food accounting framework whereby supply equals utilisation (in quantities). Each FBS is composed of numerous commodity-unique supply utilization accounts (SUA) that are balanced and aggregated, in primary equivalents[8], by commodity „tree" groups (e.g. wheat & wheat products). The supply side components are production, imports, and stock withdrawals, while some of the main utilization components are food (available for human consumption), animal feed, quantities destined for seeding, exports - and loss. The loss component does not refer exclusively to the "food" component, but covers all losses related to all the other components along the production/supply chain (such as quantities lost post-harvest on-farm, damaged while held as stock, lost during transport, and so forth). As already stated, very few of these loss data are obtained officially from countries, and so the vast majority has to be imputed. FAO, nevertheless, does request commodity-specific loss data directly from countries in the annual agricultural production questionnaires that are expedited to all countries. Furthrmore, all possible sources of loss data, from official statistical websites to national publications and published studies, are continuously scrutinized.

As highlighted earlier, the FBS framework is the only tool currently available capable of implicitly validating data on food loss. In fact, through the FBS balancing mechanism, the resulting food loss estimates make use of the magnitude and reliability of the data for the other components (such as animal feed, industrial use, etc.)

The **hierarchical linear model** that is presently[9] used, as an interim solution, to estimate data gaps in food loss consists of four levels: the lowest is country-commodity specific estimates, followed by commodity-specific estimates, then food group estimates, and finally by perishable food group estimates.

The coefficients in the model are estimated simultaneously to ensure they are consistent, and the resulting estimations are further validated through the FBS balancing process. To date, preliminary results have been produced but the model will be further refined by referencing case studies, reviewing empirical data, and by the review of national and international experts (such as the IAEG-AG[10]). Furthermore, FAO is poised to provide support and guidance to countries to enable the adaptation of the model to specific national data situations (e.g. by adding variables on quality of infrastructure and climatic conditions) in order to generate national estimates.

7. The food loss index (FLI)

To monitor progress against SDG 12.3, and by using the official and imputed loss data in the FBS database, individual country indices will be calculated which will then be combined using specific weighting to produce regional and global aggregates of the Food Loss Index (FLI). These indices are Laspeyres quantity indices based on the sum of the base period price-weighted[11] quantities of the food loss data. The country index shows the relative level of the aggregate quantity of losses for each year in comparison with a base period.

The choice of prices as weighting factor, is due to the fact that using calories may produce bias by possible over estimates in calorie per capita (kcal/caput) terms, as not all the food quantities involved in these calculations, in the FBS framework and as explained above, are strictly destined for human consumption.

8. FAO country support in the context of SDG 12.3

As the SDG process is intrinsically country-driven, the work carried out by FAO on food loss concept and methodologies of data estimations and index calculations will involve the countries through direct collaboration. A draft country-support programme of work focusing on the loss component of SDG 12.3 (the second of FAO's two-pronged approach) is being finalised, and includes:

- Promoting the FAO concept of food loss and related methodologies, and raising awareness on the links to SDG 12.3 (seminars and information/training material)

[8] Processed foods are derived from their primary/parent commodities with extraction rates that can be calculated. In the FBS methodology these processed quantities are converted back into their primary equivalents using the inverse extraction rates. For example, 10 kg of flour are equivalent to around 13 kg of wheat (with an extraction rate of around 75%)

[9] In the past, two different estimation methods were used/tested with unsatisfactory results. The first one, estimated the losses simply as a ratio of food supply. The second method consisted of an econometric model with the loss ratios in the SUA/FBS, in log scale, as response to time and to crop and country specific factors (regional/individual/commodity groups, percentage of paved roads and GDP). However, results have shown a poor predictive ability of the model highlighting the need for more reliable data and to use more sophisticated estimation techniques.

[10] The Inter-Agency and Expert Group on Food Security, Agricultural and Rural Statiscs.

[11] International commodity prices (ICP)

- Assessing national situations and capacities in food loss measurement (country/regional technical missions)
- Establish/strengthen data reporting and data exchange mechanisms between countries and FAO (e.g. online platform and questionnaire)
- Devising country-tailored food loss data estimation mechanisms and index calculations (in collaboration with the SDG national committee and the national statistical office) to monitor progress against SDG 12.3

9. Conclusions

In its role as custodian of the indicator(s) for measuring progress against SDG 12.3 FAO is undertaking a two-pronged approach comprised of assisting countries in developing techniques for measuring food losses along the production/supply chain; and in estimating missing data within the framework of the FBS.

The nature of the SDG 12.3 with its two distinctly worded components, waste and loss, implies that in reality two separate targets must be reached. For this reason, combining them both into one overall indicator will be problematic. As a solution, FAO is proposing the creation of two separate indicators and monitoring mechanisms distinguishing food loss and food waste. Furthermore, terminology, mechanisms and reporting must be defined and established with urgency to allow countries.

An internationally adopted concept of food loss (and waste) is essential to ensure global comparability and meaningful analysis. The hierarchical linear model that is presently used, as an interim solution, to estimate data gaps in food loss, has shown encouraging results, but is nevertheless being fine-tuned (e.g. inclusion of exogenous variables such as climate and infrastructure).

The resulting estimations are further validated through the FBS balancing process. In fact, the FBS framework is the only tool currently available capable of implicitly validating data on food loss by making use of the magnitude and reliability of the data for the other components (such as animal feed, industrial use, etc.). FAO country support should enable the generation of national food loss data necessary for the calculation of loss indices for monitoring progress against SDG 12.3.

THEMATIC SET

C16 MEASURING FOOD PRICE VOLATILITY AND PRICE TRANSMISSION

Session Organizer
S. Dubey | FAO | Rome | Italy

LIST OF PAPERS

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J. B. Habyarimana | University of Rwanda | Kigali | Rwanda
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Cassava output supply response in Nigeria: A Vector Error Correction Model (VECM) approach
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Did the Fertilizer Cartel Cause the Food Crisis?
H. Gnutzmanna | Faculty of Economics and Management, Leibniz Universität | Hannover | Germany
P. Spiewanowski | Institute of Economics, Polish Academy of Sciences | Warsaw | Poland
DOI: 10.1481/icasVII.2016.c16d

C16

Measuring Food Price Volatility and its Pass-Through Effect on Inflation in Zimbabwe

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ABSTRACT

Volatility of global food prices has been increasing recently as has been empirical efforts trying to sort out their macroeconomic effect on the performance of small open economies. This study sought to measure global food price volatility and to establish its pass through effect on headline inflation in Zimbabwe relying on annual data observed from 1980 through 2007. Using the GARCH techniques to model volatility and a standard backward looking Phillips curve framework that controls for an output gap, the results of the study indicate that global food price volatility did not have any significant contribution on the worrisomeinflation levels suffered in Zimbabwe during the last decade. The result is plausible in light of price control systems in Zimbabwe as well as presence of a fragmented commodity market.

Keywords: Food Price Volatility, Pass through effect, Headline Inflation, GARCH, Zimbabwe

PAPER

1. Introduction

The last 6 years or so witnessed a proliferation of studies seeking to address the implications of volatile commodity prices on macro-performance of small open economies. This proliferation of empirical efforts born soon after the 2008 food price hike partly reflected the supremacy of the global food market in explaining volatility of domestic inflation. An area of interest in this respect has been establishment of the pass through effect; a phenomenon viewed primarily as the proportion of the world global price change that feeds into domestic inflation. From a macroeconomic viewpoint, food price volatility can be inflationary through the trade channel for developing countries that depend on the world food market to feed their populace.

The pass through can be complete or incomplete depending on such factors as an economy's level of global integration, provision of subsidies and so on. It is said to be complete if the entire global price change transmits into the domestic headline inflation and incomplete if part of the change is absorbed along the supply chain. A number of empirical studies (Zoli, 2009, Awokuse and Yang, 2002, Jumah and Kunst, 2007, Blomberg and Harris, 1995, Ferrucci,Jiménez-Rodríguezand Luca Onorante, 2010 and Jalil and Zea, 2011) have been conducted to examine the pass through effect of global food prices on domestic inflation in developing countries and majority of them confirm an incomplete pass through. Despite such an overwhelming board of related literature however, no known country specific study is available for Zimbabwe.

Relative to other countries, Zimbabwe is an eventful economy with respect to macroeconomic experiences. More important is that producers and consumers in Zimbabwe largely interact in fragmented and often disorganised commodity markets; a unique feature which makes a pass through analysis for Zimbabwe capable of producing unique empirical evidence and distinct results.On the other end, the economy of Zimbabwe went through flames of a remarkable hyperinflation in 2008 which exceeded1500 percent amid a concurrent global recession. This unprecedented hyperinflation was characterised by continuous efforts by monetary authorities to revalue the Zimbabwean dollar and this period saw a number of studies attempting to establish precipitating forces of inflation. Less effort in any case was made that time to formally understand the role of global food prices on inflation and this, combined with the presence of a fragmented commodity market makes a study of this sort worth undertaking. Probing the link between suppressed inflation and money demand, Muñoz (2006;4) notes that prices in Zimbabwe appeared to have responded to other factors other than changes in monetary policy but his limited scope and coverage with respect to underlying sources of inflation left open the question of how food price movements might relate to inflation. This analysis attempts to fill this gap by focusing on the role of global food price volatility on inflation in Zimbabwe. It is plausible to think of global food prices as a potential driver of inflation given that the hyperinflationary in Zimbabwe developed at a time when economy was under a dramatic transformation from being a bread basket to a net food importer.

Conventional wisdom posits that countries that largely depend on the global market are vulnerable to external shocks that may translate into increased domestic inflation. Food in Zimbabwe occupied a weight of around 31 percent in the consumer price index in 2001 (Muñoz, 2006) while total food imports accounted for more than 20% of annual GDP. The country's reliance on the global food market is therefore worrisome on account of global price shocks that are turning out to be a recurrent scenario. Being a price- taker with respect to the global market, the pass- through effect caused by changes in global commodity prices might compromise domestic macro-performance and the tremendous inflation growth witnessed in Zimbabwe during the last decade could be evidence of this situation.

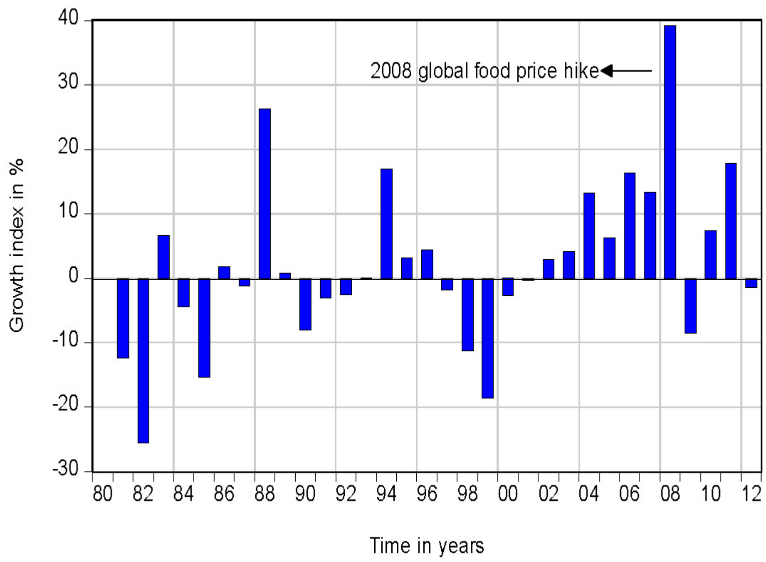
The central objective of this study is therefore to establish how volatility of global food prices explains variation in headline inflation in Zimbabwe. Food and Agricultural Organization (2014) provides a more recent study of this sort but they focus on regional level pass through which suffers from an unrealistic assumption of regional homogeneity with respect to policy responses from global food price movements. It is necessary to perform a country specific study that allows one to isolate the pass through effect on a particular country at the same time acknowledging the heterogeneity in policy responses across individual countries. We additionally do away with a generic approach of focusing on general price movements and focus primarily on the pass through effect of global food price volatility. World agricultural prices have been experiencing an increase in the degree of volatility in the last decade according to FAO (2011) and addressing the inflationary effects of such volatility is essential for designing appropriate monetary policy responses geared at local price stabilization.

The remainder of the study is organised as follows, section 2 provides a brief overview of global food price movements, evolution of inflation in Zimbabwe and review of related literature, section 3 highlights the econometric methods employed, empirical findings are presented and discussed in section 4 while a conclusion of the study and policy implications are provided in section 5.

2.0 Global Food Price Movements (1960-2012)

Figure 1 illustrates annual growth rates of global food prices from 1980 – 2012.

Figure 1 - Annual Growth Rates of Global Food Prices (1980 – 2012)



A visual inspection of Figure 1 shows that growth rates of global food prices have generally been fluctuating from 1980-2012. The 2008 food price hike is probably the highest since 1980. Also, episodes of upward and downward swings are almost equal in terms of frequency during the 32year period. Factors responsible for such worrisome price hikes vary in empirical literature but most accounts link them to the rapid population growth especially in East Asia, a higher demand for oil as well as the limited supply of agricultural commodities emanating from climate change (Shi and Arora 2012).

2.1 Evolution of Inflation in Zimbabwe (1980-2007)

The period 1980-2007 saw a massive economic meltdown. Growth was subdued starting from late 90s before getting worse post the new millennium. The central bank of Zimbabwe made regular attempts to defend the domestic currency to no avail as the Zimbabwe currency continued to lose value in relation to the currencies of its trading partners. Government interventions through price controls to protect consumers ended up in a situation where the remedy was worse than the disease. The interventions in particular created an informal market and the shortage of basic goods in the formal market coupled with excess printing of the Zimbabwean dollar by the Reserve Bank of Zimbabwe gave rise to a demand pull type of inflation. Domestically produced goods became too expensive and local consumers substituted domestic goods for foreign produced goods. Given that food occupied a larger proportion in the Consumer Price Index (CPI) as shown in table 1, the situation created further pressure on inflation.

Table 1 - Composition of the Consumer Price Index in Zimbabwe (2001)

Category	Weight (2001=100)
Food and Non-Alcoholic	31.9335
Alcoholic beverages and tobacco	4.9068
Clothing and Footwear	5.7061
Rent, Fuel and Power	16.2291
Furniture, Household Equipment and Maintenance	15.1069
Health	1.3055
Transport	9.7671
Communication	0.9875
Recreation and culture	5.7452
Education	2.8521
Restaurants and Hotels	1.5177
Miscellaneous goods and services	3.9425
Total	**100**

Source: ZIMSTATS

As illustrated in Table 1, food in Zimbabwe had relatively more weight as compared to other categories in 2001. This means that food contributed largely to movements in headline inflation during the study period. By 2007, annual inflation had grown by more than 1000 percent and the government finally opted to abandon its currency in favour of the multicurrency system.

2.2 Recent Inflation Developments

The multicurrency system adopted in 2009 brought about inflation stability. The current strength of the United States dollar against the Rand has encouraged more importation of food imports and when combined with the prevailing weak domestic aggregate demand, this has created a deflationary environment. Monthly food inflation dropped from -2.9 percent in April to -3 percent in May 2014. Overall inflation measured by the consumer price index has remained negative and is expected to remain so until June 2016 (ZIMSTATS, 2015).

2.3 Related literature

Conventional wisdom posits that headline inflation can be influenced by movements in global food prices and this can take place through the trade channel. In particular, an increase in global food prices implies that food imports become relatively expensive and therefore in the absence of trade restrictions, the price increase of the imported commodities from the world market is likely to get reflected in domestic headline consumer price indices. Empirical literature related to pass through effects is very rich though the results are not directly comparable due to the differences in data, study areas, model specification, estimation techniques and other methodological aspects by distinct authors. Zoli (2009), shortly after the 2007/2008 food price hike employed panel data techniques on 18 countries and observed that global commodity price shocks fed through to domestic headline inflation and the effect was asymmetric. Similar conclusions were reached by Awokuse and Yang (2002) and Jumah and Kunst (2007) despite the use of different methodological approaches.

Contrary to this theoretical prediction and empirical observation by Zoli (2009), Blomberg and Harris (1995) and Furlong and Ingenito (1996) had earlier confirmed no relationship between commodity prices and inflation. Though the authors could not explicitly show why this could be so, a recent empirical study by Ferrucci,Jiménez-Rodríguezand Luca Onorante (2010) provides a number of reasons why commodity price shocks may not necessarily translate into increased headline inflation. Firstly, they argue that external price shocks may not be inflationary if they get absorbed in producers' margins or neutralised by advances in domestic productivity. Secondly, global commodity price shocks may have no noticeable effect on inflation if local consumer pricesare subject to other offsetting internal shocks at any given point in time. Other related studies have been conducted at regional level and found that local food prices respond to regional price shocks, while global price shocks do not have any significant effect on headline inflation (Huh et al, 2012). The latter result could be taken as further evidence in favour Harris (1995) and Furlong and Ingenito's (1996) conclusion confirmed in the mid-90s which is almost two decades from now.

One of the contentious issues surrounding the pass through literature relates to the choice between focusing on headline or core inflation. Jalil and Zea (2011) address this issue when focusing on the pass through effect of global commodity prices, food inflation and core inflation for a set of Latin American countries. Like Huh et al (2012), the author employed a vector error correction model (VECM) which essentially describes the long run pass through and the corresponding short run dynamics. After controlling for other domestic monetary variables such as the exchange rate and the interest rate, the author found a limited pass through effect of global food prices on domestic food prices, a result that is very much in line with that confirmed by Huh et al (2012).Relative to estimation of a system of equations as did Huh et al (2012) and Jalil and Tamayo Zea (2011, a study by FAO (2014) prefers a unidirectional equation error correction model on grounds that the direction of the relationship, from international market prices to consumer prices, is clear given the two extremes of the value-chain to which these prices refer to. We therefore estimate a single reduced form equation for inflation. Despite the gain in asymptotic efficiency of parameters when one use a system of equations particularly VARs or VECMs, our analysis is based on low frequency data which might consume a number of degrees of freedom after controlling for additional lags of the explanatory variables in the system.

3.0 Methodology

3.1 Modeling Food Price Volatility

Volatility of global food prices is modelled here using the Generalised Auto-Regressive Conditional Heteroscedasticity (GARCH (1, 1)) model. GARCH models essentially characterize the conditional distribution of e_t by imposing serial dependence on the conditional variance of the innovations. Specifically, the variance model imposed by GARCH, conditional on the past, is given by;

$$var_{t-1}(y_t) = E_{t-1}(\varepsilon_t^2) = \sigma_t^2 \ldots\ldots\ldots\ldots\ldots.1$$

Where;

$$\sigma_t^2 = k + \sum_{i=1}^{p} G_I\,\sigma_{t-1}^2 + \sum_{j=1}^{q} A_j\,\varepsilon_{t-j}^2 \ldots\ldots\ldots\ldots\ldots\ldots 2$$

From equation 1 and 2, σ_t^2 is the forecast of the next periods variance given the past sequence of variance forecasts, σ_{t-1}^2 and past realisations of the variance of itself, ε_{t-j}^2. Equation 2 is referred to as a GARCH (p, q) model thus if $p = q = 0$, then the variance process will simply collapse to a white noise with variance . Volatility of global food prices will be confirmed here by presence of autoregressive conditional heteroscedasticity effects after estimation of a GARCH (1, 1) model by the maximum likelihood technique.

3. 2 The Pass-Through Effect on Inflation

The generated volatility series of global food prices is then inserted in the backward-looking Phillips curve specification similar to the one used by Gelos and Ustyugova (2012) and Christensson (2009) to appreciate its pass through effect. The model takes the following form.

$$\pi_t^{headline} = \gamma + \sum_{i=1}^{n} \delta_i\,\pi_{t-i}^{headline} + \sum_{i=0}^{m} \beta_i\,Output\ gap_{t-i} + \sum_{i=0}^{p} \theta_i\,Food\_price\_vol_{t-i} + \varepsilon_t$$

Since the model contains a lagged term of the dependent variable as one of the explanatory variables, the full pass through effect will be determined by;

$$\frac{\sum_{i=0}^{p} \theta_i}{1 - \sum_{i=1}^{n} \delta_i}$$

Where $\pi_t^{headline}$ denotes headline inflation at time period t, y, δ and θ represent unknown model parameters to be estimated. We consider an ARDL (1, 1, 1) model in order to establish whether or not volatility of local food prices could be prelude to headline inflation. The output gap is defined as the difference between actual output from potential output. During the study period, Zimbabwe suffered attendant short-term price rigidities and other demand shocks that could have partially altered the level of domestic output resulting in an increased gap and corresponding inflation. Output gap has been generally measured using the Hodrick and Prescott Filter method which essentially generates a smoothed series where deviations of actual output from this smoothed series are termed output gap. Despite its simplicity, this approach suffers from the weakness of having virtually no economic logic regarding the sources of growth. We therefore resort to the use of a production function which unlike the Hodrick and Prescott filter method takes into account economic forces of growth particularly factor accumulation and total factor productivity (Heytens and Zebregs, 2003). We do so by regressing[1] real GDP on labour and capital stock and define output gap as the disequilibrium residuals. Data on inflation and global food prices is obtained from the UNCTAD while real GDP, labour and capital stock is drawn from Penn World Tables 8.0. The study stretches from 1980 to 2008 and this period allows us to capture Zimbabwe's transition from being a breadbasket to a net food importer.

[1]The model is estimated using the Stock and Watson dynamic ordinary least squares technique (DOLS) which controls for endogeneity through inclusion of leads and lags of the first differenced endogenous variables. We use 1 lag and 1 lead based on the Schwarz Information Criteria.

3.0 Empirical Findings

A first step in our inquiry was computation of food price volatility using a GARCH (1, 1) model. Basing on information from the autocorrelation functions and the partial autocorrelation function, the residuals from the mean equation could be best described as an ARMA (1, 1) process. Due to failure of the normality assumption to hold, the GARCH model was estimated with a t-distribution to capture excess kurtosis. The estimated GARCH (1, 1) model was diagnosed of ARCH effects and their presence confirmed that global food prices were volatile during the study period. On the other hand, the sum of the ARCH and GARCH term in the variance equation were close to one signalling an inefficient global food market where unexpected shocks could remain persistent for quite a long period of time. This observation could perhaps justify why the upward swings in global food prices have turned out to be more of a recurrent scenario. With respect to output gap, another variable which we control for in the headline inflation model, we observed that for most parts of the time period between 1980 and 2008, actual output was way below the potential output signalling a negative output gap. Figure 2 which revealed the output gap is not presented here for brevity sake but can be made available upon request. A positive output gap was observed in the early and late 80s and late 90s respectively. Thepotential output series did recognise the economic slowdown suffered in Zimbabwe post 2000. The generated output gap was then inserted in the standard backward Phillips curve specification along with our food price volatility indicator to appreciate how they relate to headline inflation in Zimbabwe. The results are presented in Table 1.

Table 1 - Pass Through Effect of Global Food Price Volatility on Headline Inflation

Variable	Coefficient	Standard error	t-statistic
δ_i	0.413	0.451	0.915
β_i	1.472	1.528	0.963
θ_i	0.914	1.424	0.641
$\frac{\sum_{i=0}^{p} \theta_i}{1 - \sum_{i=1}^{n} \delta_i}$	0.59		
Ramsey RESET	0.219		
DW statistic	1.421		
ARCH test	0.045		
Serial LM test	0.294		

The full pass through is found to be 0.59 indicating that about 5.9 percent can be passed on to headline inflation in Zimbabwe following a 10 percent increase in global food price volatility during the study period. Surprising is that the coefficient is not significantly different from zero suggesting that volatility of global food prices is not significantly transmitted to headline inflation in Zimbabwe. This could be a reflection of massive government interventions particularly price controls that characterised the economy of Zimbabwe during the study period especially post the new millennium. The government of Zimbabwe regularly intervened in the market by setting maximum permissible prices, a situation which led to an establishment of a black market in the informal economy. Such price controls by the government of Zimbabwe forced local producers to absorb all external price shocks, a situationwhich could explain why in this study shocks in global food prices are not translated into headline inflation in Zimbabwe. A second possibility could be presence of a disorganised and fragmented commodity markets. This means that the increase in domestic headline inflation in the formal economy might cause consumers to divert their consumption towards goods offered in fragmented markets where prices are in most cases lower than those from the formal market. In any case, the results are consistent with those obtained by Blomberg and Harris (1995) and Furlong and Ingenito (1996). At regional level, Huh et al (2012) also found that global price shocks do not have any significant effect on headline inflation.

Conclusion

World agricultural prices have been experiencing an increase in the degree of volatility in the last decade, a situation which has ignited concern among researchers when it comes to their effects on the performance of small open economies. This study focused on the pass through effect of global food price volatility on headline inflation in Zimbabwe using annual time series data stretching from 1980-2007. The results of the study indicate that movements in global food prices have not had any noticeable effect on headline inflation. The same is true for the output gap. Policymakers in Zimbabwe should therefore not be wary of global food prices as their volatility is not significantly passed through to domestic headline inflation. The study can be extended by looking at asymmetric effects to establish whether or not upward or downward swings in food prices have uniform effects on headline inflation.

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Modeling Spatial Price Volatility and Transmission: A Spatial Panel VAR Model for Cereal Price Across East African Community

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ABSTRACT

This paper adopts and explains the application of Panel Vector Autoregressive (PVAR) and Spatial Panel Vector Autoregressive (SPVAR) models to econometrically analyze food price volatility and transmission across countries members of East African Community (EAC). Results revealed that it takes time for spatial effects to influence the price happening at markets and results suggests that price volatility and transmission are more predictable in prices with spatial effects than in those without spatial effects. Impulse response functions show that a one unit shock in one cereal market create persistent and positive cereal price variations in that market and in the other markets. Variance decomposition results show that in terms of 100% variations caused by a one unit shock in the price of cereals at one market create strong variations that, in short and long-run, are reverberated in the price of cereals in the other markets. Two policy implications may flow from this paper: on one hand, policy makers should take measures to stabilize food prices across the EAC in order to ensure food access in the region; on the other hand, trade policies should be formulated considering the gains of trading with the near-neighboring markets in order to avoid delayed spatial effects on price volatility and transmission. The last, is explained by the fact that when a market j is not a neighbor of market i the delayed spatial effects depends on the number of neighboring markets between markets j and market i and on the price prevailing on those markets.

Keywords: Cereals, price volatility and transmission, PVAR and SPVAR, EAC.

PAPER

1. Introduction

Food price volatility is one of the most pressing problems to ensure food security in EAC. Food price volatility in EAC results from four main factors. First, the population growth in EAC is high which has a medium and long term effects on food demand in EAC. Second, EAC as other parts of the world experiences climate change, hence the accumulated effects of impact born from and/or caused by climate variability, result in crop yield and production instability. Third, the link between global food price volatility and agricultural production. From the combined effects of population and climate variability, EAC partner states became more reliant to one each other and to the world market especially in terms of cereals demand. Fourth, the food price volatility as result of spatial effects. Geographical location can determine food price volatility and transmission across the EAC because variations in the distance between a costal country i and non coastal country j or between country i neighbor/far from country j determines the cost of transport between those two countries i and j.

Therefore, this study tries to explore cereals price volatility and transmission among five countries of six member states of EAC (Burundi, Kenya, Rwanda, Uganda and Tanzania) and South Sudan is not included in the current analysis. These countries were chosen based on three dimensions. First, they are in the same community which has implement different agricultural policies to increase cereals productivity and with a common import tariff. Second, they are linked by two commercial corridors (the northern and central corridors) that can facilitate easy market integration in EAC and intra-imports of cereals. Third, they are different in terms of surface, population density and location which may define differences in the level of cereals production and demand across EAC member states and then trade level with the world market determined by the factor that coastal countries (Kenya, Tanzania) have easy access to world market than non-coast countries (Burundi, Rwanda and Uganda).

Given these three dimensions, this study aims to answer the following three main questions: i) Does the volatility in the market price of cereals occurs at the same degree in those five countries? ii) Is there any interrelationship between domestic markets price volatility and transmission in those countries? And iii) If there is any price transmission, what is the speed of cereal price adjustment from price variations caused by a one unit shock in one market to cereal price short-run and long-run equilibrium in other markets and in that market its self?

2. Methodology and data

The literature, James (1998), Michael and Daniel (2005), Michael and Daniel (2007), Jan (2009), Shuai (2012), Fabio and Matteo (2013), has shown the increasing use of PVAR and SPVAR models in measuring volatility and transmission in financial time series. This paper adopts and explains the application of PVAR and SPVAR models with multiple commodities to econometrically analyze food price volatility and transmission across countries members of EAC. The application of Panel VAR model with multiple commodities allows us to combine food commodities and countries to estimate price volatility and transmission. The PVAR and SPVAR models adopted in this paper are panel in the price of commodities at each market (in

this paper we consider each country member of EAC as a market) "Pc_{it}" where P stands for price and c stand for country/market and {Pc_{it}: Price of i^{th} commodity at time t in country/market c}.

Hence the PVAR model of lag 2 can be specified as:

$$Pc_{it}= V+ \beta_1 Pc_{it-1}+\beta_2 Pc_{it-2} +u_{it}(1)$$

where i represents different prices of cereal commodities (wheat, rice, maize, and sorghum); V is the vector of cereal price effect at each market (*Pb = cereal price at Burundi market, Pk = cereal price at Kenya market, Pr = cereal price at Rwanda market, Pu = cereal price at Uganda market, and Pt = cereal price at Tanzania market*); β_1 and β_2 are the coefficients of variables (*Pb, Pk, Pr, Pu and Pt*) in lag(1) and lag(2) and u_{it} is the vector of error terms.

The SPVAR of lags 2 can be specified as:

$$Pc_{it}= V + \beta_1 S_1 Pc_{it-1}+ \beta_2 S_1 Pc_{it-2} + u_{it} \text{ and } u_{it} =S_2 e_{it} \qquad (2)$$

where S_1 and S_2 are fixed matrix of spatial weights. In this SPVAR model, only the neighbors have dynamic repercussion on market c within one period while the rest is assumed to have negligible effects. SPVAR structure implies that a shock originating in market c can be transmitted after one period to market k if market k is a neighbor of market c. However, if market k is not a neighbor of market c, delayed effects are longer and will depends on how many markets are between market k and market c.

All the original data used in this paper are available and calculated from online database of the FAO that publishes data on the price of agricultural commodities. We consider to use the annual average of the producer price of four cereal commodities at five markets. We choose the sample period covering 1991 to 2014. For incomplete series like Uganda series, the price were sourced from other different sources and extrapolation and interpolation techniques were used to estimate the price of incomplete series. For the purpose of analysis, the price of each i cereal commodity is expressed in USD per Kg. A part from the actual price of cereals used in this paper, this paper acknowledge the effect of spatial distribution of markets across EAC on price volatility and transmission, here to capture the spatial effects we estimate the new prices at each market with spatial effects Pc^*_{it} (See Annex 1: Extended methodology).

3. Empirical findings and discussion

3.1. Unit root test

In order to infer the degree of integration and stationary properties of the respective variables and uncover if there are possibilities for undertaking panel co-integration tests, we rely on Pesaran (CIPS, 2007) test. Results in Table 1 reject the null hypothesis that all series are I(1) at 5% and 10% (without and with trend) in prices without spatial effects and at 1% and 5% (without and with trend) level of significance in prices with spatial effect. Therefore, cereal price at all the five markets are I(0). The precondition to test for cointegration is that all of the series must be integrated of order 1 "I(1)". However, as our data are integrated of order Zero "I(0)" we proceed with VAR and there is no evidence of testing for co-integration and then proceed with VECM. As we are using panel data, in this paper we estimate a panel VAR model and a Spatial Panel VAR both of lags(2) in the next section of this paper.

Table 1 - Pesaran (2007) Panel Unit Root test (CIPS)

	Without spatial effect		With spatial effect	
Variable	Without trend	With trend	Without trend	With trend
Pb	-2.339 (0.010)	-1.337 (0.091)	-3.490 (0.000)	-2.538 (0.008)
Pk	-3.558 (0.000)	-2.366 (0.009)	-3.248 (0.001)	-2.093 (0.018)
Pr	-3.373 (0.000)	-2.267 (0.012)	-2.533 (0.006)	-1.996 (0.023)
Pu	-3.197 (0.000)	-2.304 (0.011)	-3.289 (0.001)	-2.492 (0.006)
Pt	-2.796 (0.000)	-1.718 (0.043)	-3.807 (0.000)	-2.710 (0.003)

3.2. PVAR and SPVAR models estimation

We estimate PVAR and SPVAR using a least squares dummy variable estimator. The estimator fits a multivariate panel regression of each dependent variable on lags of itself and on lags of all the other dependent variables. The analysis of the PVAR and SPVAR models can be divided into three parts. First, PVAR and SPVAR by least squares dummy variable estimator method estimate model coefficients to explain the relationship among variables. Second, they estimate impulse response functions to draw the figures of dynamic shock responses, from which we can observe the dynamic changes of each variable under different shocks. Finally, they estimate result of variance decompositions for each variable, to evaluate the contributions of different stochastic shocks on the variables in the PVAR and SPVAR systems.

On one hand, when spatial effects are not taken into account, PVAR results in Table 2can be summarized under five headings:

- When Burundi cereal market is taken as dependent variable, a one unit shock at Burundi market one time back and Uganda market two time back increase the current cereal price at Burundi market to some degree (0.898 and 1.214) while a one unit shock at Kenya market two time back decreases the current cereal price in Burundi (-0.55).

- When Kenya cereal market is taken as dependent variable, a one unit shock at Kenya market one time back increases the current cereal price in Kenya at some degree (0.731).

- When Rwanda cereal market is taken as dependent variable, a one unit shock at Burundi market two time back decreases the current cereal price in Rwanda (-0.653).

- When Uganda cereal market is taken as dependent variable, a one unit shock in Burundi market two time back decreases the current cereal price in Uganda(-0.461).

- When Tanzania cereal market is taken as dependent variable, a one unit shock at Rwanda market one time back decreases current cereal price in Tanzania (-0.293).

On the other hand, when spatial effects are taken into account, results in Table 2can be summarized under four headings

- When Burundi cereal market is taken as dependent variable, a one unit shock in at Burundi market two time back increases the current cereal price in Burundi (0.785).

- When Kenya cereal market is taken as dependent variable, a one unit shock at Kenya market two time back increase the current cereal price in Kenya (2.681) while a one unit shock at Rwanda market and Uganda market decreases the current cereal price in Kenya to some degree respectively of -2.424 and 2.340.

- When Rwanda cereal market is taken as dependent variable, a one unit shock in cereal price at Kenya, Tanzania and Burundi markets two time back increase the current cereal price in Rwanda (2.89, 1.67 and 0.55), while a one unit shock at Uganda and Rwanda markets two time back decrease the current cereal price in Rwanda (-2.606 and -2.545).

- When Tanzania cereal market is taken as dependent variable, a one unit shock at Burundi and Tanzania markets two time back increase the current cereal price in Tanzania (0.715 and 1.650) while a one unit shock at Uganda and Rwanda markets two time back decrease the current cereal price in Tanzania (-2.281 and -2.608).

Table 2 - Estimation results of PVAR and SPVAR

	Independent variable	Pb		Pk		Pr		Pu		Pt	
		Coef.	P>t	Coef.	P>t	Coef.	P>t	Coef.	P>t	Coef.	P>t
Without Spatial Effect	l1_Pb	0.898	0.003	0.082	0.754	0.049	0.906	0.260	0.244	0.369	0.150
	l1_Pk	0.361	0.278	0.731	0.015	-0.232	0.616	0.218	0.381	0.445	0.122
	l1_Pr	-0.026	0.892	-0.054	0.752	0.077	0.775	-0.069	0.634	0.265	0.113
	l1_Pu	-0.559	0.458	0.038	0.955	1.713	0.106	0.555	0.327	-0.696	0.285
	l1_Pt	0.062	0.698	0.183	0.200	0.114	0.609	0.023	0.847	0.335	0.017
	l2_Pb	-0.437	0.119	-0.276	0.267	-0.653	0.096	-0.461	0.030	-0.393	0.104
	l2_Pk	-0.553	0.074	-0.201	0.463	-0.266	0.535	-0.372	0.109	-0.426	0.109
	l2_Pr	-0.188	0.295	-0.119	0.453	0.386	0.124	-0.040	0.765	-0.293	0.059
	l2_Pu	1.214	0.093	0.812	0.205	-0.083	0.934	0.860	0.112	0.966	0.120
	l2_Pt	0.042	0.808	-0.165	0.285	-0.238	0.324	-0.097	0.457	0.066	0.656
	cons	0.090	0.004	0.010	0.703	0.080	0.061	0.053	0.021	0.088	0.001
With Spatial Effect	l1_Pb	0.130	0.769	-0.467	0.139	-0.569	0.072	-0.437	0.227	-0.576	0.085
	l1_Pk	0.599	0.776	-0.770	0.607	-1.485	0.323	0.369	0.830	0.228	0.885
	l1_Pr	-0.056	0.975	1.170	0.361	2.002	0.120	0.145	0.921	0.483	0.721
	l1_Pu	-0.364	0.849	1.221	0.371	1.499	0.273	0.589	0.707	0.325	0.821
	l1_Pt	0.910	0.482	-0.303	0.742	-0.634	0.491	0.473	0.654	0.645	0.507
	l2_Pb	0.785	0.071	0.465	0.131	0.554	0.074	0.577	0.104	0.715	0.030
	l2_Pk	1.930	0.334	2.681	0.061	2.888	0.044	2.012	0.218	2.315	0.125
	l2_Pr	-2.430	0.159	-2.424	0.049	-2.545	0.039	-2.325	0.100	-2.608	0.046
	l2_Pu	-1.899	0.297	-2.340	0.073	-2.606	0.047	-1.895	0.204	-2.281	0.098
	l2_Pt	1.148	0.366	1.524	0.093	1.672	0.066	1.337	0.199	1.650	0.086
	cons	0.084	0.008	0.071	0.002	0.077	0.001	0.059	0.021	0.058	0.014

When results without spatial effects are compared with results that account spatial effects, it is clear to say that the level of two time back to predict variations in the current cereal price across countries member of EAC increases and the number of markets influencing the variations in the current price of cereal at any given market also increases. The typical examples can be taken at Kenya, Rwanda and Tanzania markets. This can be summarized under two headings:

- Results show that it takes time for spatial effects to influence the current price happening at markets (most significant effects are those from two time back from the current price).

- Results also demonstrates that the effects of price variations in one market to the price variations in the other market are high with spatial effects than those estimated without spatial effects. This suggests that price volatility and transmission are more predictable in prices with spatial effects than in those without spatial effects.

3.3. Impulse Response Functions

In order to assess the two-way cereal price effects among Burundi, Kenya, Rwanda, Uganda and Tanzania cereal markets, we compute impulse-response functions of the PVAR and SPVAR models. The usefulness of Impulse Response Functions is to describe the reaction of one variable to innovations in another variable of the system, while holding all other shocks equal to zero. In Annex 3, we present impulse-response functions plots, response being absorbed during 30 periods ahead and their results can be summarized as follows:

In cereal price without spatial effects,

- A one unit shock at Burundi market causes positive and measurable cereal price variations in all other four markets which effects may die out in long-run.

- A one unit shock at Kenya market causes positive and measurable cereal price variations in all other four market which effects may not die out in the long-run and remain positive.

- A one unit shock at Rwanda causes positive and measurable variations cereal price variations in all other four market which effects may die out in the long-run and remain positive.

- A one unit shock at Uganda market causes positive and measurable cereal variations in all other markets which variations effects may die out in the long-run.

- A one unit shock at Tanzania market causes negative and measurable cereal price variations in all other markets which variations effects may die out in the long-run.

In cereal price with spatial effects:

- A one unit shock at Burundi market causes positive and considerable cereal price variations in all other four markets which effects may not die out in the long-run and remain positive.

- A one unit shock at Kenya market causes positive and considerable cereal price variations in all other four markets which variations effects may totally die out in the long-run.

■ A one unit shock at Rwanda market causes positive but not considerable cereal price variations in all other four markets which effects may quickly and totally die out in short-run.

■ A one unit shock at Uganda market causes positive and considerable cereal price variations in all other four markets which effects may not die out in long-run and remain positive.

■ A one unit shock at Tanzania market causes positive and considerable cereal price variations in all other four markets which effects may not die out in long-run and remain positive.

Impulse response functions show that a one unit shock in one cereal market create persistence and positive variations in cereal price at that market its self and at the other markets. The only exceptions were observed when Tanzania is taken as impulse in only cereal prices without spatial effect and when Rwanda cereal market is taken as impulse in only cereal prices with spatial effects.

3.4. Variance Decompositions

Based on the impulse response function above, we can evaluate the relative importance of different structural shocks to endogenous variables by measuring the contributions of shocks on the variance changes of variables. Table 7 reports variance decompositions derived from the orthogonalized impulse-response coefficient matrices. The variance decompositions display the proportion of movements in the dependent variables that are due to their own shocks versus shocks to the other variables, which is done by determining how much of an s-step ahead forecast error variance of mean squared error (MSE) for each variable is explained by innovations to each explanatory variable (we report S until 30). From Table 3, we can highlight five following points:

■ A shock in cereal price in Burundi has the biggest impact on the variations of cereal price in Burundi in both short-run and long-run with a gradual declining trend. With spatial effect, a shock in Burundi, Kenya and Uganda has the biggest impact on the variations of cereal price in Burundi when compared to a shock in other markets.

■ A shock in cereal price in Kenya and Uganda has the biggest impact on the variations of cereal price in Kenya in both short-run and long-run. With spatial effect, a shock in Kenya and Rwanda has the biggest impact on the variations of cereal price in Kenya compared to a shock in other markets.

■ A shock in cereal price in Rwanda and Tanzania has the biggest impact on the variations of cereal price in Rwanda in both short-run and long-run. With spatial effect, a shock in Rwanda and Tanzania has the biggest impact on the variations of cereal price in Rwanda when compared to a shock in other markets.

■ A shock in cereal price in Rwanda, Uganda, Kenya, Tanzania, and Burundi has the biggest impact on the variations of cereal price in Uganda in both short-run and long-run. With spatial effect, a shock in Uganda, Tanzania, Kenya, Burundi and Rwanda has the biggest impact on the variations of cereal price in Uganda both in short-run and long-run.

■ A shock in cereal price in Tanzania has the biggest impact on the variations of cereal price in Tanzania in both short-run and long-run. With spatial effect, a shock in Uganda, Tanzania, Kenya, Burundi and Rwanda has the biggest impact on the variations of cereal price in Tanzania both in short-run and long-run.

Table 3 - Variance decomposition

		Without Spatial Effect					With Spatial effect				
		Pb	Pk	Pr	Pu	Pt	Pb	Pk	Pr	Pu	Pt
Pb	10	0.466	0.012	0.007	0.504	0.010	0.033	0.025	0.006	0.111	0.825
Pk	10	0.047	0.263	0.002	0.681	0.009	0.028	0.136	0.006	0.144	0.686
Pr	10	0.035	0.075	0.062	0.806	0.023	0.024	0.240	0.083	0.097	0.557
Pu	10	0.071	0.108	0.011	0.800	0.010	0.025	0.053	0.004	0.182	0.736
Pt	10	0.063	0.072	0.030	0.611	0.223	0.019	0.088	0.015	0.175	0.702
Pb	20	0.402	0.021	0.006	0.561	0.010	0.022	0.013	0.003	0.113	0.848
Pk	20	0.039	0.172	0.007	0.768	0.015	0.019	0.076	0.004	0.136	0.764
Pr	20	0.024	0.072	0.051	0.824	0.029	0.018	0.145	0.048	0.111	0.679
Pu	20	0.049	0.094	0.015	0.824	0.017	0.017	0.030	0.002	0.153	0.797
Pt	20	0.054	0.074	0.026	0.675	0.171	0.014	0.050	0.008	0.151	0.776
Pb	30	0.371	0.025	0.007	0.585	0.012	0.019	0.010	0.002	0.114	0.855
Pk	30	0.033	0.147	0.011	0.790	0.019	0.017	0.056	0.003	0.132	0.793
Pr	30	0.021	0.071	0.048	0.829	0.032	0.016	0.111	0.036	0.113	0.724
Pu	30	0.041	0.089	0.018	0.831	0.021	0.015	0.022	0.002	0.144	0.817
Pt	30	0.048	0.074	0.026	0.701	0.151	0.013	0.037	0.006	0.142	0.801

In terms of 100% variations along 30 steps ahead from the current price caused by a one unit of shock in the price of cereals at each market, results can be summarized under five headings:

- From a one unit shock at Burundi market, strong variations are reverberated in the price of cereals in Burundi and Uganda in the price without spatial effects, while with spatial effects strong variations are reverberated in the price of cereals in Tanzania.

- From a one unit shock at Kenya market, strong variations are reverberated in the price of cereals in Uganda and somehow in Kenya in prices without spatial effects, while with spatial effects strong variations are reverberated in the price of cereals in Tanzania.

- From a one unit shock at Rwanda, strong variations are reverberated in the price of cereals in Uganda in prices without spatial effects, while with spatial effects strong variations are reverberated in the price of cereals in Tanzania and somehow in Kenya.

- From a one unit shock at Uganda, strong variations are reverberated in the price of cereals in Uganda in the price without spatial effects, while with spatial effects strong variations are reverberated in the price of cereals in Tanzania.

- From a one unit shock at Tanzania, strong variations are reverberated in the price of cereals in Uganda in the price without spatial effects, while with spatial effects strong variations are reverberated in the price of cereals in Tanzania its self.

4. Conclusion

This paper adopts and explains the application of Panel Vector Autoregressive (PVAR) and Spatial Panel Vector Autoregressive (SPVAR) models to econometrically analyze food price volatility and transmission across countries members of East African Community (EAC). The main results of this paper suggest that it takes time for spatial effects to influence the current cereals price happening at markets. This paper uncovered that cereal price volatility and transmission across EAC are more predictable in prices with spatial effects than in those without spatial effects. Furthermore, the results of this paper demonstrate that a one unit shocks in one cereal market across EAC create persistence and positive cereal price variations in that market and in the other markets. Moreover, this paper shows that price variations caused by a one unit shock in the price of cereals at one market create strong variations that, in short and long-run, are reverberated in the price of cereals in the other markets across EAC.

It is very important for policy makers to recognize the relationship among different prices of cereals across different countries, because they provide us with new thoughts into food security analysis. Therefore, two policy implications may flow from this paper. On one hand, since there is a short-run and long-run relationship among cereals prices across EAC, agricultural policies should focus on ensuring crop yield stability and enhancing regional food distribution system in order to stabilize food prices across the EAC in particular and ensure and improve regional food access in general. On the other hand, as the main results of this paper show that spatial distribution of markets highly contributes to cereal price volatility and transmission across the region, trade policies should be formulated considering the gains of trading with the nearneighboring markets. This last may be taken into consideration in order to avoid delayed spatial effects on price volatility and transmission from which when a market *k* is not a neighbor of market *c* the delayed spatial effects depends on the number of neighboring markets between market *k* and market *c* and the price prevailing on those markets.

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Annex 1: Extended Methodology

a. Hausman's (1978) test to choose between fixed and random effects model

Hausman's (1978) specification test compares an estimator $\ddot{\theta}_1$ that is known to be consistent with an estimator $\hat{\theta}_2$ that is efficient under the assumption being tested. The null hypothesis is that the

estimator is indeed an efficient (and consistent) estimator of the true parameters. If this is the case, there should be no systematic difference between the two estimators. The Hausman statistic is distributed as chi-square and is calculated as $H = (\beta_c - \beta_e)'(V_c - V_e)^{-1}(\beta_c - \beta_e)$. Where β_c is the coefficient vector from the consistent estimator, β_e is the coefficient vector from the efficient estimator, V_c is the covariance matrix of the consistent estimator and V_e is the covariance matrix of the efficient estimator. When the difference in the variance matrices is not positive definite, a Moore–Penrose generalized inverse is used.

b. Panel cross-section dependence tests

To test for cross-sectional independence in balanced panels,

$$H_0: \hat{\rho}_{ij} = \hat{\rho}_{ji} = cor\,(u_{it}, u_{jt}) = 0 \text{ for } i \neq j \text{ and } H_1: \hat{\rho}_{ij} = \hat{\rho}_{ji} \neq 0 \text{ for } i \neq j. \quad \text{(A1)}$$

Pesaran's (2004) CD test rely on the following formula

$$CD = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij}\right) \text{and } \hat{\rho}_{ij} = \hat{\rho}_{ji} = \frac{\sum_{t=1}^{T}\hat{u}_{it}\hat{u}_{jt}}{(\sum_{t=1}^{T}\hat{u}_{it}^2)^{1/2}(\sum_{t=1}^{T}\hat{u}_{jt}^2)^{1/2}}. \quad \text{(A2)}$$

Where $\hat{\rho}_{ij}$ is the sample estimate of the pairwise correlation of the residuals and $\hat{u}_{it}$ is the estimate of u_{it} (panel residuals). Under the null hypothesis, u_{it} is assumed to be independent and identically distributed *(i.i.d.)* over periods and across cross-sectional units. Under the alternative, u_{it} may be correlated across cross sections, but the assumption of no serial correlation remains. The number of possible pairings (u_{it}, u_{jt}) rises with N. The *CD* formula shows that under the null hypothesis of no cross-sectional dependence $CD \xrightarrow{d} N(0, 1)$ for $N \rightarrow \infty$ and T sufficiently large.

Friedman (1937) proposed a nonparametric test based on Spearman's rank correlation coefficient. The coefficient can be thought of as the regular product-moment correlation coefficient, that is, in terms of proportion of variability accounted for, except that Spearman's rank correlation coefficient is computed from ranks. In particular, if we define $\{r_{i,1},\ldots,r_{i,T}\}$ to be the ranks of $\{u_{i,1},\ldots,u_{i,T}\}$ such that the average rank is $(T + 1/2)$, Spearman's rank correlation coefficient is given by $r_{ij} = r_{ji}$ and Friedman's statistic which is based on the average Spearman's correlation is given R_{ave}. Hence

$$r_{ij} = r_{ji} = \frac{\sum_{t=1}^{T}\{r_{i,t}-(T+\frac{1}{2})\}\{r_{j,t}-(T+\frac{1}{2})\}}{\sum_{1=1}^{T}\{r_{i,t}-(T+\frac{1}{2})\}} \text{and } R_{ave} = \frac{2}{N(N-1)}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{r}_{ij}. \quad \text{(A3)}$$

where $\hat{r}_{ij}$ is the sample estimate of the rank correlation coefficient of the residuals. Large values of Rave indicate the presence of nonzero cross-sectional correlations. Friedman showed that $FR = (T - 1)\{(N - 1) Rave + 1\}$ is asymptotically χ^2 distributed with $T - 1$ degrees of freedom, for fixed T as N gets large.

c. Unit root test

Pesaran's (2007) cross-sectionally augmented unit root tests are designed for cases where cross-sectional dependence is due to a single factor. Pesaran (2007) suggests a cross-sectionally augmented Dickey-Fuller (CADF) test where the standard DF regressions are augmented with cross-sectional averages of lagged levels and first differences of the individual series. He also considers a cross-sectional augmented IPS (CIPS) test, which is a simple average of the individual CADF-tests. Null for CIPS tests series is I(1) and CIPS test assumes cross-section dependence is in form of a single unobserved common factor.

d. PVAR model of lag 2

We can set the panel VAR model of lag two by writing (1) in matrix form as:

$$\begin{pmatrix} Pb_{it} \\ Pk_{it} \\ Pr_{it} \\ Pu_{it} \\ Pt_{it} \end{pmatrix} = \begin{pmatrix} V_{bj} \\ V_{kj} \\ V_{rj} \\ V_{uj} \\ V_{tj} \end{pmatrix} + \begin{pmatrix} \theta_{11i1} & \theta_{12i1} & \theta_{13i1} & \theta_{14i1} & \theta_{15i1} \\ \theta_{21i1} & \theta_{22i1} & \theta_{23i1} & \theta_{24i1} & \theta_{25i1} \\ \theta_{31i1} & \theta_{32i1} & \theta_{33i1} & \theta_{34i1} & \theta_{35i1} \\ \theta_{41i1} & \theta_{42i1} & \theta_{43i1} & \theta_{44i1} & \theta_{45i1} \\ \theta_{51i1} & \theta_{52i1} & \theta_{53i1} & \theta_{54i1} & \theta_{55i1} \end{pmatrix} \begin{pmatrix} Pb_{it-1} \\ Pk_{it-1} \\ Pr_{it-1} \\ Pu_{it-1} \\ Pt_{it-1} \end{pmatrix} + \begin{pmatrix} \theta_{11i2} & \theta_{12i2} & \theta_{13i2} & \theta_{14i2} & \theta_{15i2} \\ \theta_{21i2} & \theta_{22i2} & \theta_{23i2} & \theta_{24i2} & \theta_{25i2} \\ \theta_{31i2} & \theta_{32i2} & \theta_{33i2} & \theta_{34i2} & \theta_{35i2} \\ \theta_{41i2} & \theta_{42i2} & \theta_{43i2} & \theta_{44i2} & \theta_{45i2} \\ \theta_{51i2} & \theta_{52i2} & \theta_{53i2} & \theta_{54i2} & \theta_{55i2} \end{pmatrix} \begin{pmatrix} Pb_{it-2} \\ Pk_{it-2} \\ Pr_{it-2} \\ Pu_{it-2} \\ Pt_{it-2} \end{pmatrix} + \begin{pmatrix} \mu_{1it} \\ \mu_{2it} \\ \mu_{3it} \\ \mu_{4it} \\ \mu_{5it} \end{pmatrix} \quad (A4)$$

where i represents different prices of cereal commodities (wheat, rice, maize, and sorghum); v is the vector of cereal commodity effect at each market; θ are the coefficient matrices of variables (Pb, Pk, Pr, Pu and Pt) in lag(1) and lag(2).

e. The SPVAR model of lags 2

In matrix form, first, we start by estimating the W matrix reflecting first order rook's contiguity relations for the five markets which is a symmetric matrix. As we are dealing with the price of cereal commodities at five markets in EAC (Burundi, Kenya, Rwanda, Uganda, and Tanzania), W is a square matrix of 5X5 dimensions that record neighborhoods among the markets. From the first row: the neighboring markets to Burundi market are Rwanda and Tanzania. From the second row: the neighboring markets to Kenya market are Uganda and Tanzania. From the third row: the neighboring markets to Rwanda market are Burundi, Uganda and Tanzania. From the fourth row: the neighboring markets to Uganda market are Kenya, Rwanda and Tanzania. From the third row: the neighboring markets to Rwanda market are Burundi, Uganda and Tanzania. From the fifth row: the neighboring markets to Tanzania market are Burundi, Kenya, Rwanda and Uganda. Second, we transform W matrix in the way of having row-sums of unity to get a standardized first-order contiguity matrix noted as C. And then we combine C and Pc_{it} a vector column matrix to have new prices Pc^*_{it} with spatial effects. And for simplicity, the new price for i commodity at t time at each market is the arithmetic mean of the price of that i commodity at t time of neighboring markets:

$$W = \begin{pmatrix} 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 1 & 1 \\ 1 & 0 & 0 & 1 & 1 \\ 0 & 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 1 & 0 \end{pmatrix} and C \begin{pmatrix} 0 & 0 & 1/2 & 0 & 1/2 \\ 0 & 0 & 0 & 1/2 & 1/2 \\ 1/3 & 0 & 0 & 1/3 & 1/3 \\ 0 & 1/3 & 1/3 & 0 & 1/3 \\ 1/4 & 1/4 & 1/4 & 1/4 & 0 \end{pmatrix} \qquad (A4)$$

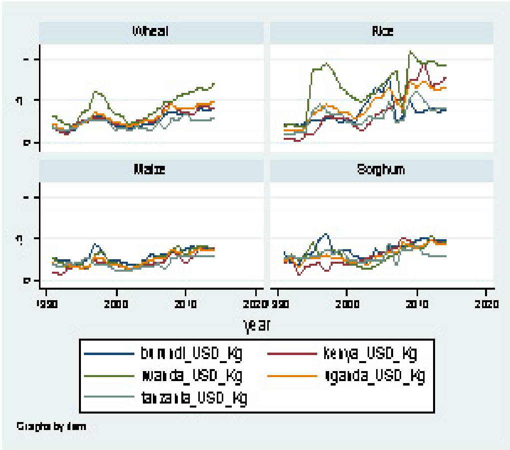
$$\begin{pmatrix} Pb^*_{it} \\ Pk^*_{it} \\ Pr^*_{it} \\ Pu^*_{it} \\ Pt^*_{it} \end{pmatrix} = \begin{pmatrix} 0 & 0 & 1/2 & 0 & 1/2 \\ 0 & 0 & 0 & 1/2 & 1/2 \\ 1/3 & 0 & 0 & 1/3 & 1/3 \\ 0 & 1/3 & 1/3 & 0 & 1/3 \\ 1/4 & 1/4 & 1/4 & 1/4 & 0 \end{pmatrix} \begin{pmatrix} Pb_{it} \\ Pk_{it} \\ Pr_{it} \\ Pu_{it} \\ Pt_{it} \end{pmatrix} = \begin{pmatrix} 0.5Pr_{it} + 0.5Pt_{it} \\ 0.5Pu_{it} + 0.5Pt_{it} \\ 1/3Pb_{it} + 1/3Pu_{it} + 1/3Pt_{it} \\ 1/3Pk_{it} + 1/3Pr_{it} + 1/3Pt_{it} \\ 1/4Pb_{it} + 1/4Pk_{it} + 1/4Pr_{it} + 1/4Pu_{it} \end{pmatrix} \qquad (A5)$$

After then, we write (2) in matrix form as follows:

$$\begin{pmatrix} Pb^*_{it} \\ Pk^*_{it} \\ Pr^*_{it} \\ Pu^*_{it} \\ Pt^*_{it} \end{pmatrix} = \begin{pmatrix} V_{1j} \\ V_{2j} \\ V_{3j} \\ V_{4j} \\ V_{5j} \end{pmatrix} + \begin{pmatrix} \rho_{11i1} & \rho_{12i1} & \rho_{13i1} & \rho_{14i1} & \rho_{15i1} \\ \rho_{21i1} & \rho_{22i1} & \rho_{23i1} & \rho_{24i1} & \rho_{25i1} \\ \rho_{31i1} & \rho_{32i1} & \rho_{33i1} & \rho_{34i1} & \rho_{35i1} \\ \rho_{41i1} & \rho_{42i1} & \rho_{43i1} & \rho_{44i1} & \rho_{45i1} \\ \rho_{51i1} & \rho_{52i1} & \rho_{53i1} & \rho_{54i1} & \rho_{55i1} \end{pmatrix} \begin{pmatrix} Pb^*_{it-1} \\ Pk^*_{it-1} \\ Pr^*_{it-1} \\ Pu^*_{it-1} \\ Pt^*_{it-1} \end{pmatrix} + \begin{pmatrix} \rho_{11i2} & \rho_{12i2} & \rho_{13i2} & \rho_{14i2} & \rho_{15i2} \\ \rho_{21i2} & \rho_{22i2} & \rho_{23i2} & \rho_{24i2} & \rho_{25i2} \\ \rho_{31i2} & \rho_{32i2} & \rho_{33i2} & \rho_{34i2} & \rho_{35i2} \\ \rho_{41i2} & \rho_{42i2} & \rho_{43i2} & \rho_{44i2} & \rho_{45i2} \\ \rho_{51i2} & \rho_{52i2} & \rho_{53i2} & \rho_{54i2} & \rho_{55i2} \end{pmatrix} \begin{pmatrix} Pb^*_{it-2} \\ Pk^*_{it-2} \\ Pr^*_{it-2} \\ Pu^*_{it-2} \\ Pt^*_{it-2} \end{pmatrix} + \begin{pmatrix} \varepsilon^*_{it} \\ \varepsilon^*_{it} \\ \varepsilon^*_{it} \\ \varepsilon^*_{it} \\ \varepsilon^*_{it} \end{pmatrix} \quad (A6)$$

where i represents different prices of cereal commodities (wheat, rice, maize, and sorghum); v i the vector of cereal commodity effect at each market; ρ are the coefficient matrices of variables (*Pb*, *Pk*, *Pr*, *Pu* and *Pt*) with spatial effect in lag(1) and lag(2).

Annex 2: Price trends by commodity and market



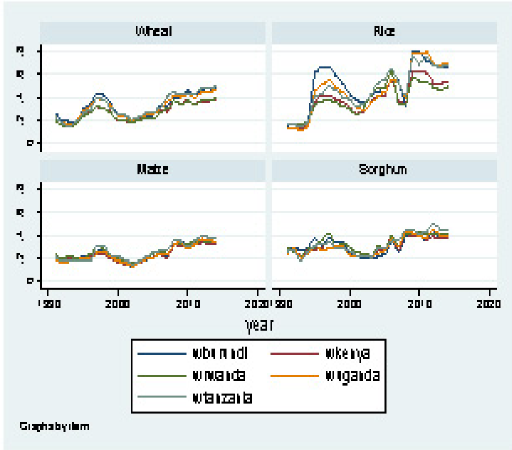


Figure 1: *Actual cereal prices* **Figure 2:** *Price with spatial effects*

Annex 3: Impulse responcse functions

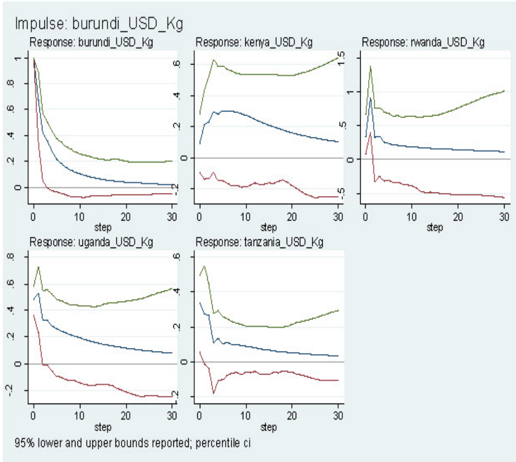


Figure 3: *Without spatial effects*

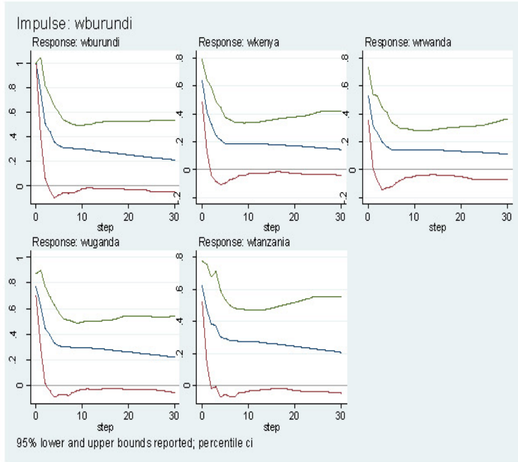


Figure 4: *With spatial effects*

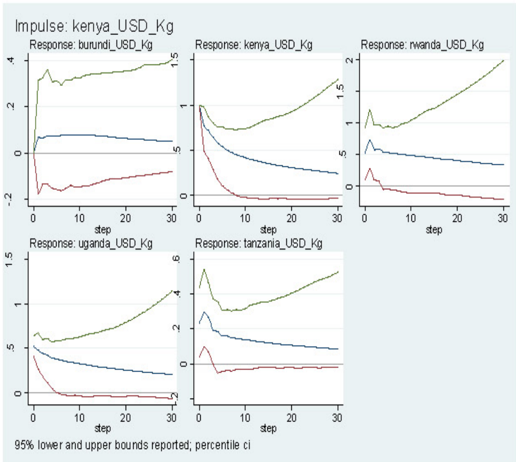


Figure 5: *Without spatial effects*

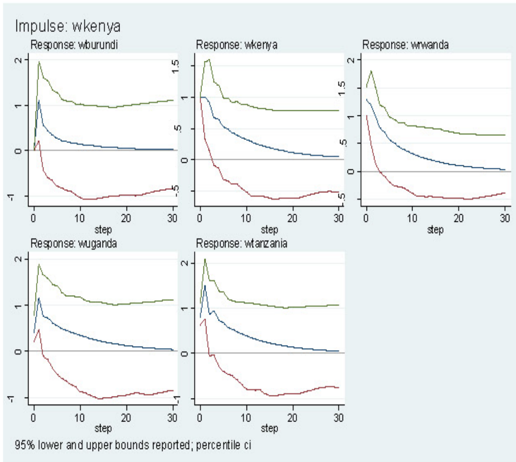


Figure 6: *With spatial effects*

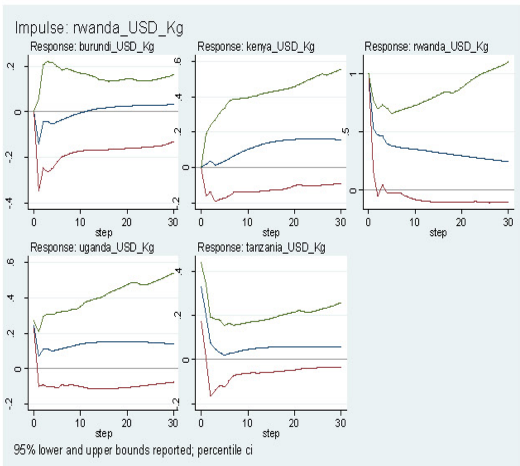


Figure 7: *Without spatial effects*

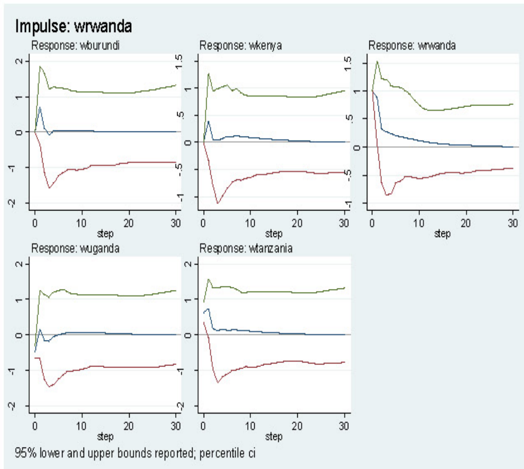
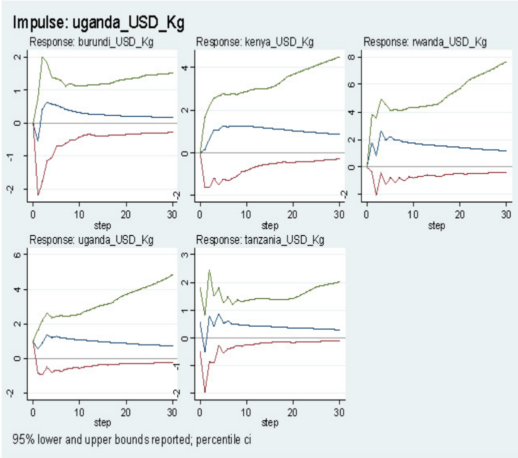
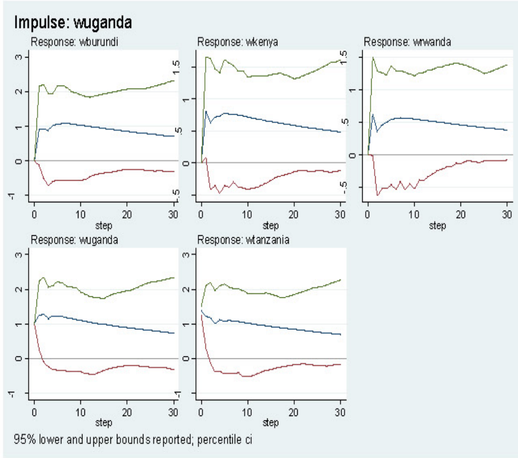
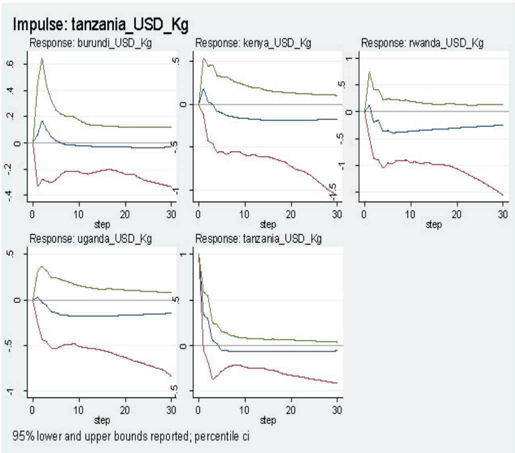


Figure 8: *With spatial effects*







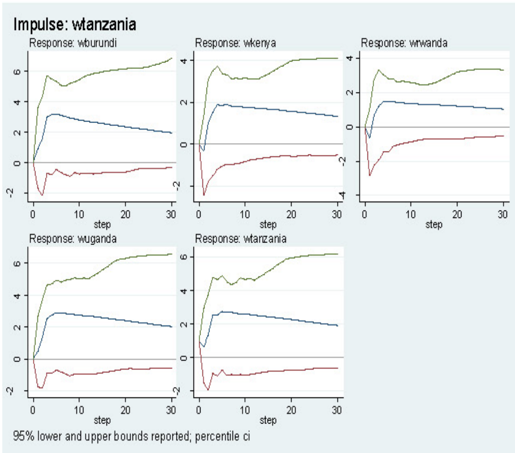
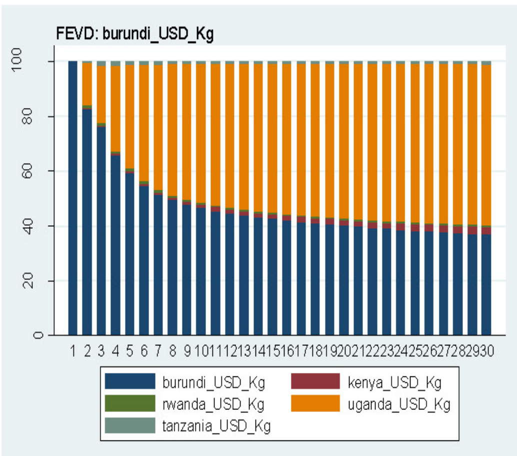


Figure 9: *Without spatial effects* **Figure 10**: *With spatial effects*

Annex 4: Forecast-error variance decomposition



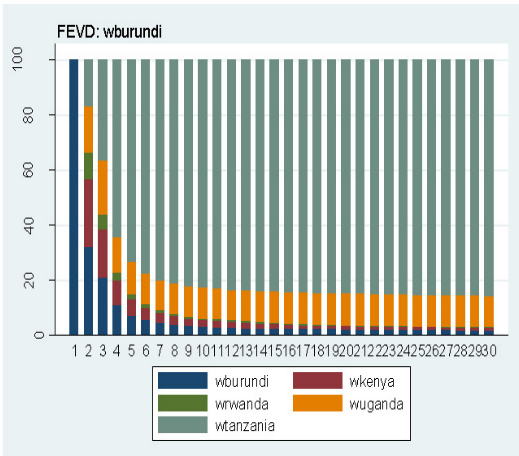


Figure 11: *Without spatial effects* **Figure 12**: *With spatial effects*

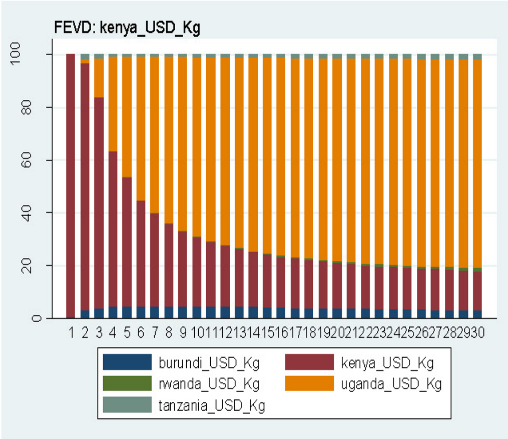


Figure 13: *Without spatial effects*

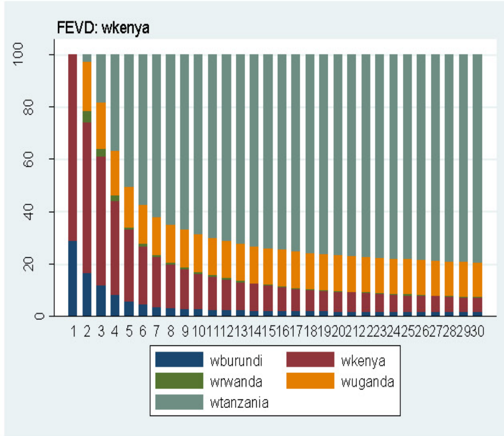


Figure 14: *With spatial effects*

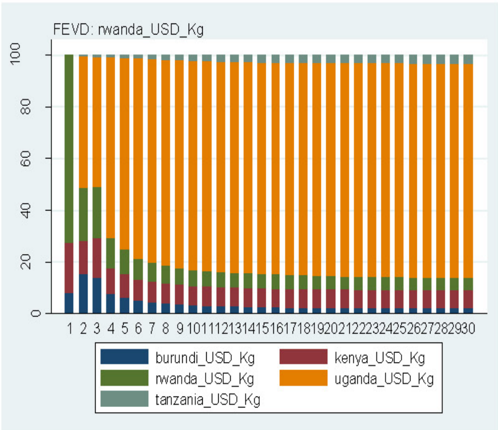


Figure 15: *Without spatial effects*

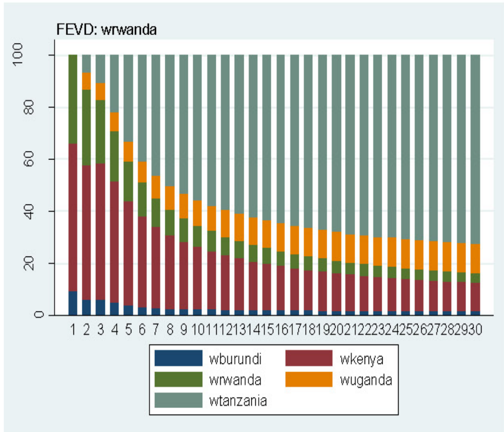


Figure 16: *With spatial effects*

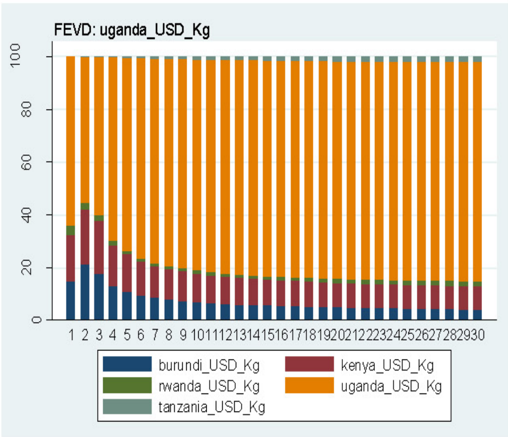


Figure 17: *Without spatial effects*

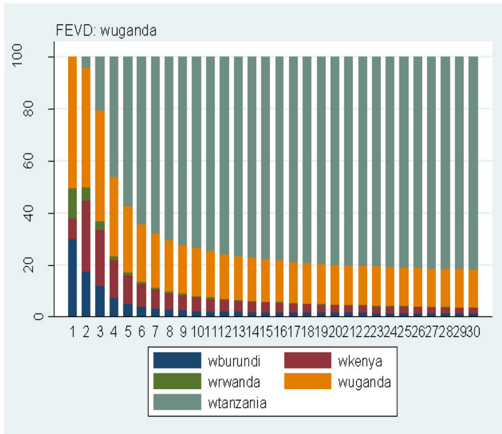


Figure 18: *With spatial effects*

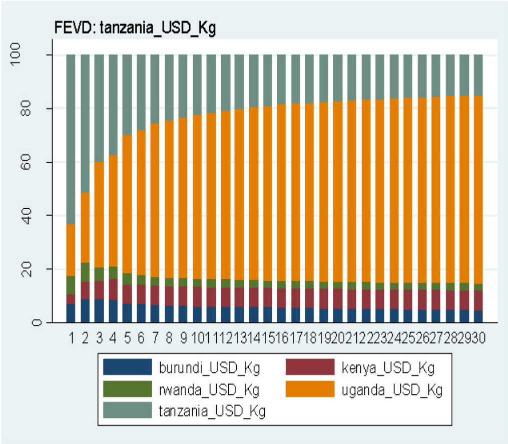


Figure 19: *Without spatial effects*

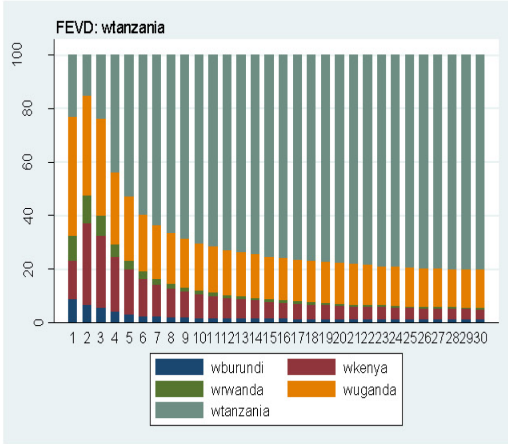


Figure 20: *With spatial effects*

C16

Cassava output supply response in Nigeria: A Vector Error Correction Model (VECM) approach

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ABSTRACT

The response of agricultural commodities to changes in price is an important factor in the success of any reform programme in agricultural sector of Nigeria. The producers of traditional agricultural commodities such as cassava face the world market directly. Consequently, the producer price of cassava has become unstable and this creates a dis-incentive for production thus making output and exports suffer. This study investigated cassava supply response to changes in price. Data collected from FAOSTAT from 1966 to 2010 were analysed using Vector Error Correction Model (VECM) approach. The results of the VECM for the estimation of short run adjustment of the variables toward their long run relationship showed a linear deterministic trend in the data and that Area cultivated and own prices jointly explain 74% and 63% of the variation in the Nigeria cassava output in the short run and long-run respectively. Cassava prices (P↓0.001) and land cultivated (P↓0.1) had positive influence on cassava output in the short-run. The short-run price elasticity was 0.38 indicating that price policies are effective in the short-run promotion of cassava production in Nigeria. However, in the long-run elasticity cassava does not responsive to price incentives significantly. This suggests that price policies are not effective in the long-run promotion of cassava production in the country owing to instability in governance and government policies.

Keywords: Cassava output price, Co-integration, long-run elasticity

PAPER

1. Introduction

In recent times, the producers of traditional agricultural commodities in Nigeria face the world market directly. They reap profits when prices are good but absorb shocks and suffer losses when prices fall. Consequently, the producer price of these commodities has become unstable and this creates a dis-incentive for production, thus making output and exports to suffer (Mesike et al., 2008). This could have negative implications for the agricultural industry and for the national income. Consequently, the prices at which cassava and other cash crops farmers in Nigeria are able to sell their output, to a large extent, depend on how they respond to both local and global demand. For many low income countries, the impact of structural reforms on economic growth and poverty alleviation crucially depends on the response of aggregate agricultural supply to changing incentives. The ability of the agricultural policy community to respond to this challenge is impaired by relative scarcity of current market prices and missing information of basic information about the supply of agricultural output, which makes the forecasting of supply response difficult. Agricultural supply response is the change in agricultural output owing to a change in agricultural output price (Mythili, 2008) and this may be policy-induced. In Nigeria, the producers of traditional agricultural commodities like cassava face the world market directly. They reap profits when prices are good but absorb shocks and suffer losses when prices fall (Obayelu and Salau, 2010). Consequently, the producer's price of these commodities has become unstable and this create dis-incentive for production and thus making output and exports to suffer (Mesike et al., 2008). This could have negative implications for the agricultural industry and for the national income.

In agricultural development economics, the most important issue is supply response since the responsiveness of farmers to economic incentives largely determines agriculture's contribution to the economy. The response of agricultural supply to price movements has been the subject of long and vigorous discussion, going back to Nerlove's classic treatment of the long-run supply elasticity for corn, cotton and wheat in the United States (Nerlove 1958). Estimates of supply elasticity (short-run and long-run) based on the Nerlove model vary widely by crop and region. Furthermore, the response elasticities are also important for policy decision regarding agricultural growth. Therefore considering of these limitations, the current study utilizes the new developments of econometric techniques in analysis that can estimate distinct short-run and long run elasticities to overcome the problem usually encountered in the traditional Nerlovian model. However, the Error Correction Model (ECM) with co-integration analysis is preferred to the Nerlovian model because it not only overcomes the restrictive dynamic specification of the Nerlove method, but also captures the forward-looking behaviour of producers optimising their production in dynamic situations. ECM is used to analyse non-stationary time series that are known to be co-integrated.

The measurement of agricultural supply response not only prove useful to policy makers, it also facilitates informed decision making by farmers and other players in the production marketing chain and ultimately better prices for the consumers. The responsiveness of farmers to price and non-price incentive or disincentives will provide a clear picture of contribution of agricultural sector to the economy and this will depend often on the responsiveness of domestic agricultural production to price in particular. In Nigeria, a substantial literature on agricultural output supply response exists but little of this is directly relevant to cassava. However, crop-specific data on supply elasticities are needed to ensure relevant policy analysis. Ojiako et al., 2008 studied cassava output supply response but limited their studies to non-price factors. Any attempt to reform the structure of incentives provided by cassava farmers will require a detailed knowledge of cassava supply parameters. Hence, the use of VECM approach to investigate the response of cassava output supply to the real prices with a lapse of time. This study therefore analyzes cassava farmers' responsiveness on the price from the period of 1966 (when the first military coup took place) to 2010.

2. MATERIALS AND METHODS

The study sourced data from Food and Agricultural Organization of the United Nation (FAO), Central Bank of Nigeria (CBN) and National Bureau of Statistics (NBS). The variables chosen include cassava output, area, real prices of cassava, land area cultivated. Raw cassava price data from 1966 to 2010 were deflated using 2012 consumer price index. Each of the series was then tested for the presence of a unit root by estimating an Augmented Dickey Fuller (ADF) equation. The first lagged difference of all non-stationary series and again estimated ADF equation both with and without the deterministic trend.

The cointegration and the Vector Error Correction Model (VECM) were estimated using the Johansen (1988) test which estimates Vector Error Correction Models (VECM) of the form:

$$\Delta Y_t = c + \sum_j \alpha_j \Delta Y_{t-1} + \delta D_t + \gamma T + \lambda \varepsilon_{t-1} + \vartheta_t \quad (1)$$

$$\varepsilon_{t-1} = lnY_{t-1} - \sum_j \beta_j Y_{jt-1} \text{ (error/equilibrium correction term)} \quad (2)$$

Where where Δ is the deference operator such that $\Delta Y_t = Y_t - Y_{t-1}$, Ys are the (assumed) co-integrated time series variables (including pervious supply levels $Y_{t-n}$and explanatory variablesX_{t-n}). D_t is a vector of stationary exogenous variables; δ is vector of parameters of exogenous variables; λ is the coefficient of error correction term ε_{t-1}. αj and βj are respectively vectors of short-run and long-run supply elasticities with respect to factor j.

The Johansen method provides two likelihood ratio tests, namely the Trace and the Maximum Eigen Value statistic tests, which are used to determine the number of co-integrating equations given by the co-integration rank r. A co-integration equation is the long-run equation of co-integrated series. The Trace statistic tests the null hypothesis of r co-integrating relations against the alternative of k co-integrating relations, where k is the number of endogenous variables for r = 0, 1,..., k – 1. The Maximum Eigen Value statistic tests the null hypothesis of r co-integrating vectors against the alternative of r + 1 cointegrating vectors.

When the co-integration rank r is equal to 1, the normalisation restriction for the parameters produces a unique estimate of what the economic theory suggests (Golinelli, 2003). However, when there is more than one co-integration equation the Johansen approach to co-integration analysis is preferred to the Engle-Granger approach (Thiele, 2003).

The VECM was specified as:

$$\Delta \ln Y_t = c + \alpha_0 \Delta \ln P_{t-1} + \alpha_1 \Delta \ln k_{t-1} + \alpha_2 \Delta \ln C_{t-1} + \gamma T + \lambda \varepsilon_{t-1} + \vartheta_t \quad (3)$$

Where $\varepsilon_{t-1} = \ln Y_{t-1} - \beta_1 \ln P_{t-1} - \beta_2 \ln K_{t-1} - \beta_3 \ln C_{t-1}$

For this study:

$$\Delta \ln Y_{t-1} = C + \alpha_0 \ln P_{t-1} + \alpha_1 \ln A_{t-1} + \varepsilon_{t-1} \quad (4)$$

Where:

Y_{t-1} = lagged Output

P_{t-1} = lagged price of cassava

A_{t-1} = lagged Area of land cultivated

C = Constant

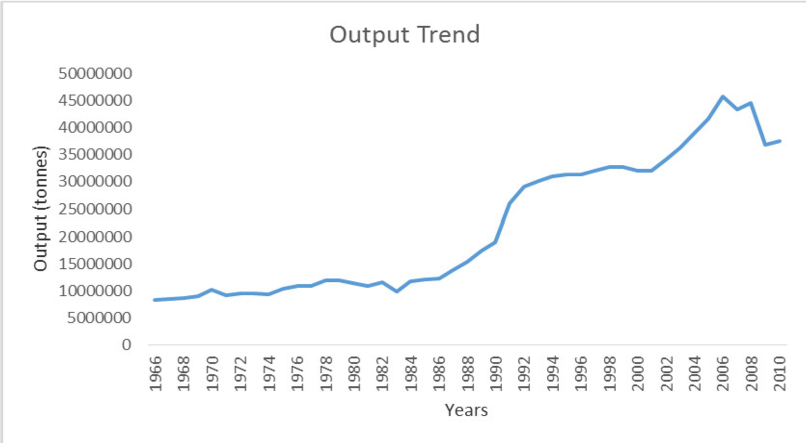
ε_{t-1} = lagged Error term

3. RESULTS AND DISCUSSION

The trend analysis in Figure 1 shows that between the periods of 1966-1985, what has popularly come to be known as the pre-Structural Adjustment Program (SAP) era, cassava production was at best described as stagnant as there was no real growth in the sector. This was the outcome of the oil boom of the 1970s, which later led to the "Dutch syndrome". In the late 1980s, the military regime international financial institutions supported the introduction of Structural Adjustment Programme (SAP) in Nigeria to correct market and price distortions. The SAP was a policy measure towards a more market-friendly trading system and the dissolution of commodity marketing boards as well as elimination of the heavy dependence on crude oil export and import of consumer and producer good (Ihimodu, 1993). During the SAP era, cassava output grew steadily from about 10 million tonnes (MT) in 1985 to 30 MT 1994. Thereafter, it took a downward trend but for the timely intervention of the Presidential Cassava Initiative under the Obasanjo regime from 1999 to 2007 and peaked in 2006 to about 49 MT.

Efforts of the Obasanjo regime to diversify the Nigerian economy from an oil-based economy led to growth in the agricultural sector including the exponential expansion of cassava production from 2003 to 2007. However, the glut created in the market, which coincided with a change in government and government policy focus, led to sharp decline in cassava output to about 35 MT in 2008. The seven-point agenda of the Yaradua government included agricultural sector development but were later actualised by Goodluck Jonathan regime. Local content policies, such as the popular cassava flour inclusion in the milling industry and bilateral agreements with multinationals in the textile and the pharmaceutical industries, resulted in the upward trend of cassava output in 2010.

Figure 1 - Trend Analysis of Cassava Production Output



Trend Analysis of Raw Cassava Prices

The agricultural production like any other around the world responds not only to non-price factors such as policies and weather but also to price incentives. Figure 2 shows that cassava prices were low and stable relatively during the pre-SAP period (1966-1985) but a sharp change is noticed in the price movement which also corresponds with exponential increase in production output immediately after the introduction of SAP. The sharp decline in the price of cassava around 2008 can be attributed to the glut in the market at the period. From then onwards, there has been an undulating increase in the trend of cassava price.

Figure 2 - Trend Analysis of Cassava Prices.

Stationarity Tests

The unit root test using the Augmented Dickey Fuller (ADF) is presented in Table 1 shows that that all the variables are non-stationary in their levels but are stationary at first differences. The test used the MacKinnon (1991) critical values for the rejection of the null hypothesis of no unit root. This indicates that the variables are I(1) and any attempt to specify the dynamic function of the variable in the level of the series will be inappropriate and may lead to spurious results and not such results cannot be used for prediction in the long-run (Mesike et al., 2010). Therefore, the test of co-integration was applied to the series data which were integrated in the same order I(1) and did not have a unit root.

Table 1 - Augmented Dickey Fuller (ADF) Stationarity Test Results

ADF Test Critical Values					
Variables	Statistics	1%	5%	10%	Inference
D(Y)	0.5469	-3.6056	-2.9369	-2.6069	I(0)
	-3.6416	-3.6105	-2.9390	-2.6080	I(1)
D(A)	-1.6330	-4.9809	-3.5155	-3.1883	I(0)
	-5.8244	-4.1865	-3.5181	-3.1897	I(1)
D(P)	-1.0804	-4.1985	-3.5236	-3.1929	I(0)
	-4.7951	-4.2050	-3.5266	-3.1946	I(1)

Key: ADF = Augmented Dickey Fuller; I(0) = non-stationary at level; I(1) = stationary at first difference; D(Y) = Output of Cassava; D(A) = Area; D(P) = Price of Cassava;

Cointegration Test

The Johansen's co-integration test shows the presence of three co-integrating equations at 5% level of significance implying that there is a common trends in the process (Table 2). The co-integration tests are to test whether there is a statistical significant linear relationship between the different time-series data. Test statistics from the maximum Eigen value are consistent in suggesting that there are two integrating vectors among the variables. This implies that the explanatory variables are co-integrated and have short run and long run relationships with the dependent variable.

The statistical evidence of co-integration supports the theory of long-run equilibrium between supply and output. It also supports three co-integration relation between the series and hence the decision regarding co-integration equation. The results, based on both the trace test and maximum Eigen value test showed the existence of three co integrating vectors and the rejection of the null hypothesis of r = 0. Thus, there is a long-run co-integrating relationship among the variables. This is consistent with the findings of Hallam and Zanoli (1992) as cited in Obayelu and Salau (2010) that where only one co-integrating equation exists, its parameters can be interpreted as estimate of long-run co integrating relationship between the variables concerned.

Table 2 - Summary of Co integration Test. (Result of Johansen Trace Test).

Hypothesised No. of CE	Null Hypothesis	Alt. Hypothesis	Eigen Value	Trace Stat.	5% Critical value
None	r = 0	r=1	0.6611	92.6800	69.8188*
Atmost 1	r<1	r=2	0.5199	55.8934	47.8561*
Atmost 2	r<2	r=3	0.4202	30.9472	29.7971**
Atmost 3	r<3	r=4	0.2974	12.4147	15.4949
Atmost 4	r<4	r=5	0.0122	0.4157	3.8415

Hp: rank = p(no deterministic trend in data) Hr: rank r<p Co integration relations.
** (*) denotes rejection of hypothesis at 5% (1%) significant levels. Test indicates 3 cointegrating equations(CE) at 5%.

Vector Error Correction Estimates

Lagged variables were used in the estimation of cassava output, as the production decisions of the famers are mostly made in the previous period and they are not altered on real time basis due to change in any of the variables. The result shows that the independent variables jointly explain 74.01% of the variations in the cassava output in the short-run. The elasticity of current production with respect to previous production is 37.7%. Most parameter estimates are within reasonable ranges and suggests a relatively strong short-run supply response to prices, meaning an increase in aggregate cassava output in the short-run will lead to a decrease in the price of cassava (Obayelu and Salau, 2010). The estimated speed of adjustment was significant at one percent and this reveal that cassava supply adjusts to correct for short-run disequilibrium between itself and its price. The error correction coefficient was very high (98%) and has a negative sign as expected, suggesting that feedback mechanism is high in converging cassava supply towards long run equilibrium despite the shocks in cassava supply and prices.

Production decisions are mostly made in the previous year and they are not subject to alterations on real time basis due to change in any of the variables (Ozkan, 2011). Thus, considering the annual structure of the cassava production, the amount of production in the previous year is correlated with the current production. The negative sign on the lagged cassava output suggest that when there is a market glut in the previous period, cassava could be replaced with its substitutes such as yam and sweet potatoes. In other words, an increase in cassava supply resulting in a decline its price will make the famers shift cassava production to its close substitutes like yam, thereby reducing its output supply. This makes them eligible for this substitution in the long-run. The opportunity to utilize substitutes is a key proviso that is attributable to the negative constant of the estimation. The cassava price elasticity and the elasticity of farm size in the short-run were 0.38 and 0.27 respectively suggesting that a percentage increase in both the lagged price of cassava and farm size price lead to a less than proportionate percentage increase in aggregate cassava supply in the short-run. This indicates that cassava supply is price inelastic in the short-run. Also, cassava farmers in Nigeria do not make adequate short-run production expansion adjustments in response to changes in expected prices. This may be due to relative price stability overtime and non-price determinants of supply response.

Table 3 - Short-run Relationship Estimates.

Variables	Co-efficient	St. Error	t. value
C	-270459.2	238197.5	-1.135441
D(Y-1)	-0.377316***	0.118843	-3.174918
D(A-1)	0.2749004*	0.141884	1.937497
D(P-1)	0.382407***	0.104133	3.672281
E-1	-0.980299***	0.148231	6.613324
R. Squared.	0.740103		
Adj. R. Square	0.704255		
S.E. Equation	1.388426		
Sum of Sq. res.	5.59E+13		
Log likelihood	-526.4250		
F. Statistics	20.64568		
Mean dep. Var.	-258167.6		
S.D Var.	2553079		
Akaike Info. C.	31.26029		
Shwarz C.	31.48476		
Dubin Wat. St.	1.014693		

(***) * Significant at (1%) and 10% respectively

In the long-run all the explanatory variables explain 63 percent of the variations in the cassava output. The coefficient of the error term is significant and greater than unity in the long-run and is consistent with the findings of Obayelu and Salau (2010), implying a high speed of adjustment towards equilibrium. In other words, the speed at which cassava output adjusts to the explanatory variables in the long-run is 100.5%, which is a marginal increase from 98% in the short-run. However, lagged cassava price is not significant in the long-run suggesting that price policies are not effective in the long-run promotion of cassava production in the country owing to instability in governance and government policies. This is consistent with the findings of Ozkan et al., 2013 that current production did not respond significantly to the lagged own price of wheat in the long-run in Turkey. However, it contrasts the findings of Ogundari and Nanseki (2013) that maize supply responds significantly and positively in the long run to own price in Nigeria.

Table 4 - Long-run relationship estimates.

Variables	Co-efficient	Standard Error	t-value
C	767457.7***	249459.7	3.076480
Y-1	-0.03460	0.172640	0.200535
A-1	0.733647	1.721046	0.426280
P-1	0.2182142	2.083508	0.104734
E-1	1.005688***	0.156314	6.433782
R. Squared.	0.637226		
Adj. R. Square	0.587188		
S.E. Equation	1452898		
Sum of Sq. res.	6.12E+13		
Log likelihood	-527.9682		
F. Statistics	12.73488		
Mean dep. Var.	773655.9		
S.D Var.	2261304		
Akaike Info. C.	31.55107		
Shwarz C.	31.42762		
Dubin Wat. St.	1.060433		

(***) significant at 1%.

4. CONCLUSION

The result of the trend analysis showed that cassava development and production output have risen over the years in Nigeria in the recent past and that price plays a significant role in production decisions as evidenced by the fall in production around the period of 2008. Cassava has the potential to feed the growing population and still have reserves for export purposes if the current policies, initiatives are maintained and improved upon. It is recommended that policy makers (e.g. government) should come up with a way of stabilising production and price by taking care of the glut in the system. The farmers can also protect themselves from the effects of price fluctuations are to diversify by providing other value addition on cassava.

The area elasticity coefficient from the short run VECM analysis shows that increase in the area cultivated will lead to an increase in cassava output, efforts should therefore be put in place by government and extension agents to increase the area cultivated and improve the yield potentials in terms of productivity of the fields thereby maximising output.

It has been observed from the short run VECM study, that cassava has high price elasticity. Policies should be put in place that stabilises the price of cassava in the market.

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C16 # Did the Fertilizer Cartel Cause the Food Crisis?

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ABSTRACT

Food commodity prices escalated during the 2007/2008 food crisis, and have scarcely fallen since. We show that high fertilizer prices, driven by the formation of an international export cartel as well as high energy prices, explains the majority of the recent price spikes. In particular, we estimate the pure fertilizer cartel effect explains up to 50% of crisis food price increases. While population growth, biofuels, high energy prices and financial speculation doubtlessly put stress on food markets, our results help to understand the severity and sudden emergence of the crisis and suggest avenues to prevent its repetition.

Keywords: food crisis, fertilizer, cartel, competition policy JEL: F10, L40, Q02

PAPER

1. Introduction

During the 2007–2008 food crisis, commodity prices escalated leading to food insecurity and political instability in the developing world (Timmer, 2010). Simultaneously an export cartel for fertilizer, an essential input to industrial crop production, established itself and fertilizer prices tripled (Jenny, 2012). This paper estimates that the cartel directly led to a 40-50% overcharge in the fertilizer market, which – through cost passthrough to agriculture – translated into up to a 20% increase in food prices. Since food prices rose on average by 40% during the crisis, we can attribute nearly 50% of the price increase to the formation of the fertilizer cartel. Moreover, while the cartel channel has apparently been overlooked in the literature so far, it can explain not only the severity but also sudden emergence of the food crisis which other explanations – such as population growth or high energy prices – do not. More generally, our results indicate an urgent need to better understand the role of export cartels in addressing future challenges to food security (Grote, 2014).

Commensurate to the importance of the food crisis, a large literature is developing to estimate its causes[2]. On the demand side, analysts emphasize population growth and rising per capita meat consumption (Trostle, 2010). Mitchell (2008) focuses on the role of biofuel subsidies in raising demand for crops, although subsequent research is ambiguous at best (Serra and Zilberman, 2013). Adverse supply shocks due to high energy prices are a potential explanation (Harri et al., 2009), although challenged by Zhang et al. (2010). Bad weather in some regions certainly did not help (Headey and Fan, 2010, chapter 2), although harvests were not unusually poor during the crisis period. Synchronous low grain stocks, or more precisely low stockto-use ratios is also frequently blamed (Bobenrieth et al., 2013). Current research and debate largely focuses on determining the relative importance of these causal factors to the food crisis[3]. Additionally, a growing body of research investigates the role of financial speculation in the food crisis, e.g. Irwin and Sanders (2012); Fattouh et al. (2013); Sanders and Irwin (2010), although there is considerable evidence against herd behaviour (Steen and Gjolberg, 2013). Finally, trade shocks (Headey, 2011) may have been a factor.

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[2] Headey and Fan (2010) provide a very comprehensive survey

[3] One view is succinctly expressed by then-President George W. Bush in a White House press conference on 29.04.2008: "I thought it was 85 percent of the world's food prices are caused by weather, increased demand and energy prices ... 15 percent has been caused by ethanol"

Fertilizer has so far been at best at the sidelines of the discussion. While high fertilizer prices during the crisis are sometimes noted, they are often attributed to high energy prices (e.g. Headey and Fan (2010, p. 25)). Mitchell (2008) notes that "energy–intensive" components of total production costs account for 6.7%–13.4% in USDA farm survey data; but we know from economic theory that prices depend on marginal cost in a competitive industry. According to USDA (2014a), the average fertilizer cost share in years 1975-2013 accounted for 32% of the marginal cost of wheat and 37% of the marginal cost of maize.[4] High fertilizer prices can also have adverse impacts on the government budget of developing countries; e.g. Dorward and Chirwa (2011) point out that high fertilizer prices increased Malawi's fertilizer subsidy expenditures in 2008/2009. Yet we are not aware of previous literature taking fertilizer seriously as a driver of the food crisis, or estimating a formal econometric model in this direction.

An appreciation of the role of fertilizer may be crucial to understanding the past food crisis and mitigating future ones. Given the large share of agricultural marginal cost accounted for by fertilizer, strong price passthrough from fertilizer to food is predicted by standard economic theory[5]; careful econometric analysis is thus needed. Second, fertilizer prices are at times determined by an international export cartel (Hoekman and Saggi, 2007) or the degree of market concentration (Hernandez and Torero (2013)) and not market forces. Understanding the extent of the cartel overcharge is crucial to estimating the potential effects international competition enforcement against such cartels could have on food markets– particularly on developing countries, where households spend roughly half their income on food (Mitchell, 2008).

Contribution: We contribute to the literature in three ways. First, using established time series methodology (cf. Baffes (2010); Nazlioglu and Soytas (2011); Zhang et al. (2010)), we establish the strong cost passthrough from fertilizer to food. Second, we estimate the cartel overcharge (Connor and Bolotova, 2006; Connor, 2010) in the fertilizer market during the crisis period. Finally, we conduct a simulation of food prices in the counter–factual case that no cartel would have been formed and show that the majority of the crisis food price increase can be explained by the fertilizer cartel alone.

This paper proceeds by briefly presenting the role of fertilizers in modern agriculture and describing the fertilizer market. Subsequently, data and methods are introduced in section 3, succeeded by a discussion of the economic motivation of the regression equation and our the estimation strategy. We present results in section 4, and place them in the context of the literature. Section 5 simulates the development of food prices had no cartel been in place. Robustness checks are collected in section 6. Finally, we conclude.

2. Fertilizers and Market

Mineral fertilizers - nitrogen, potassium and phosphorus are the key nutrients crucial for plant growth and hence modern agriculture. The increase in use of commercial fertilizers was the main component of the so called green revolution and at least 30 to 50% of crop yield is attributable to commercial fertilizer nutrient inputs (Stewart et al., 2005). Currently the world fertilizers market is worth approximately $170 billion annually.

The fertilizer industry is conducive to cartelization, for individual nutrients and all three nutrients together. This feature of the fertilizer industry is based on heavy concentration of the essential mined inputs - potassium and phosphorus - where reserves are being exploited only in few countries and by few firms. Together with the high investment required in mining operations and the presence of export associations such as e.g. PhosChem and Canpotex, the fertilizer industry provides favorable conditions for collusion; indeed, cartel episodes have been documented since the late 19th century (see Taylor and Moss (2013) for a detailed study of the industry). Since the main input for nitrogen fertilizer is energy (used to convert atmospheric nitrogen to a nutritionally available form via the Haber-Bosch process), one would expect a higher degree of competitiveness on that market. However, many of the major phosphorus producers also manufacture nitrogen fertilizer, partly because a source of nitrogen is required to stabilize phosphorus, and partly because many fertilizer manufacturers sell blended nitrogen-phosphorus-potash fertilizer at wholesale and retail (Taylor and Moss (2013).

Furthermore, producers of fertilizers are often central to their local economies – e.g. PotashCorp for the Sasketchewan region of Canada – or indeed leading national exporters, as in the case of Office Cherifien des Phosphates (OCP) in Morocco or the Belarusian Potash Corporation, they are politically entrenched and backed by legal or de facto exemptions from usual antitrust enforcement.

[4] Those figures represent the share of marginal costs. For total costs one must add an overhead – largely the rental cost of capital and land, since US agriculture is not labor intensive. These overheads can be interpreted as a largely fixed cost, which should not affect competitive market prices.

[5] See section 3 for details

Dating the Cartel: The propensity of the fertilizer industry to establish cartels is well known (al Rawashdeh and Maxwell, 2014). However, competitive periods – after breakdown of a cartel – also occur. This makes it imperative to precisely date cartel periods for empirical analysis. Taylor and Moss (2013) conduct a detailed micro–level study to distinguish different phases of market competition in fertilizers. They conclude, based on qualitative and quantitative evidence, that the cartel exercised in market power in the 2008–2012 period[6].

Furthermore, there exists evidence suggesting a successful attempt to form a Moroccan–lead phosphates cartel in 1974. In that period, Morocco's share of the international market was 40 percent, and with the other African and Middle Eastern producers, Morocco controlled 55 percent of world trade in phosphates (Johnson, 1977). However, due to significant decrease in exports (by 30 percent) during 1975, Morocco was forced to announce a price reduction in January, 1976. Later that year the Afro-Arab Phosphate Commission (APC), an export group to which Morocco, Tunisia, Senegal, and Jordan belong, announced that they would not further tighten the supply highlighting that they only pursued price stabilization and a guaranteed minimum price.

3. Data and Methods

Model Specification: Our interest is in determining the price passthrough from fertilizer and energy indices on food prices. Thus, based on annual time series data, we estimate reduced form regressions explaining food commodity prices as a function of fertilizer and energy indicies, controlling for inflation and allowing a linear time trend. This yields the regression model:

$$\begin{aligned} log(X_t) &= \mu + \beta_1 log(\mathrm{FERTILIZERS}_t) + \beta_2 log(\mathrm{ENERGY}_t) \\ &+ \beta_3 log(\mathrm{MUV}_t) + \beta_4 log(\mathrm{USD}_t) + \tau t + \epsilon_t \end{aligned} \quad (1)$$

where t denotes a year between 1960 and 2013, $\mathrm{FERTILIZERS}_t$ is the index of fertilizer prices and ENERGY_t the index of energy prices; moreover, a price deflator, denoted MUV_t, US dollar exchange rate USD_t and linear time trend *t* are a ded as controls. The dependent variable is denoted X_t; in our analysis, we consider a general food price index FOOD as well as prices for main agricultural commodities, wheat and maize, soybeans, barley, sorghum and rice. To facilitate comparison with the existing literature, we also estimate a reduced model where the restriction 1 = 0 is imposed. Furthermore, similarly to Nazlioglu and Soytas (2011) we present a specification without MUV and similarly to Baffes (2010) a model without the exchange rates.

Finally, we estimate the reduced model with the fertilizer index as the dependent variable. Throughout, we follow Engle-Granger methodology, i.e. we use OLS as our estimation method and carefully check for non-stationarities using appropriate versions of the Augmented Dickey Fuller (ADF) test. We assume that unobserved variables (e.g. other cost–push factors such as wages) are uncorrelated with the error term; further properties of the error time series will be subjected to statistical testing below. Specifying the model as in equation 1 we implicitly assume existence of a single cointegration relation between all variables in the equation. We find no evidence to reject this hypothesis if the residuals of the regression from equation 1 are stationary, as non-stationarity of the error term invalidates the OLS approach. If we can't reject the hypothesis about residuals non-stationarity, we reject the hypothesis of a single cointegrating and are unable to interpret the model parameter estimates.

This statistical model can be given a structural economic interpretation. Consider a competitive industry, where each firm produces according to a constant returns to scale Cobb–Douglas production function. Then, the unit marginal cost function has the functional form of (1), allowing for a time trend in total factor productivity and possibly non–neutrality of money (unless β 3 = β1 β2). Coefficients 1 and 2 can thus be interpreted as the factor weights in the production function; moreover, the predicted cost share of each factor corresponds to the coefficients i. For proof see the appendix.

Data Sources: Our commodity price series is based on the World Bank Global Economic Monitor Commodities database (World Bank, 2014). We study the broad–based food price index (series IFOOD), which includes grains, cereals and oils among other food items as our dependent variable of interest; furthermore, key commodities – maize, wheat, soybeans, barley, sorghum and rice – are studied separately. Our explanatory variables are the fertilizer index (series IFERTILIZER), which includes all widely used fertilizer types: potassium, nitrogen and phosphate rock, and energy prices (IENERGY index). More detailed description of the composition of each of the indices is presented in the appendix.

Individual commodity prices are given in nominal USD; indices are also of nominal prices, with 2010 as the base year. The Manufactured Unit Value (MUV) index, also provided by the World Bank, is included in the regressions as a deflator.

[6] Since the fertilizer export cartel is not constrained by usual anti–trust enforcement, the cartel is relatively transparent. For example, according to the Potash Investing News, potassium producers simultaneously announced in 2009 an intention to further reduce output (Toovey, 2009). Following a rapid collapse in fertilizer prices, Uralkali Chief Executive Officer Vladislav Baumgertner was detained in a prison in Belarus in August 2013 after talks on restoring the cartel were apparently unsuccessful (Fedorinova and Kudrytski, 2013)

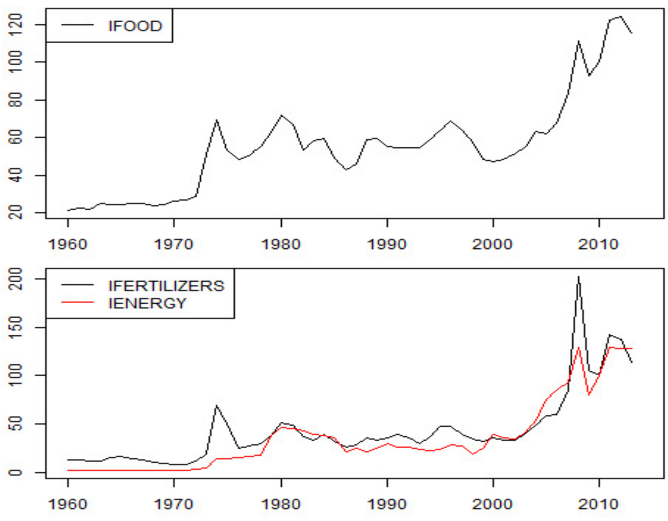
Furthermore, we account for USD real exchange rates, based on Breugel Institute's monthly data series[7] (Darvas, 2012). Data were current as of December 2014. The dataset is closely related to Baffes (2010), who studies the 1960–2008 period; however, his analysis omits consideration of fertilizer prices as an explanatory variable.

Descriptive Analysis: The starkness of the ongoing food crisis is illustrated in figure 1. Food prices are drawn in the top panel; in 2010, they were 40% higher than two years previously; moreover, after a brief recovery in 2009, prices at the end of the sample period exceed the peak of the crisis level. Simultaneously with the food crisis, energy prices also rose – yet more mildly, by merely 25% over the same period. But by far the most drastic change in the crisis period took place in the fertilizer market: by 2010, fertilizer prices *more than tripled* compared to 2006 levels.

All time series are trending upwards; this includes those in the data set that are not drawn in the figures. By visual inspection, one may suspect nonstationarity in the form of a unit root; this intuition is supported through autocorrelation functions. Below, we conduct an ADF test to test this view against the alternative hypothesis of a trend stationary process.

Fertilizer-Energy Link: Fertilizer and energy price indices are closely linked. This is apparent from visual inspection: from the mid-1970s to 2005 or so, energy and fertilizer indices move almost entirely in parallel. This is explained by the fact that fertilizer production is highly energy-intensive, be it due to mining (potassium, phosphate rock) or as a direct input (e.g., natural gas in the Haber-Bosch process). Yet there is independent variation in fertilizer prices: in both 1973/1974 and 2007/2008, fertilizer prices are much higher than one would expect from energy prices. Moreover, in both of these periods food prices were abnormally high – indeed, at crisis levels. It is this variation that underlies the more formal analysis below and allows us to estimate the direct impact of fertilizer prices on food commodities.

Figure 1 - Trends in food and energy/fertilizer prices



4. Fertilizer Matters

Unit Root Tests: We use the Augmented Dickey-Fuller (ADF) test testing the null hypothesis of a unit root against the alternative of a stationary autoregressive process. The optimal lag order is determined through the Akaike Information Criterion (AIC); results are presented in table 1. It is evident that for the levels series – displayed in the left panel – the ADF test largely fails to reject the unit root hypothesis. For the fertilizer and USD, there is weak evidence for stationarity at the 10% level; we consider this significance level insufficient to reject the null. Thus, all levels series are considered to have a unit root. In the right panel, the corresponding ADF test for the first-differenced series is displayed. Here, results are rather straightforward: the null hypothesis is rejected at the 1% level for all series. Hence, the evidence suggests that our data follows an $I(1)$ process.

The $I(1)$ finding has profound implications for our econometric analysis of model (1). On the one hand, standard errors and the R2 statistic are biased towards excessive significance (the "spurious regression" problem); hence significance tests need to be interpreted with care. On the other hand, as we show below, the model in fact provides a *cointegrating regression*; hence the error term t will be stationary and, importantly, OLS parameter estimates are super consistent, i.e. they converge to the population at a faster rate than in an $I(0)$ regression with the same sample size.

[7] Official FED USD exchange rates are reported only since the collapse of the Bretton Woods system in 1971.

Table 1 - Unit Root Tests

Levels			First Differences		
	ADF	lags		ADF	lags
FERTILIZERS	-3.29*	1	D.FERTILIZERS	-6.16***	1
ENERGY	-2.78	5	D.ENERGY	-4.77***	1
FOOD	-2.16	3	D.FOOD	-6.48***	1
MUV	-1.59	1	D.MUV	-4.05***	1
USD	-3.20*	1	D.USD	-4.04**	1

Note: *p<0.1; **p<0.05; ***p<0.01

Estimation Results: Table 2 collects estimation results. Given the I(1) data, universally high values of adjusted R^2 are expected, therefore the statistics are not reported in the regression tables; encouragingly, we are able to reject statistical significance of some parameters. In particular, there appears to be essentially no time trend in commodity prices. Moreover, the deflator MUVt is mostly insignificant, reaching the 5% level only in few specifications. In regressions (1-3), which include the fertilizer index, there is robust evidence in favor of cointegration. The Augmented Dickey Fuller test, computed on residuals of the estimated equation, is able to reject the null hypothesis of a unit root in all cases at the 5% level. There is mixed evidence regarding cointegration in the restricted model which omits the fertilizer index (specifications 4-6). The no cointegration null hypothesis cannot be rejected even at the 10% level in specification (4), in which as in Baffes (2010) only energy and price index are included. In specification (5), as in Nazlioglu and Soytas (2011), i.e. with energy and exchange rate indexes the no cointegration null hypothesis can be rejected only at the 10% level. Once both USD exchange rate and the price index are included the no cointegration null hypothesis can be rejected at the 5% level. Relatedly, Zhang et al. (2010) also reject both cointegration and Granger causality from fuel to food in a different dataset. Baffes (2010) found cointegration for a similar dataset to ours, but with a shorter time period. In line with Harri et al. (2009), our results indicate lack of a robust cointegration relationship between energy and food across different commodities.

Fertilizer is a consistently statistically and economically significant price driver in food markets. Estimates for $\beta 1$ range from 0.28 to 0.42 depending on the specifi cation; this implies that a doubling in fertilizer prices would be predicted to lead to at least a 28% increase in food prices. The estimates may, at first, seem surprisingly high, but they indeed stay very much in line with the fertilizer cost shares in variable costs from the USDA farm cost surveys as shown on figure 2. We compare cost share coefficients from the reduced form regressions (see appendix for the regressions tables) and the average fertilizers share in the variable production cost using USDA data for years 1975-2013[8] (USDA (2014a)). The data points on figure 2 lay along the 45, which indicates that a nearly perfect match is achieved, thereby confirming the validity of the approach.[9]

There is mixed evidence supporting statistically significant effect of energy on food prices once fertilizer is included. This finding is especially striking in light of the spurious regression problem: due to biased standard errors, it may be difficult to reject truly insignificant parameters. The estimates at around 5-13% stay in line with USDA survey suggesting that the combined costs for "fuel, lube and electricity" account for 9% to 12% of operating costs for the main crops (USDA, 2014a). Note that since commodity prices are generally quoted "free on board", the bulk of transportation costs does not enter directly in the data.

The energy–food price link reappears once fertilizer prices are excluded. Our estimates suggest an cost elasticity in the range 0.3 of food prices with respect to the energy index; these findings are close to earlier estimates in the literature[10].

Combined with the lack of cointegation between energy and food, this suggests that earlier studies – which omitted fertilizer – may have identified only the *indirect* impact of energy on food, channeled through higher fertilizer prices.

At an estimated 38-62% cost share (specifications 7-9 of table 2), energy prices have a very strong cost passthrough to fertilizer prices. Due to the energy–intensive production of fertilizers – with energy costs accounting for up to 90% of nitrogen fertilizer cost (Headey and Fan, 2010, p. 25) – the estimate is plausible.

[8]The estimates are based on producer surveys conducted about every 4-8 years for each commodity and updated each year with estimates of annual price, acreage, and production changes. Estimates for non-survey years use the actual survey year as a base and use price indexes and other indicators to reflect year-over-year changes. The cost estimates include both cash expenditures and non-cash costs that constitute an economic cost. The USDA cost classification was changing over time. To reconstruct a cost category "Total, variable cash expenses" available only for the older series, hired labor costs were added to category "Total, operating cost".

9For the analysis all food commodities for which data are available in both USDA and GEM databases except for rice. The exclusion of rice from the analysis is on both on econometric and economic grounds. The former are due the the fact that we can't reject the hypothesis that rice price is I(0). From more economic perspective, rice markets are very thinly traded and the market price is often driven by import and export regulations and not by the cost factors (see e.g. (Timmer, 2010)).

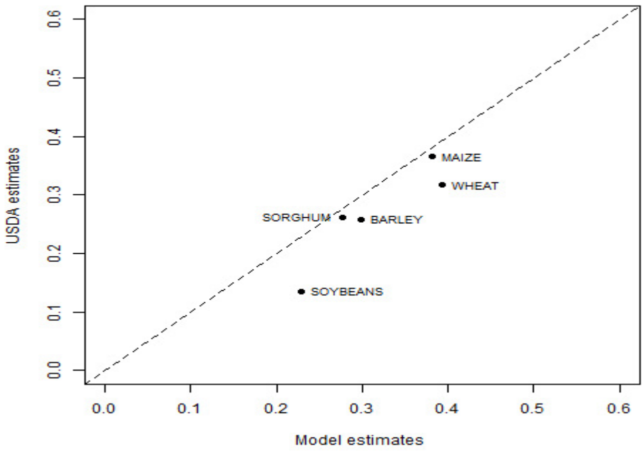
[10]Baffes (2010), using a similar data set until 2008, estimates an elasticity of 0.28; due to persistently high energy and food prices, the correlation appears to be stronger in the extended sample used in the present analysis. Relatedly, Gilbert (1989) estimates an elasticity of 0.25 using quarterly data from 1965.Q1 to 1986.Q2

Table 2: Estimation Results

	Dependent variable:								
	FOOD	FOOD	FOOD	FOOD	FOOD	FOOD	FERT	FERT	FERT
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
FERTILIZERS	0.419***	0.276***	0.278***						
	(0.057)	(0.052)	(0.063)						
ENERGY	0.047	0.129***	0.126**	0.308***	0.233***	0.293***	0.624***	0.377***	0.601***
	(0.052)	(0.032)	(0.051)	(0.054)	(0.031)	(0.039)	(0.093)	(0.068)	(0.075)
MUV	0.256**		0.008	0.005		−0.273**	−0.598**		−1.012***
	(0.107)		(0.116)	(0.146)		(0.114)	(0.253)		(0.219)
USD		−0.927***	−0.917***		−1.363***	−1.563***		−1.582***	−2.322***
		(0.200)	(0.246)		(0.225)	(0.231)		(0.491)	(0.444)
t	−0.004	0.002	0.002	0.001	0.004	0.008***	0.012*	0.006	0.022***
	(0.003)	(0.002)	(0.003)	(0.004)	(0.003)	(0.003)	(0.007)	(0.006)	(0.006)
Constant	1.391***	6.833***	6.759***	2.968***	9.482***	11.210***	3.761***	9.609***	16.007***
	(0.362)	(1.002)	(1.474)	(0.419)	(1.074)	(1.254)	(0.724)	(2.343)	(2.415)
ADF	−3.598**	−3.957**	−3.951**	−2.831	−3.312*	−3.814**	−3.385*	−3.203*	−3.946**
Observations	54	54	54	54	54	54	54	54	54

Note: *p<0.1; **p<0.05; ***p<0.01

Figure 2 - Cost share estimates: model fit vs. USDA (2014a) survey data



5. Did the Fertilizer Cartel cause the Food Crisis?

During the "perfect storm" of 2007/2008, the food crisis coincided not only with an energy crisis but also the establishment of a fertilizer cartel. Given our estimation results above, we are interested in isolating the effect of the cartel formation on fertilizer prices, and hence, ultimately on food. To this end, we first seek to date the recent cartel period in the fertilizer industry and then we estimate an augmented fertilizer pricing equation in the spirit of model (1). Based on predicted fertilizer prices in the counter–factual case of no cartel formation, we then simulate what food prices would have been had a cartel not been formed.

Estimating Cartel Overcharges: We seek to estimate a model that disentangles the impact of energy prices and cartel formation on fertilizer prices. To this end, we augment the version of model (1) already used to estimate potash prices with the cartel variables. To accommodate for the non-competitive periods in the fertilizer industry described in section 2 we introduce a new dummy variable CARTEL0812t, which takes value 1 in those years and zero otherwise (i.e. 1960–2007 and 2013). To account for the Morocco-lead phosphates cartel from the 1970s we introduce a dummy variable CARTEL7475t, which takes value 1 in year 1974 and 1975 and zero otherwise. The cartel impact on fertilizer prices is very strong, as shown in table 3. According to the model, the 2008 cartel formation was associated with a 42-51% overcharge in the fertilizer market. The previous attempt to form a cartel resulted in slightly higher overcharge at approximately 51-65%. Statistical significance at the 1% level, in spite of only few years of observations with the cartel in place, is a reflection of the magnitude of the economic effect. Such large overcharges are not uncommon: in a meta–study of cartel overcharges, Connor and Bolotova (2006, table 3) report an average overcharge of 54.2% for international cartels based on a sample size of 365 cartel episodes. Allowing for the cartel reduces the earlier estimate of energy passthrough on fertilizers; this is intuitive, since the cartel period coincided with high energy prices.

A possible threat to the estimation strategy is the impact of the oil crises on the relation between energy and fertilizer prices and the market turbulences in the aftermath. Therefore, to check the robustness of the results we introduce dummy variables for the 1973-74 and 2007-08 oil crises years (DUMMY7374 and DUMMY0708 respectively). The inclusion of additional out-of-the-sample information affects the results only marginally reassuring that strong fertilizer price spike was not caused only by the increase in energy prices.

Impact on the Food Crisis: The fertilizer cartel can potentially explain up to a halve of food price increases during the crisis time. According to our earlier estimates, the 42-51% fertilizer cartel overcharge would be expected to lead to a 12-21%[11] increase in food prices. Given the observed increase in the food price index of 40%, our model attributes 29-53% of the crisis price hike to the fertilizer cartel. Figure 3, based on specification (1) in table 3, shows the counter–factual food and fertilizer prices without cartel formation side–by–side with actual values: it is apparent that, according to our estimates, food prices could have remained nearly stable over recent years in the absence of the cartel.

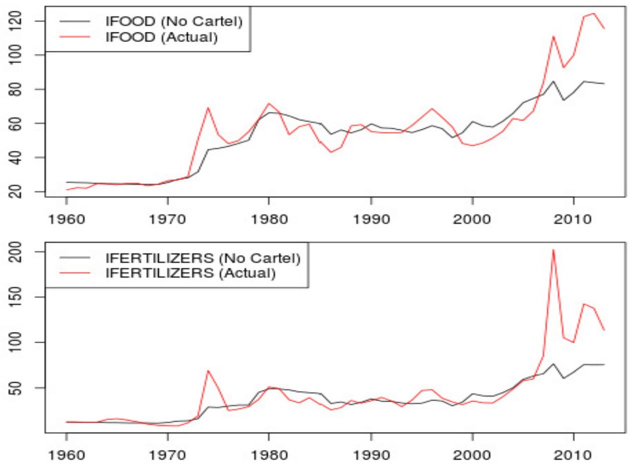
[11] The lower bound is given by the lowest estimates from tables 2 and 3 (0.276*0.423=11.7%) while the upper bound calculated based on the highest estimates (0.419*0.508=21.3%)

Table 3 - Regression Results: Cartel

	Dependent variable: FERTILIZERS					
	(1)	(2)	(3)	(4)	(5)	(6)
CARTEL0812	0.434***	0.423***			0.508***	0.505***
	(0.136)	(0.133)			(0.116)	(0.110)
CARTEL7475			0.562***	0.508***	0.650***	0.600***
			(0.168)	(0.186)	(0.144)	(0.150)
ENERGY	0.527***	0.502***	0.550***	0.551***	0.455***	0.424***
	(0.073)	(0.072)	(0.070)	(0.070)	(0.064)	(0.061)
MUV	−0.625**	−0.537**	−0.877***	−0.865***	−0.405*	−0.270
	(0.235)	(0.235)	(0.204)	(0.205)	(0.204)	(0.199)
USD	−1.860***	−1.789***	−1.926***	−1.877***	−1.325***	−1.147***
	(0.433)	(0.425)	(0.421)	(0.429)	(0.384)	(0.370)
t	0.012*	0.010	0.024***	0.023***	0.012**	0.009*
	(0.006)	(0.006)	(0.005)	(0.005)	(0.005)	(0.005)
DUMMY0708		0.298*				0.344**
		(0.164)				(0.134)
DUMMY7374				0.126		0.172
				(0.181)		(0.145)
Constant	12.776***	12.202***	13.717***	13.441***	9.583***	8.363***
	(2.438)	(2.403)	(2.300)	(2.347)	(2.178)	(2.109)
ADF	−4.018**	−3.925**	−3.575**	−3.519**	−3.606**	−3.111
Observations	54	54	54	54	54	54

Note: *p<0.1; **p<0.05; ***p<0.01
ADF stands for ADF test statistic on residuals of the long run model.

Figure 3 - Actual and counter–factual food and fertilizer prices without cartel formation



6. Robustness Checks

To assert a robust impact of fertilizer prices on food commodities we replace the food price index with the main food commodities as the dependent variable in equation 1. More specifically, we test the following commodities: wheat, maize, soybeans, barley, sorghum and rice. Similarly as in section 4 we proceed with stationarity tests reported in the appendix. As we can't reject the hypothesis about stationarity of the rice price time series we limit our attention to the remaining commodities in the cointegrating regression. The regression results suggest a strong impact of fertilizer consistent across specifications and commodities. In all specifications the coefficient on fertilizer is highly significant and in line with the USDA cost survey data presented on figure 2. The fertilizer cost share for soybeans is significantly lower than for other crops due to legumes' nitrogen-fixing abilities. The ADF test on residuals suggests the existence of a cointegrating vector between the commodities. Results of specification (1) from table 2 are presented in columns (1-5), specification (2) in columns (6-10) and specification (3) in columns (11-15) of the table in the appendix.

The availability of storing technology distorts the standard Marshallian supplydemand cross (Wright, 2011). To control for the possible impact of storage on price dynamics, stock-to-use ratios for each of the commodities have been added to the regression. Although, the stationarity of commodity prices suggests that food stocks are not used as an investment device for arbitrage opportunity seeking investors, the distortions caused by state buffer stocks cannot be excluded. Therefore, similarly to Baffes and Dennis (2013) we include the stock-to-use ratio directly in the regression framework[12]. The estimates on stock-to-use ratio are potentially biased due to endogeneity problems, however good instruments were not available to us. Except for wheat, stock-to-use ratios for all commodities are *I*(1) so we include them in the cointegrating regression. Results presented in specifications (16-20) in the appendix show that while being highly significant and negatively correlated with commodity prices, stock-to-use ratios do not affect the coefficients on fertilizers. This suggests that any endogenity problems in the stock-use-ratio do not affect our estimates of the fertilizer effect.

[12] We calculate stock-to-use ratio following the methodology and data (USDA, 2014b) as suggested by Bobenrieth et al. (2013)

The broad range of regressions performed robustly show the importance of fertilizers in determining food prices. For each of the five food commodities, in each of the four regression specifications, fertilizers persistently prove to be a major cost contributor of food commodity prices. Importantly, the changes in the specifications do not significantly affect the estimates of the fertilizer effect.

7. Conclusion

Since the Green Revolution, the increased application of fertilizer has been instrumental in raising crop yields worldwide. But, as this paper shows, this dependence on fertilizer is not merely technological, but economic: high fertilizer prices directly translate into high food prices. This link is crucial to our understanding of the recent food crisis, during which prices rose by 40% on average. We estimate this was largely caused by the formation of an international export cartel for fertilizers. According to our model, the cartel overcharge in the fertilizer market amounted to nearly 50%. his directly led to a 26% increase in the food price index. In other words, the formation of the fertilizer cartel explains up to a halve of the crisis price increase.

While many factors doubtlessly contributed to the food crisis, we believe the role of fertilizer should be taken seriously. First, while our results are stark, they are in line with the related literature. We estimate fertilizer cost passthrough from aggregate time series data running many years; but the share of fertilizer in marginal cost implied by our model is close to estimates obtained from production budgets and farmer surveys. Our estimated cartel overcharge of 42-51% is typical for international export cartels. Finally, we control for energy prices; according to our estimates, food prices would certainly have been high in 2007/2008 – due to the simultaneous energy crisis – but they would not have reached crisis levels. These results highlight the importance of addressing fertilizer cartel – the "OPEC of world potash markets" (Scherer, 1996) – in combating food crises. In recent history, various export cartels have at different times dominated the fertilizer market (cf. al Rawashdeh and Maxwell (2014); e.g. Newman (1948) discusses the role of the German potassium cartel in the Nazi economy). These cartels flourished, with either explicit or implicit state backing, because of the absence of effective international competition authorities and enforcement (Marquis, 2014)[13]. Sokol (2008) discusses possible institutional reforms to mitigate export cartels; Taylor and Moss (2013) make the case for global antitrust enforcement in the fertilizer industry. Perhaps above all, this paper is a call for further research. Since the "fertilizer hypothesis" is new, it is in need of further corroboration for additional food commodities and from other datasets. The recommended steps include data disaggregation. The analysis performed on the indices may miss some important subtleties of the fertilizer and energy markets. It would be very valuable for the agricultural policy to understand the co-movement of prices of nitrogen, potassium and phosphorus fertilizers. Furthermore, the recent dramatic shocks to the fertilizers markets caused by the cartel formation and the significant decrease of natural gas prices may help to identify the links between the different fertilizer types. Furthermore, a focus on the oil and natural gas prices rather than the analysis compound index would allow to separate the effect of cartel formation from the recent processes that change the shape of the relation between food, energy and fertilizer prices - the introduction of the fracking technology and the recent increase in the use of biofuels. Finally, we treated fertilizer cartel formation as exogenous; but a better understanding of the reasons for success and breakdowns in fertilizer cartels over time is sorely needed.

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[13] See in particular the discussion on pp. 65.

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Appendix

Food, Energy and Fertilizers Indices Composition

The main objective of this study is to understand the change of food prices. We use various World Bank's price indices, the composition of which may not be clear to the reader. Indeed, the information about how price indices are constructed is surprisingly scarce. Therefore, to inform about what is actually being measured in this paper we reconstruct the price indices used throughout the the text.

To reverse-engineer the indices we perform OLS regressions of indices against all commodities included in the database from the given commodity group. To solve the collinearity problem first differences of all variables of interest are taken. If constant weights were used throughout the sample period to construct the indices of interest, this approach allows for full index reconstruction.

The number of food commodities in the data base is close to the number of observations, which leaves few degrees of freedom for the estimation of food price index, therefore, we take a two stage approach. First, we identify the subindices also included in the GEM database that IFOOD is made of. Subsequently, we identify components of each of the subindices. Finally, we verify if , indeed all components of subindices are included in the IFOOD index.

The IFOOD index is built of three subindices - IFATS_OIL with over 40% and IGRAINS and IOTHERFOOD with approximately 30% share each. The detailed composition of IFOOD with it's shares (using 2010 prices) and weights with which particular prices enter the index presented in the table below.

Soybeans prices (beans, meal and oil) are by far the most important component of the IFOOD index with over 25% weight. Also changes in palm oil, maize and sugar prices can significantly affect the index with each commodity having an over 10% share in the index.

Simialr analysis has been performed on the other two indices. Fertilizer price index has 4 components - potash, phosphate rock, TSP (triple superphosphate) with around 20% share each and urea with 40% share with details presented in table A.2. The energy price index is dominated by crude oil with 85% share equally divided between Brent, WTI and Dubai classifications. The remainder is coal (5%) and natural gas (10%) averaged over the European, US and Japanese prices, as shown in detail in table A.3.

Cost shares - a proof

Suppose that food production function is given by:

$$FOOD = A * FERT^{\beta}$$

Where A represents all other costs other than fertilizers. Cost share is given by:

$$\text{Cost }\% = \frac{p_{FERT}}{p_{FOOD}} * \frac{FERT}{FOOD}$$

Table A.1 - FOOD price index decomposition

	Food index share	Weights (OLS results)	t value
COCONUT_OIL	1.2540%	0.0011161	1176687707
GRNUT_OIL	1.1427%	0.0008140	993608721
PALM_OIL	12.3360%	0.0136940	5320371770
SOYBEAN_MEAL	10.7236%	0.0283396	3043535992
SOYBEAN_OIL	5.3270%	0.0053026	1811628597
SOYBEANS	10.0643%	0.0223752	1724849275
BARLEY	1.0448%	0.0065967	452387979
MAIZE	11.4777%	0.0617367	4811226064
RICE_05	8.4829%	0.0173508	7273502220
WHEAT_US_HRW	7.0982%	0.0317475	3411287726
BANANA_US	4.8652%	5.6029550	2520442216
BEEF	6.8377%	2.0402311	4176851463
CHICKEN	5.9577%	3.1483942	2030720627
ORANGE	3.6060%	3.4901202	2014492304
SUGAR_EU	1.2048%	2.7271556	1025261897
SUGAR_US	0.4595%	0.5798444	228419671
SUGAR_WLD	8.1178%	17.2960284	7604308883

Food index share is a product of OLS coefficient estimates and commodity prices in 2010

Table A.2 - Fertilizers price index decomposition

	Fertilizers index share	Weights (OLS results)	t value
PHOSROCK	16.8571%	0.1370264	218762956481
POTASH	20.1269%	0.0606479	401704526858
TSP	21.6704%	0.0567453	195088605142
UREA_EE_BULK	41.3455%	0.1432666	654964650625

Food index share is a product of OLS coefficient estimates and commodity prices in 2010 PHOSROCK - Phosphate rock (Morocco), 70% BPL, contract, f.a.s. Casablanca; POTASH - Potassium chloride (muriate of potash), standard grade, spot, f.o.b. Vancouver; TSP - triple superphosphate, up to September 2006 bulk, spot, f.o.b. US Gulf; from October 2006 onwards Tunisian, granular, f.o.b.; UREA_EE_BULK - Urea, (Black Sea), bulk, spot, f.o.b. Black Sea (primarily Yuzhnyy)

Table A.3 - Energy price index decomposition

	Fertilizers index share	Weights (OLS results)	t value
COAL_AUS	4.6574%	0.0470608	46850219932
CRUDE_BRENT	28.4024%	0.3566549	32423841898
CRUDE_DUBAI	27.8409%	0.3566549	27260655583
CRUDE_WTI	28.3275%	0.3566549	72265575737
NGAS_EUR	4.2439%	0.5120861	35603862442
NGAS_JP	0.7917%	0.0729780	3819604998
NGAS_US	5.7361%	1.3080540	94312595385

Food index share is a product of OLS coefficient estimates and commodity prices in 2010

Given producers optimal decisions setting marginal product to the marginal price the cost share equation simplifies to β.

$$\frac{\beta * A * FERT_t^{\beta-1} * FERT}{A * FERT^{\beta}} = \beta$$

Unit root test results

Table A.4 - Unit Root Tests

	tau3	sig	lags
WHEAT	-3.3	*	1.00
MAIZE	-1.75		2.00
SOYBEANS	-1.69		2.00
BARLEY	-2.43		2.00
SORGHUM	-2.79		1.00
RICE	-3.71	**	1.00
WHEAT_SUR	-4.18	***	2.00
MAIZE_SUR	-1.83		1.00
SOYBEAN_SUR	-1.75		4.00
BARLEY_SUR	-3.45	*	1.00
SORGHUM_SUR	-2.09		1.00

	tau3	sig	lags
D.WHEAT	-5.97	***	1.00
D.MAIZE	-6.24	***	1.00
D.SOYBEANS	-6.61	***	1.00
D.BARLEY	-7.24	***	1.00
D.SORGHUM	-6.1	***	1.00
D.RICE	-6.14	***	1.00
D.WHEAT_SUR	-5.75	***	5.00
D.MAIZE_SUR	-5.91	***	1.00
D.SOYBEAN_SUR	-6.34	***	3.00
D.BARLEY_SUR	-6.63	***	2.00
D.SORGHUM_SUR	-4.89	***	1.00

Robustness check - regression results

Table A.5 - Cost Share Estimation

	Dependent variable:				
	WHEAT	MAIZE	SOYBEANS	BARLEY	SORGHUM
	(1)	(2)	(3)	(4)	(5)
FERTILIZERS	0.474***	0.473***	0.400***	0.373***	0.396***
	(0.061)	(0.077)	(0.077)	(0.061)	(0.077)
ENERGY	0.051	0.063	0.068	0.038	0.094
	(0.055)	(0.070)	(0.070)	(0.055)	(0.069)
MUV	0.238**	0.082	0.221	0.165	0.076
	(0.115)	(0.145)	(0.145)	(0.114)	(0.144)
t	−0.005*	−0.003	−0.004	0.016***	−0.001
	(0.003)	(0.004)	(0.004)	(0.003)	(0.004)
Constant	2.253***	2.536***	3.077***	1.668***	2.632***
	(0.387)	(0.489)	(0.489)	(0.385)	(0.487)
ADF	−5.373***	−3.802**	−4.624***	−4.865***	−3.840**
Observations	54	54	54	54	54

	Dependent variable:				
	WHEAT	MAIZE	SOYBEANS	BARLEY	SORGHUM
	(6)	(7)	(8)	(9)	(10)
Fertilizers	0.364***	0.405***	0.252***	0.288***	0.316***
	(0.062)	(0.078)	(0.073)	(0.061)	(0.077)
Energy	0.129***	0.087*	0.138***	0.091**	0.117**
	(0.038)	(0.048)	(0.045)	(0.038)	(0.047)
USD	−0.642***	−0.499	−1.012***	−0.523**	−0.616**
	(0.236)	(0.299)	(0.278)	(0.234)	(0.293)
t	−0.0003	−0.001	0.001	0.019***	0.001
	(0.002)	(0.003)	(0.003)	(0.002)	(0.003)
Constant	6.215***	5.285***	8.833***	4.806***	5.952***
	(1.183)	(1.500)	(1.396)	(1.176)	(1.469)
ADF	−5.326***	−3.785**	−4.849***	−4.941***	−3.884**
Observations	54	54	54	54	54
Note:					*p<0.1; **p<0.05; ***p<0.01

Table A.5 - cont'd: Cost Share Estimation

	Dependent variable:				
	WHEAT	MAIZE	SOYBEANS	BARLEY	SORGHUM
	(11)	(12)	(13)	(14)	(15)
FERTILIZERS	0.393***	0.381***	0.229**	0.299***	0.276***
	(0.074)	(0.095)	(0.088)	(0.074)	(0.092)
ENERGY	0.097	0.114	0.164**	0.079	0.162**
	(0.059)	(0.076)	(0.070)	(0.059)	(0.074)
USD	−0.526*	−0.594	−1.105***	−0.481	−0.778**
	(0.288)	(0.367)	(0.341)	(0.288)	(0.358)
MUV	0.096	−0.079	−0.077	0.035	−0.134
	(0.137)	(0.174)	(0.162)	(0.137)	(0.170)
t	−0.002	0.001	0.003	0.019***	0.004
	(0.003)	(0.004)	(0.004)	(0.003)	(0.004)
Constant	5.332***	6.010***	9.544***	4.485**	7.186***
	(1.730)	(2.201)	(2.048)	(1.728)	(2.147)
ADF	−5.390***	−3.804**	−4.885***	−4.940***	−3.968***
Observations	54	54	54	54	54

	Dependent variable:				
	WHEAT	MAIZE	SOYBEANS	BARLEY	SORGHUM
	(16)	(17)	(18)	(19)	(20)
FERTILIZERS	0.363***	0.408***	0.246***	0.275***	0.322***
	(0.071)	(0.083)	(0.089)	(0.061)	(0.087)
ENERGY	0.080	−0.001	0.177**	−0.037	0.157**
	(0.056)	(0.073)	(0.071)	(0.054)	(0.069)
USD	−0.304	0.364	−0.861**	−0.622**	−0.454
	(0.283)	(0.408)	(0.339)	(0.240)	(0.359)
MUV	0.193	0.669**	−0.047	0.090	−0.082
	(0.134)	(0.255)	(0.156)	(0.113)	(0.161)
t	−0.003	−0.015**	0.002	0.029***	−0.004
	(0.003)	(0.006)	(0.004)	(0.004)	(0.005)
SUR†	−0.314**	−0.406***	−0.145*	−0.489***	−0.117**
	(0.119)	(0.110)	(0.073)	(0.101)	(0.056)
Constant	3.708**	−1.370	7.952***	4.183***	5.306**
	(1.735)	(2.753)	(2.037)	(1.422)	(2.154)
ADF	−5.028***	−3.533**[25]	−4.879***	−6.384***	−3.895**
Observations	53	53	49	53	53
Note:					*p<0.1; **p<0.05; ***p<0.01

† SUR - stock-to-use-ratio for each of the commodity respectively

THEMATIC SET

C17

MEASURING TRADE PROTECTION AND OTHER FORMS OF INDIRECT TAX/SUBSIDLES

Session Organizer
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Towards a consolidated database of distortions agricultural incentives: the Ag-Incentives Consortium
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C17

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PAPER

I. Executive Summary

This report reviews the agriculture support policies of 18 Latin American and Caribbean (LAC) countries, which together account for 92% of the region's agriculture value added. Although agricultural policies and programs in LAC are heterogeneous, there are clear trends and commonalities. The review measures agriculture support policies and programs using the OECD Producer Support Estimates methodology[1].

Collectively, during the last year when data was measured, the LAC countries covered in this review transferred an annual amount of US$27.2 billion to farmers, and they spent an additional US$ 5.8 billion on agriculture public goods and services (here called general support services or GSSE). LAC Countries (as other emerging economies) have gone from taxing their agriculture sector in the 1990s to providing net levels of support. On the other hand, the level of support from high-income (OECD[2]) countries has been reducing, therefore showing some convergence and the opportunity for the agriculture sector of LAC to compete in a more level playing field. 7% of the gross agricultural receipts (agriculture income) of an average farmer in the LAC countries covered under this review (2010-2014) came from agriculture support policies and programs. This is very low compared to 18% in OECD countries (2014). There has also been an important shift within LAC in moving from market price support (MPS) which distort market prices for agriculture products, to direct farmer support (through fiscal support). However, 37% of producer support still comes from MPS.

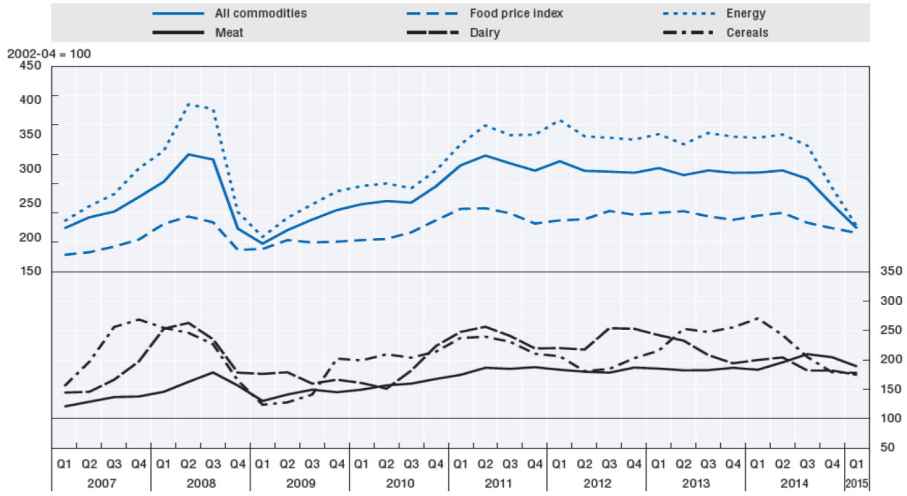
II. Economic and Agriculture Market Developments in LAC

Over the last two decades, LAC countries have shown positive trends for agriculture development, and in particular agricultural trade. Although trade in agricultural products has declined as a percentage of overall trade worldwide, its value has grown substantially. The LAC region has captured an increasing share of this growing market and currently holds a much larger portion of world trade in agriculture (13 percent, up from about 8 percent in the mid-1990s) than in minerals and metals (8 percent) and manufactured goods (3 percent). Agriculture and food now represent about 23 percent of the region's exports and 10 percent of global trade. Over the period 1995–2009, export growth averaged 8 percent a year. Temperate products (cereals, oilseeds, and livestock products) accounted for more than half of this growth. Seafood, fruits and vegetables contributed around 15 percent, followed by processed products like beverages and tobacco. Of course, this pattern varies by sub-region, with, for example, fruits and vegetables being the dominant contributor in Mexico and the Andean region. Almost all LAC countries contributed to the export growth, but Brazil made the largest contribution by far (more than 35 percent), followed by the Southern Cone (around 30 percent). Except Colombia, the region's largest exporters have all increased their global market shares.Among the second tier of exporters, Peru, Ecuador, Paraguay, and Uruguay have also increased their market share. Central American and Caribbean countries, except Costa Rica and Guatemala, have maintained or lost their market shares. Though the EU and the United States remain LAC's most important destinations—accounting for a combined 45 percent of LAC's exports in 2009, down from 57 percent in 1995—developing countries are becoming the most dynamic destination for the region's exports (UN COMTRADE Data). Over 1995–2009, China and the rest of the world, with a combined 30 percent of the market share, contributed 36 percent of the growth of exports from the region, nearly the 38 percent contribution of the EU (20 percent) and the United States (18 percent).

[1] See: www.oecd.org

[2] Please note that there is one country in LAC, Mexico, which is part of the OECD, and therefore is counted in both groups..

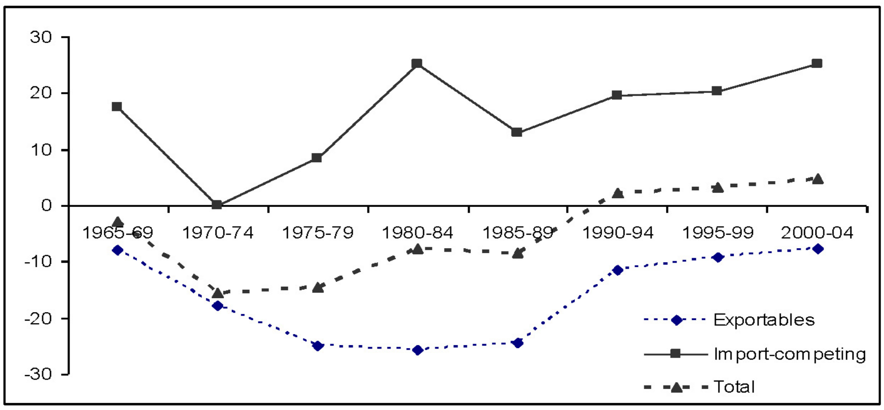
Graph 1 - Commodity world price indices, 2007-2014



Source: OECD (2015). Agriculture Policy Monitoring and Evaluation 2015. Highlights.

Also, while developed economies imported primarily fruits, animal fodder, coffee, beverages, and seafood from LAC, products from the soybean complex (seeds, oil, and cake), meat, and sugar represented almost 60 percent of the trade with developing economies. However, commodity prices declined broadly in 2014 (see Graph 1) and this has put some downward pressure on sector profits and government revenues from the sector. In their own agriculture trade policies, LAC countries have made great strides since the 1960s and 1970s, when highly protectionist trade policies and exchange rate regimes promoted industry-led development. This created in LAC and most other developing countries a strong anti-export and anti-agriculture incentive structure. Relative rates of assistance show the protection of manufacturing compared with that of agriculture, with negative values indicating an anti-agricultural bias (Graph 2). In LAC, the overall incentive structure has been close to neutral since the early 1990s. By contrast, some developing regions (including Africa) still maintain a net taxation of agriculture, while others have moved to the agricultural subsidization model of the high-income countries. This does not imply, however, that there is no need for further reform in LAC. The overall neutral structure masks a greater protection of import substitutes than of exportables, creating an anti-export bias for agricultural production. Nonetheless, this difference has greatly diminished since the 1980s, indicating that this anti-export bias has lessened, and one of the latest important changes has been the elimination of almost all agriculture export taxes by Argentina at the end of 2015.

Graph 2 - Nominal Rate of Assistance (NRA) of agrifood products from LAC



Source: Anderson and Valdez (2008).

III. Main agriculture policies and programs in LAC

Agriculture policies and programs of LAC countries are diverse and change quickly in several countries. While many countries have a mix of policy measures and programs, policy designs differ between countries. The landscape of agricultural policies can be characterized by five different approaches:

1. **Market Price Support (MPS), through border measures**: Those policy instruments prevail in terms of Producer Support Estimates (PSE) in Uruguay, Peru, Suriname, all 5 Central American countries[3], Jamaica, Ecuador and Colombia.

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[3] Includes Nicaragua, El Salvador, Honduras, Costa Rica and Guatemala. Excludes Panama and Belize.

2. **Reducing costs of purchased inputs and capital**: Subsidies to farm-purchased variable inputs, such as energy and fertilizers have recently become more important in Brazil, Chile and Mexico. Concessional credit schemes to stimulate agricultural investments are cornerstone policies in Brazil and Colombia.

3. **Emphasis on policies that mitigate the downside risks to revenue and income**: This hasrecently been reinforced in Peru, Brazil and Mexico.

4. **Emphasis on extension services to farmers**: Recent increase in provision of extension services to farmers were observed in Chile, Peru, Paraguay and Uruguay.

5. **Emphasis on enabling business environment for agriculture**: Countries that focus their policy instruments on general services with a public good character include Chile, Peru, and Uruguay.

The specific dualistic nature of the sector leads to a twin-pillar policy approach. One set of policies addressing the competitive commercial segment, and another set addressing a struggling small-scale segment. Brazil and Chile explicitly differentiate their policies between those segments and typically provide support to small farmers through a variety of measures that reduce costs of capital and other purchased inputs and facilitate better market integration.

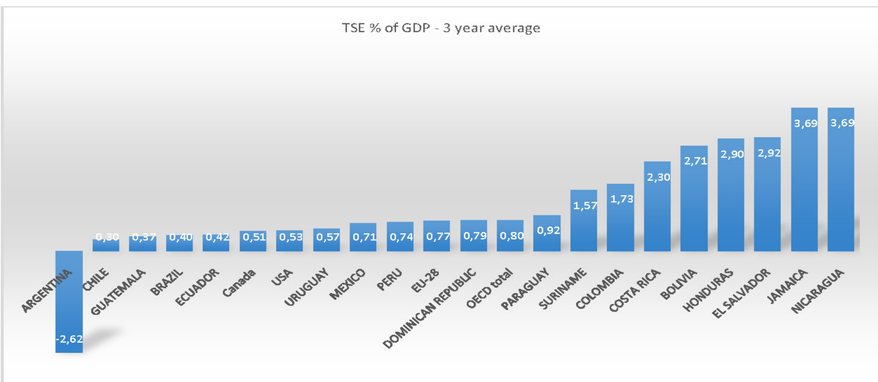
Several countries make efforts in agricultural innovation systems to improve productivity and sustainability in the long term. Much of those efforts occur outside the field of more narrowly defined agricultural policies, which would typically cover expenditures on extension and farm advisory services, and are embedded in national innovation strategies. Finally, with agriculture contributing directly and indirectly about a quarter of global greenhouse gas (GHG) emissions, climate change mitigation is increasingly on the agricultural policy agenda. With a few exceptions (like Brazil and Uruguay[4]), actual policy efforts are relatively limited, however.

IV. Review of agriculture support estimates

Here we present the estimates of agriculture support policies and programs for LAC to assess the type of supports, the composition of supports, and its evolution over the past few years. The 18 LAC countries reviewed are the ones with data on agriculture support estimates published in the IDB Agrimonitor database[5]. However, it is important to note that for practical purposes, in some of the graphs and analysis undertaken in this section, Argentina was left out as it is an outlier in LAC, showing large negative support estimates (total and producer support estimates) due to the export taxes in place until 2015. Also, when looking at the average of OECD countries, note that Mexico is part of the OECD data. This section begins with assessing the Total Agriculture Support Estimates (TSE), its composition and its evolution. It then reviews the Producer Support Estimates (PSE), its composition, and evolution. Finally, the section focuses on Consumer Support Estimates (CSE) and General Support Services Estimates (GSSE) or agriculture public goods and services. Total Support Estimate (TSE), expressed as a percentage of GDP, illustrates the weight that countries assign to agriculture support policies. The TSE combines transfers to agricultural producers individually (measured by the Producer Support Estimate, the PSE), policy expenditures that have primary agriculture as the main beneficiary, but that do not go to individual farmers (measured by the General Services Support Estimate, the GSSE) and budgetary support to consumers of agricultural commodities (the Consumer Support Estimate, CSE, net of the market price element that is already accounted for in the PSE).

a) Total Support Estimates (TSE) and its composition (as percentage of Ag GDP and GDP)

Graph 3



(*) Note: The 3-year average takes the last 3 years when data is available on agriculture support estimates (see Agrimonitor database: http://www.iadb.org/en/topics/agriculture/agrimonitor/agrimonitor-pse-agricultural-policy-monitoring-system,8025.html). These 3-year averages can go from 2007 to 2014.

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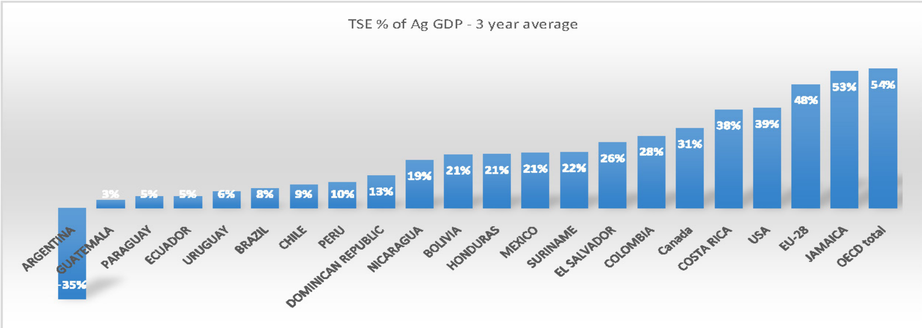
[4] Brazil has a large climate smart agriculture (CSA) policy, promoting CSA technology adoption (Programa Agricultura de Baixo Carbono – ABC. See: http://www.agricultura.gov.br/desenvolvimento-sustentavel/plano-abc). Uruguay also has a major public policy on climate change adaptation (see: http://www.mgap.gub.uy/portal/page.aspx?2,MGAP,mgap-desarrollo-y-adaptacion-al-cambio-climatico,O,es,0,).

[5] See: http://www.iadb.org/en/topics/agriculture/agrimonitor/agrimonitor-pse-agricultural-policy-monitoring-system,8025.html

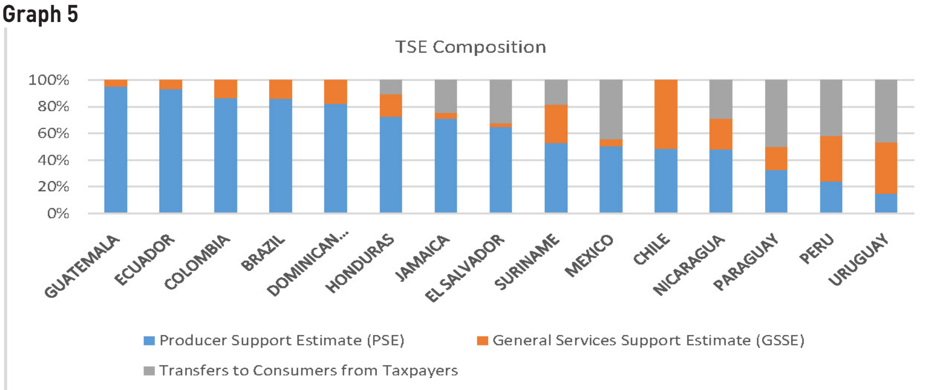
Graph 4 below shows that, with the exception of Jamaica, LAC countries provide a lower level of agriculture support (measured as TSE as % of their Agriculture GDP), than OECD, USA, and EU countries. We observe that countries in the southern cone (Argentina, Paraguay, Uruguay, Brazil, Chile and Peru) tend to have lower TSE% (less than 10%) than the rest of the LAC region. However, when comparing the TSE to overall GDP (see Graph 3 above), we observe that the TSE% is lower for OECD, USA, and EU countries than several LAC countries. This reflects the fact that agriculture represents a lower share of the total GDP of high-income countries, and therefore, although the TSE is high relative to the sector, it is low relative to the economy as a whole. On the other hand, several countries in LAC, in particular in the 5 Central American countries, have an agriculture sector that is more important in relation to the overall economy, so the size of supports to its agriculture will be larger in relation to its overall GDP than in high-income economies where agriculture represents a smaller share.

Graph 4

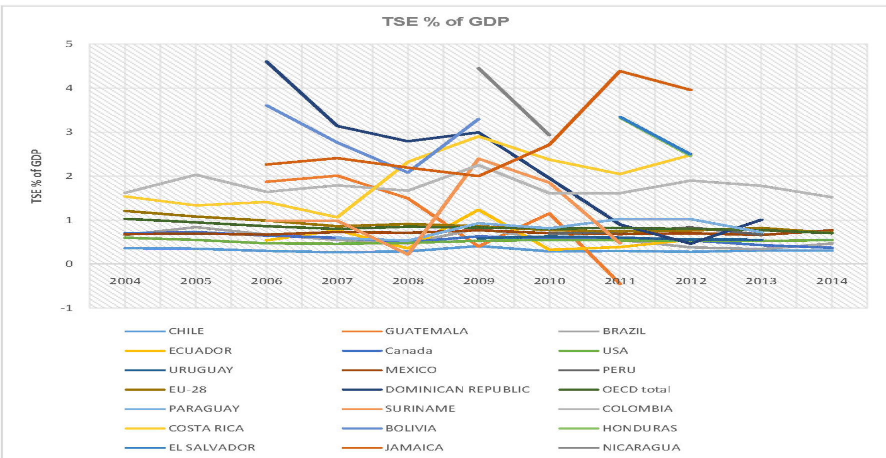


The composition of TSE (see Graph 3 below) shows that support to the producer support (PSE) is the main type of agriculture policy in LAC, with the exception of Paraguay and Uruguay, where transfers from consumers to taxpayer and general support services (GSSE) are more important respectively. Also, the evolution of TSE as % of total GDP (see Graph 5 below) shows that with the exception of Jamaica and Costa Rica, TSE has been decreasing, as it happened in higher income countries. While in 2004 more than half of LAC countries' TSE was above 1% of GDP, by 2013-2014, most were under 1%. Finally, the evolution of the composition of TSE (see Graph 6 below) shows that although PSE is still the main type of agriculture policy in LAC, it has been decreasing in importance in several countries. Chile, Colombia, Dominican Republic, Honduras, Paraguay, Peru and Uruguay have seen its PSE (as % of TSE) be reduced in importance while GSSE and increase. On the other hand, Brazil, Ecuador, Jamaica, Argentina, Guatemala and Mexico has seen its PSE increase (as % of TSE).

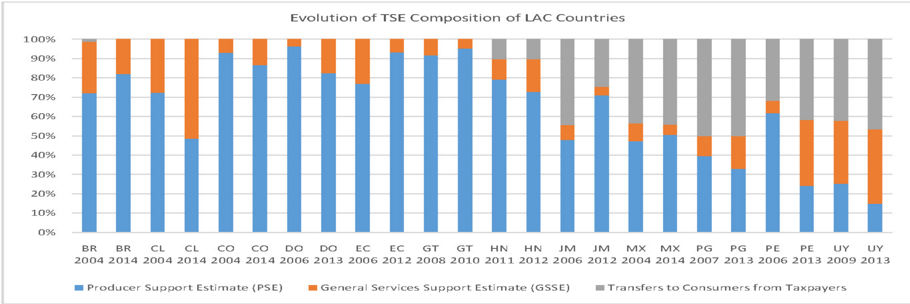
Graph 5



Graph 6

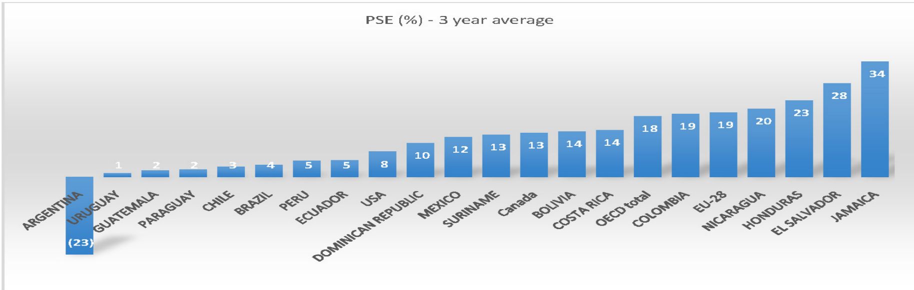


Graph 7



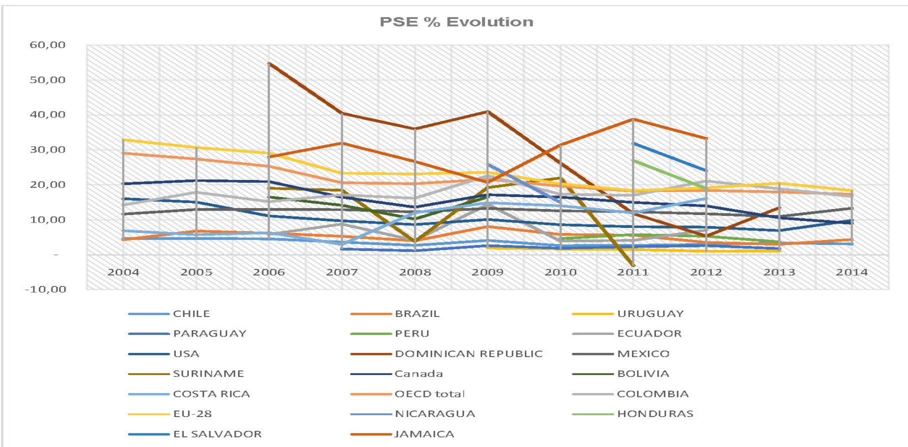
b) Producer Support Estimate (PSE) and its evolution (as percentage of gross farm receipts)

Graph 8



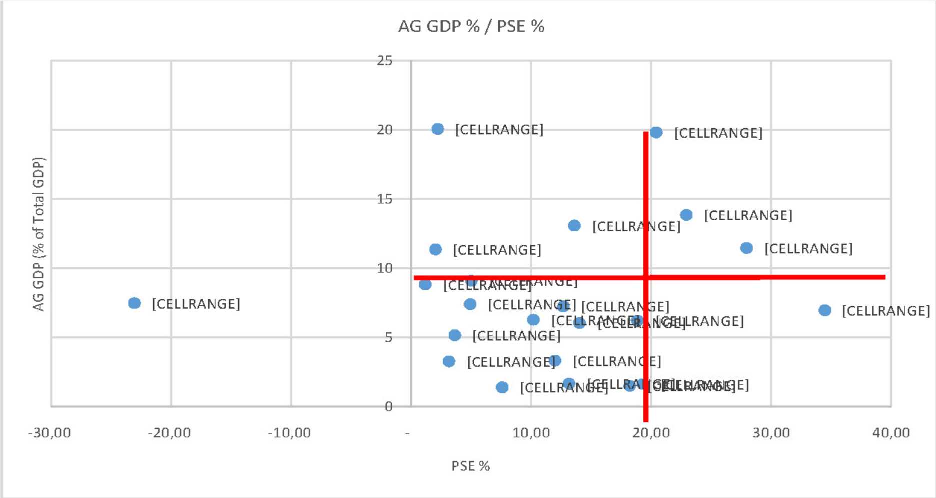
In terms of Producer Support Estimate as a percentage of gross farm receipts (PSE%), we observe again (see Graph 8 above) how Southern Cone countries have lower levels of support than the other LAC countries (with the exception of Guatemala who scores lower than Paraguay, Chile and Brazil). It is important to note the group of LAC countries with levels at or above the OECD / EU (PSE% above 18%): Colombia, Nicaragua, Honduras, El Salvador and Jamaica. This Graph 6 show important differences in terms of PSE% between LAC countries, even neighboring ones. For example, 2% of the farm income of an average farmer in Guatemala comes from agriculture support policies and programs, while for an average farmer in neighboring El Salvador it is 28% (more than a quarter of farm income). The evolution of the PSE% over time (see Graph 9 below) shows that there has been a decline in PSE%, with the exception again of Jamaica and Costa Rica, which have seen their PSE% increase. In 2004, several LAC countries showed PSE% above 20%, while by 2014, all countries with data were under the 20% mark.

Graph 9



c) Correlations between PSE level for each country and other variables (like GDP/capita, rural/urban population, agriculture GDP)

Graph 10

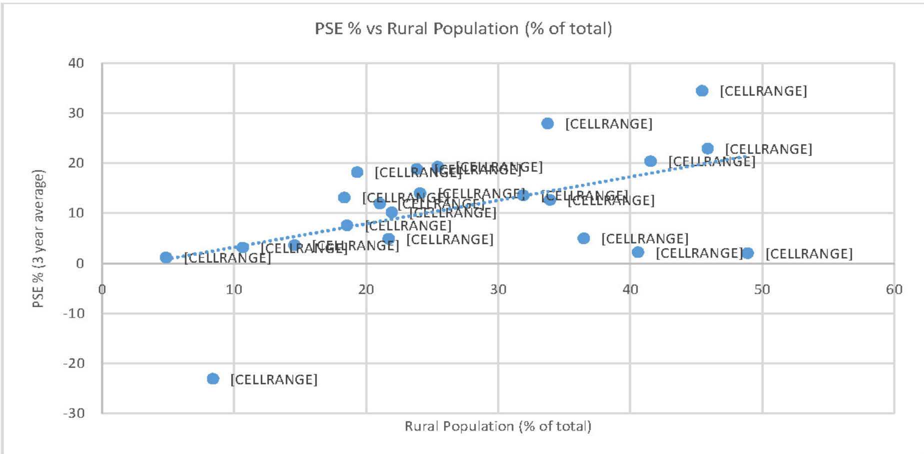


When comparing the weight of the agriculture GDP in the total GDP with the PSE% (see Graph 10 above), it is clear that most countries with an agriculture sector that represents less than 10% of its total GDP have PSE% of less than 20%. This means that less than 20% of farm income of the average farmer in most countries in LAC (as well as OECD, Canada and the US), comes from agriculture support policies and programs. However, countries like Guatemala, Paraguay and Bolivia, also show relatively low levels of PSE% (less than 20%), but their agriculture sector represents more than 10% of their total GDP. For these countries where agriculture is a large portion of the country's total GDP, the challenge is how to support their agriculture sector without burdening taxpayers (as the fiscal resources needed would need to be large as percentage of the country's total public budget).

Another group is Nicaragua, Honduras and El Salvador; countries that have agriculture sectors that represent an important size of their economy (more than 10% of total GDP), but with relatively high levels of PSE%. For these countries, both fiscally, but also for consumers, supporting the agriculture sector is a relatively large burden. Improving agriculture public expenditures and ensuring that farmers improve their competitiveness by reforming agriculture policies and programs towards non-distortive approaches should be at the center of the agriculture policy dialogue of these countries. Finally, Jamaica, a country with an agriculture sector that represents less than 10% of its GDP, but with the highest PSE% of LAC, shows that the economy and its taxpayers and consumers are heavily supporting its farmers, and that this may be afforded as its agriculture sector is relatively small compared to other LAC countries.

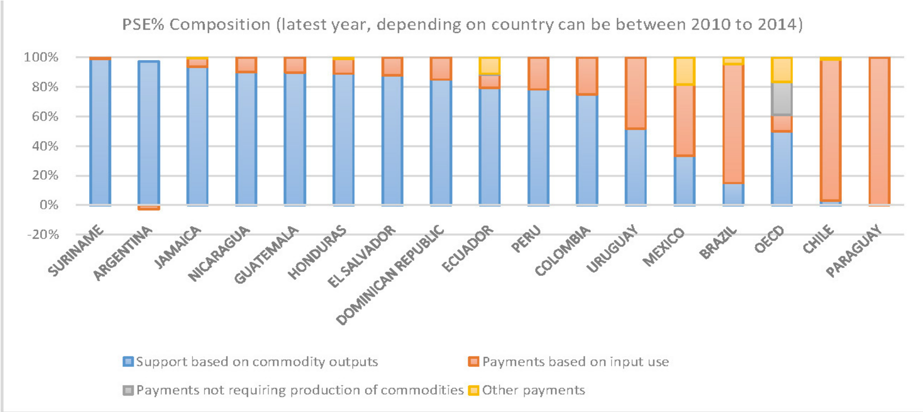
Therefore, although Graph 10 shows no clear correlation between agriculture GDP (as % total GDP) and PSE%, there are groupings of countries that emerge. A group in the lower left hand quadrant of the Graph 10, where most countries are, with low levels of agriculture GDP (as % of total GDP) and low levels of PSE%. Then there are three smaller groups (with three countries or less, each). One small group (composed of Guatemala, Paraguay and Bolivia) with a high importance of agriculture GDP in their economies, but with low levels of PSE%; another small group (composed of Nicaragua, Honduras and El Salvador), with high levels of PSE% and an important role of the agriculture sector in total GDP; and the third one composed only of Jamaica with high levels of PSE% but a relative small agriculture sector in relation to total GDP.

Graph 11



When looking at PSE% in relation to the importance of the rural population (as % of total population), we observe a correlation (see Graph 11 above). The countries with relatively larger rural populations have higher levels of PSE%. This could be due to the importance that these countries place on supporting the rural population, as agriculture incomes tend to be the single most important source of income for rural households in LAC. The higher levels of PSE% in Central American and Caribbean countries could be driven by the weight that the rural population places on prioritizing agricultural public policies and programs. However, there are some exceptions (outliers) to this correlation, specifically, Guatemala and Paraguay, which have a relatively large rural population but low levels of PSE%.

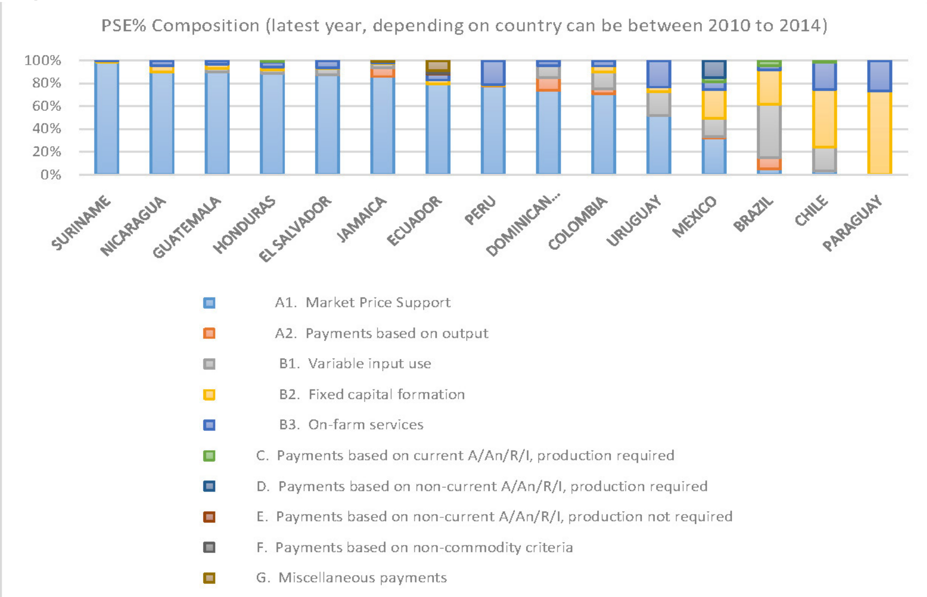
Graph 12



d) Composition of fiscal support of PSEs per country (as percentage of PSE)

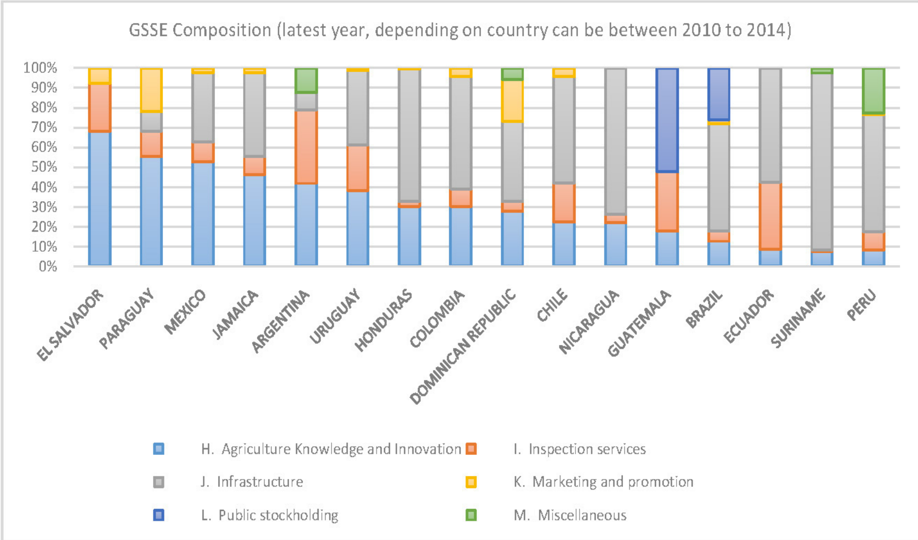
Graph 12 above shows the composition of PSE for LAC countries and the OECD. There is a clear heterogeneity in the composition of PSEs in the region. While OECD countries show a more balanced mix of supports, LAC countries rely heavily on supports based on commodity outputs, and in some countries like Chile, Brazil, and Paraguay, on payments based on inputs. A closer (more disaggregated) view of these PSE compositions (see Graph 13 below) reveal that the larger part of the support based on commodity outputs is derived from Market Price Support (MPS), which represents transfers from consumers to farmers through higher domestic prices due to tariff and non-tariff barriers. MPS does not require public expenditures, while the other types of supports do. In countries such as Chile, Brazil and Paraguay, with very little or no MPS, we observe that the supports are mainly focused on on-farm services (extension) and fixed-capital formation (asset creation), while in Brazil and Chile, supports based on variable inputs are also important.

Graph 13



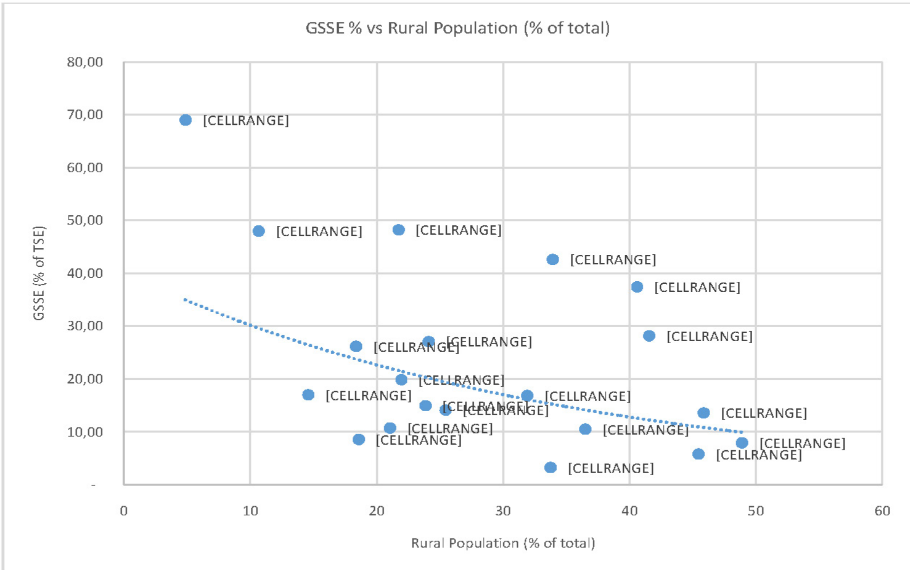
e) Composition of GSSE per country (as percentage of GSSE, US$ and percentage of Ag. GDP).

Graph 14



The composition of General Support Services (or agriculture public goods and services) is also heterogeneous across LAC (see Graph 14). Regardless of the level of GSSE, some LAC countries like Argentina, Uruguay, El Salvador, Jamaica and Paraguay spend a larger portion of GSSE resources on agriculture knowledge and innovation compared to OECD countries. Suriname, Peru, Honduras, Nicaragua, Ecuador, Colombia, Chile and Brazil spend more on infrastructure development and maintenance compared to OECD countries. Finally, only Paraguay and the Dominican Republic spend more than the OECD in marketing and promotion. Public stockholding is virtually non-existing in most LAC countries, but it is a key GSSE category for Brazil and Guatemala.

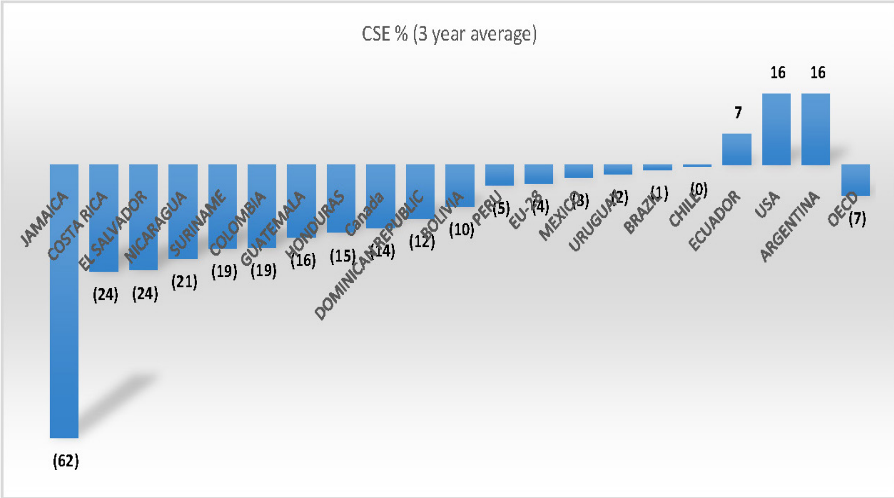
Graph 15



Contrary to the correlation between PSE% and the importance of rural population (Graph 14), Graph 15 shows that GSSE (as % of TSE) is negatively correlated with the share of the rural population in the entire population. This means that in countries where the rural population is larger (as % of total population) GSSE investments decrease in importance as a percentage of TSE. This could be reflecting a tendency for agriculture public policy to move towards direct farmer supports (PSE) in order to provide income support to low income farmers, while reducing the allocation towards GSSE. The incidence of poverty (and in particular extreme poverty) is higher in rural areas, and in countries with large rural populations, targeting agriculture as income support could be an effective way of helping reduce rural poverty.

Consumer support estimates as percentage of overall food consumption expenditures (CSE%) show that most countries (including Canada, EU, and OECD) have negative CSE (see Graph 16), meaning that consumers pay a higher price domestically than they would pay in the absence of agriculture policies and programs. Ecuador and USA have positive CSE% given that these countries provide support to consumers for food consumption (i.e. in the USA, the main program is foods stamps). Argentina has positive CSE% due to the high export taxes on agriculture products, which dampens the domestic food prices (until 2015).

Graph 16



f) Consumer Support Estimate (CSE) per country (as percentage of expenditure at farm gate)

V. Conclusions and proposed future agenda for agriculture policy reform

Collectively, the LAC countries covered in this report (excluding Argentina) transferred annually an average of USD 26.3 billion to agricultural producers in the years 2012-14 (compared to USD 601 billion of the OECD countries) and theyspent an additional USD 5.5 billion (compared to USD 135 billion of the OECD countries) on general services that support the functioning of the sector. Those transfers are burdening consumers and taxpayers, and reforms could improve the effectiveness and efficiency of policies.

However, in LAC as a whole (with the exception of Costa Rica and Jamaica), gradual progress has been made in reducing the level of support to farmers and in introducing less distorting forms of support. The level of support was reduced and the share of production and trade distorting support fell. Those changes occurred to different degrees and at different speeds, with slow changes particularly in the group of countries that rely heavily on instruments that support prices

and production. The GSSE tends to focus on agriculture knowledge and innovation and infrastructure, with less resources going to inspection and promotion and marketing. At the same time, the large use of instruments such as market price support and input subsidies in countries like Peru, Ecuador and the 5 Central America is worrying as this increases distortions on domestic and international markets and is a rather cost-ineffective way to provide assistance.

Given the competitive position of LAC in food production and trade, it is important to think about reducing vulnerability to shocks and adapting to climate change, in order to maintain a constant and reliable food supply both domestically and abroad. OECD countries, including USA and EU, are already reforming their agriculture support structures to become more competitive in the global agricultural arena. There needs to be an increase in investment in agriculture public goods and services in order to improve the capacity of the agricultural sector of LAC to respond to those challenges and to realize its full economic potential. This also reinforces the need to improve the wider policy environment in which the sector operates so as to attract financial and human resources and to foster an innovative agricultural sector that responds to societies' needs.

Such a broader re-orientation of policy approaches require a clear vision of the end-point of policy reforms at national and international levels. In the short term, an agriculture public policy dialogue needs to be undertaken in LAC countries in the following areas:

- **Prioritize investments in agriculture public goods and services**: There is a need in LAC to move away from farm income support to invest in knowledge, education and strategic infrastructure that can help improve the long-term productivity, sustainability, and profitability of the sector. This has shown to reap larger economic returns than direct income support to farmers.

- **Within agriculture public goods and services, invest in agriculture knowledge and innovation**: There is a need to strengthen the governance of innovation in agriculture to improve the strategic orientation on long-term issues. Several LAC countries invest less in agriculture knowledge and innovation than OECD countries.

If direct farmer support is needed, it is important to engage in a policy dialogue in the following areas:

▪ Market price support should be reduced, replacing it with non- distortive direct supports and/or agriculture public goods and services. LAC consumers pay the bill of MPS, especially low-income households. However, fiscal space must be available to do that, and therefore external financing could support this transition. It also delinks farmers from market signals and has been shown to be highly distortive for production and trade.

▪ Input subsidies are inefficient in assisting farmers as they increase the risk of over- or misuse of farm inputs such as fertilizers which can be environmentally harmful. Concessional credit schemes can pose a big burden to government budgets, as it is the case in Brazil. Variable input support has also been shown to be particularly production and trade distortive. Transforming from such subsidies to decoupled subsidies (as was done in Mexico and Paraguay) would need to be on the agenda in the short term.

▪ Direct payments, as was done with the PROCAMPO in Mexico, may be an efficient means in specific policy areas such as to achieve environmental benefits and supporting farm incomes. However, they need to be linked to clear objectives and targets, and well-tailored to the problem at hand. Direct payments can play an important transitory role in the process of reforming agricultural policies in LAC.

C17

Towards a consolidated database of distortions agricultural incentives: the Ag-Incentives Consortium

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ABSTRACT

It is important to measure and analyse the impacts of policy design on agricultural markets. Indirect measurement of incidence, e.g. nominal rate of protection (NRP), is one reliable method to do this, as it relies on price gaps between what producers see and what is prevailing in international markets. Ag-Incentives Consortium, a collaboration effort among international organizations that work on measuring distortions to agricultural incentives, is a new initiative that attempts to bring clarification, harmonization, and methodological guidelines to the forefront. This study, based on but not limited to Ag-Incentives, computes NRPs based on a combined input data from all IOs. The results show that high income countries have decreased protection over time, whereas middle income countries have increased it. Low income countries have higher variation in protection, and respond to food price crises of 2008 and 2011 different than high and middle income countries.

Keywords: agricultural incentives, Nominal Rate of Protection, Nominal Rate of Assistance, Producer Support Estimate

PAPER

1. Introduction

In an environment of growing demand and limited natural resources, the importance of correct policy measurement, categorization, and interpretation for the optimal design, monitoring and evaluation of agricultural, environmental, and trade policies cannot be stressed enough. In this context, it is also crucial to identify which parts of agricultural distortions are due to market failure and to distinguish these from the part that is due to effective policy intervention. Agricultural distortions, originating from either policy design or other sources, also create and influence value chains within a country or across countries. With the observed expansion of regional and global value chains, the measurement of distortions along the agricultural value chain is necessary for effective policy design as well.

There are multiple methodologies utilized and different data sets employed in the literature and by international organizations (IOs) to measure distortions to agricultural incentives. In terms of institutional efforts, World Bank started with Nominal Rate of Protection (NRP) database and updated later with Nominal Rate of Assistance (NRA). OECD has continuing efforts with Producer Support Estimate (PSE) database that has been expanded to non-OECD countries. At the same time, new efforts have taken place, such as FAO-MAFAP that focused on Africa and is now expanding to Asia. IDB-Agrimonitor uses OECD methodology and focuses on Latin America and the Caribbean countries.

With different datasets, assumptions, methodologies, and time spans, a consistent long-term measurement across all developed and developing countries has eluded policy makers. This has made it difficult for them to correctly measure, compare, and interpret the impact of their policy designs across commodities, countries, and time spans. To facilitate this, an Agricultural (Ag) Incentives Consortium has been brought into fruition including OECD, FAO-MAFAP, IDB, WB, IFPRI, and CGIAR PIM. The Ag-Incentives Consortium focuses on organizing collaboration among IOs. One pillar of this is generating a common chest of clearly defined and well-documented common indicators, with a focus on prices. Second pillar is about expanding country and product coverage. Third pillar is providing a platform for tackling new issues and improving methodologies.

In this paper, we first present a summary of the efforts in the literature to measure distortions and the relevant methodological discussions. Next, we present a synopsis of the Consortium and its goals, as well as data processing conducted for the databases of members of the Consortium. We, then, present and discuss the NRPs computed based on, but not limited to, the Ag-Incentives Consortium efforts followed by a conclusion.

2. Methodologies in the literature

There is a wide literature as well as multiple IO databases that measure agricultural incentives. Both the literature and the IOs use two main approaches: indirect measurement of incidence and direct measurement of policies.

For indirect measurement of incidence methodology, NRP estimates by Krueger, Schiff and Valdes (1988) were the first major attempt to look at both direct sector specific and indirect economy-wide policies on agricultural incentives in various developing countries. Direct effect was measured by the proportional difference between the Producer Price and border prices adjusting for distribution, storage, transport, and other marketing costs (Reference Price). Therefore, Direct NRP would be

$$NRP_d = ((PP_i / RP_i) - 1)$$

Indirect NRP is measured in two parts, first, through the impact of the unsustainable portion of the current account deficit and of industrial protection policies on the real exchange rate and thus on the price of agricultural commodities relative to non-agricultural non-tradable commodities. Second, through the impact of industrial protection policies on the relative price of agricultural commodities to that of non-agricultural tradable goods.

Anderson et al. (2008) expanded this effort by measuring NRA and outlined the many methodological issues with deriving such numbers. Different components of NRA were identified and defined, such as NRA to farm output conferred by border price support, NRA to output conferred by domestic price supports, NRA to inputs, among others. Furthermore, there is clearer identification of non-distortionary price wedges, which help in location and evaluation of prices being transmitted along the value chain.

For direct measurement of policies, OECD has continuing efforts with PSEs (OECD 2015). For OECD, PSE is more complex and is a part of the Total Support Estimate, which is an indicator of the annual monetary value of all gross transfers from taxpayers and consumers arising from policy measures that support agriculture, net of the associated budgetary receipts. Here, the percentage PSE represents policy transfers to agricultural producers, measured at the farm gate and expressed as a share of gross farm receipts.

OECD also calculates the Nominal Protection Coefficient (NPC) that includes budgetary outlays and treats input markets differently. It is the Producer Price relative to the Reference Price, with the unit value of payments based on output also included.

$$NPC = (PP + (\text{payments based on output/production quantity}) / RP)$$

Transfers included in the PSE are composed of market price support, budgetary payments, and the cost of revenue foregone by the government and other economic agents as over time. The PSE has evolved from being just a measure of market price support to including payments based on output as well as well as expanding beyond taking into account just direct payments to multiple sources of payments. The Market Price Support (MPS) for a commodity is estimated either by adding together transfers to producers from consumers and taxpayers or by multiplying the quantity of production by the market price differential (the difference between farm and border price). The MPS component of PSE is similar to NRP in that it also depends on price gaps.

FAO-MAFAP (MAFAP 2016) and IDB-Agrimonitor (2016) use methodologies developed by the World Bank and OECD respectively. Country and commodity coverage show some overlaps with these IOs.

3. Consortium structure and database

The objectives of Ag-Incentives Consortium are to bring together the findings from the organizations active in this field on a continuing basis in order to develop a global view of incentives, and to shine a light on incentives in some of the smaller economies where distortions to agricultural incentives have a particular impact on the poor. Ag-Incentives Consortium achieves these through creation of a community of practices, work on harmonization and consolidation of a database, and providing quality control and scientific rigor.

As seen in Table 1, all IOs publish measurement of distortions with some overlap across geographical and sectoral coverage and time span. The goals of the Consortium, therefore, include maintaining the mandate and the independency of each IO, and creating a collaborative approach for database, with a clear recognition of IPR.

Table 1 - Country and commodity coverage by IOs

International Organization	Economic Clusters Covered	Number of countries	Time Period	Total Commodities	Metrics Reported
OECD	OECD + Emerging	23	1986-2014	58 individual, NONMPS, Total	PSE, MPS, NPC, MPD
World Bank	various	82	1955-2007, updated 2011	72 individual	NRP, NRA
FAO-MAFAP	Selected African	9	2005-2013	27 individual	NRA
IDB-AGRIMONITOR	Latin America and Caribbean	17	2004-2013	37 individual	PSE, MPS

Note: Not all countries report all data for all commodities listed and all years

The initial focus of the Consortium has been on price distortions, with a consolidated indicator based on each IO database. We selected NRP, based on Krueger, Schiff, and Valdes (1988) to be computed and made publicly available. NRP is the ratio between the price gap and the observed reference price measured at the same point in the value chain.

We use the method for Direct NRP from Krueger, Schiff, Valdes (1988) to create a consolidated NRP with the underlying price metadata from IOs. We also compute average NRPs for the agricultural sector or a country, and global NRP for a commodity.

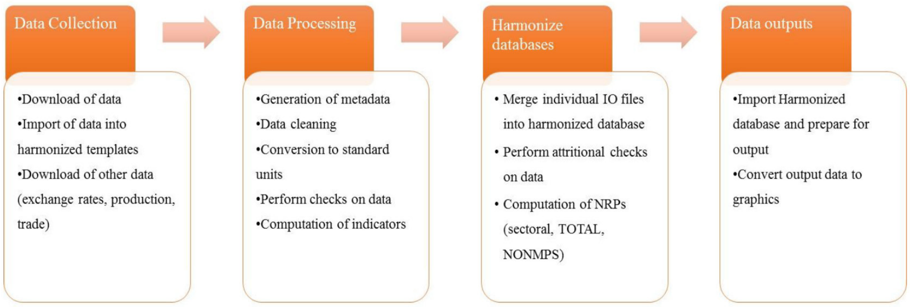
$$NRP_{TOTAL} = ((sum_c(PP_c {*} Q_c) / sum_c (RP_c {*} Q_c)) - 1)$$

$$NRP_{SECTOR} = ((sum_i(PP_i {*} Q_i) / sum_i (RP_i {*} Q_i)) - 1)$$

We use NRPs to measure distortions based on the law of one price, where the goods must be comparable (in terms of quality, processing level, and location). Reference price is border price evaluated at official nominal exchange rate adjusted for transport, storage, distribution, processing, and quality differences based on input data provided by each IO.

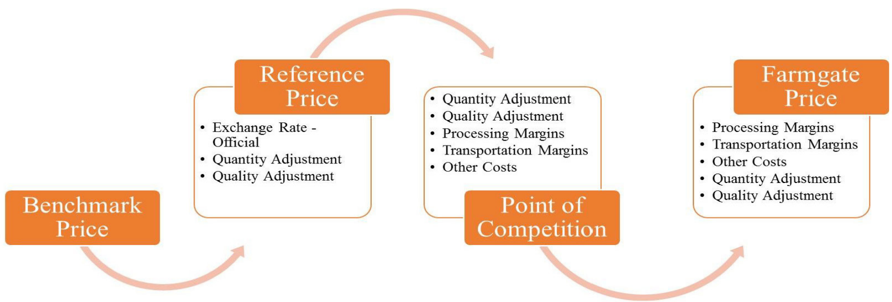
The first step before computing NRPs, is the harmonized metadata template that incorporates input data for all IOs involved and deals with and computes NRPs for commodities and countries as described in Figure 1.

Figure 1 - Harmonized data template process



We construct the harmonized metadata template is constructed to identify the path of price transmission across the Value Chain and measure changes in price along this path while computing reference price at the same point in the value chain. This is described in Figure 2.

Figure 2 - Price Transmission across Value Chain



Based on input data from IOs, we computed a continuous series of NRPs. Since there is some overlap across IOs in terms of commodity and country coverage, we use a hierarchy to select the final NRP. When there is an overlap for a period, country or commodity, the first selection for NRP is OECD database, followed by MAFAP-FAO, IDB, and World Bank. This selection process may create an NRP coverage for a country where one commodity NRP is from one data set and another commodity NRP is from another data set. Same issue exists for the time span of a commodity coverage.

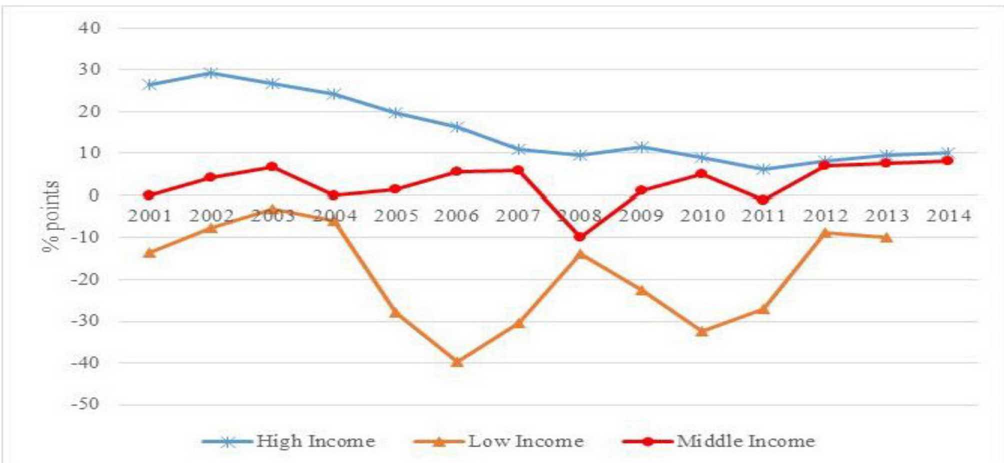
4. What do we learn from NRPs?

Figure 3 below presents average global NRPs weighted by production quantity as seen in above equations. Figure 3 also includes FAO Food Price Index based on international prices weighted with the average export shares of each of the groups for 2002-2004. As seen below, there is some, but not significant, variation in global NRP for the agricultural sector, although values are positive (except for 2008), showing that overall agricultural policies have protected farmers. As expected, we see that average NRPs and average Food Price Index move in opposite directions. When global food prices are rising, governments are insulating consumers, by reducing or eliminating import duties or adding export taxes that in turn reduce protection afforded to producers. The clearest example is in 2008 and 2011 food price crises, with the drop in global average NRP and the jump in Food Price Index.

Figure 3 - Average NRPs for agricultural sector globally and FAO Food Price Index.

In Figure 4, we present the average NRPs for the agricultural sector categorized by income levels of countries. For the period shown, high income countries have higher protection for their farmers, although the average protection rate has declined in the last decade. Although middle income countries, had lower NRPs on average than high income countries, protection to farmers has been increasing steadily and reaching the level of high income countries by 2012. Low income countries have negative NRPs in the period shown in Figure 3, as the agricultural sector is seen as a source of government revenue (mostly in Africa) and export commodities are taxed. One thing to note is the difference in NRPs for countries during the 2008 food price crisis. High and middle income countries lowered their NRPs in response to 2008 food price crises, with middle income countries' NRP dropping to negative values, choosing to insulate consumers from price increases, rather than protecting producers. However, low income countries have higher NRPs during this period for protection of farmers. This may be attributed to agriculture being a significant source of income for these countries' population, and governments' efforts to keep farm gate prices high.

Figure 4 - Average NRPs for agricultural sector by income category.



In Table 2, we present global NRPs by commodity. We observe the variation to be even higher at individual commodity level, relative to the agricultural sector NRP. Producers in livestock and dairy sectors have much higher protection relative to crop sectors. Cash crops, such as coffee and tea, have negative NRPs, as these are export commodities with exports taxes keeping farm gate prices down. Another example of this is negative palm oil NRP, with demand for palm oil exports increasing.

Table 2 - Global NRPs by Commodity

Commodity	2001	2005	2009	2014
Maize	3.16	7.73	1.59	12.64
Wheat	-0.77	-2.06	6.42	12.93
Soybeans	1.59	-1.30	-3.14	-7.59
Palm Oil	-8.80	-1.56	-0.15	-8.52
Cassava	-3.08	-8.01	10.44	31.74
Coffee	-6.21	-12.48	-12.11	-58.50
Tea	-12.88	-9.76	-12.72	
Milk	34.58	26.96	18.14	7.69
Poultry meat	7.64	8.02	13.69	4.42
Bovine meat	27.31	21.77	16.39	23.66
Pig meat	3.17	15.19	12.57	12.28

3. Conclusions

Ag Incentives Consortium is a broad collaborative effort on part of multiple IOs to create a common set of indicators that measure distortions to agricultural incentives, with a focus on prices. The Consortium also aims to create a community of practices and provide quality control and scientific rigor, not only for the common indicators but also for the individual IO efforts.

The initial output of the Consortium is a global data set of NRPs based on combined IO data. This paper presents NRPs based on, but not limited to, the Ag-Incentives Consortium efforts. The results show that global average NRP moves in opposite direction of Food Price index, indicative that government policies reacted to food price crises of 2008 and 2001. Furthermore, trends of NRPs differ by income category, with high income countries lowering protection of producers, and middle income countries increasing protection. There is significant variation in average agricultural sector NRPs for low-income countries, consisting mostly of Africa.

One aim of this exercise was to provide a unified measurement of distortions by agricultural policies for a wide audience of academics and non-academics. This type of unified approach would help governments design policies and measure them effectively. The global NRPs rely on the same methodology, utilizing each IO database, in a consistent manner. They provide continuous and consistent measurement across a wide sectoral and geographical coverage, allowing stakeholders interpret the implications of agricultural policy design in an effective manner.

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A decade of Agriculture Policy Support in Sub-Saharan Africa. A review of selected results of the Monitoring and Analysing Food and Agricultural Policies (MAFAP) Programme

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ABSTRACT

African governments have widely acknowledged the important role that the agricultural sector plays to reduce poverty and improve food security. Nonetheless, governments' stated policy objectives, the policy measures implemented to achieve these objectives and the effects they generate are often not in line. As a result, there are still many ambiguous and inadequately targeted trade and domestic agricultural policies in place aiming to protect certain interest groups, or directed to achieve certain policy goals that come at a cost for specific (non-targeted) groups within the country's or region's population.

The Monitoring and Analysing Food and Agricultural Policies (MAFAP) Project, initiated by the Food and Agricultural Organization (FAO) of the UN, works closely with governments and national agencies in order to establish monitoring and analysis systems to assess the effectiveness, efficiency and distribution effects of agricultural policies and public expenditure, in an environment where market inefficiencies are often prevalent and significant. The project focuses on key agricultural value chains with domestic relevance in terms of production, trade and food security, in order to provide governments with evidence based reform options. MAFAP is implemented in Benin, Burkina Faso, Burundi, Ethiopia, Ghana, Kenya, Malawi, Mali, Mozambique, Nigeria, Rwanda, Senegal, United Republic of Tanzania and Uganda and is expanding to include further developing economies. The dataset established by MAFAP provides quantitative indicators over the period from 2005 to 2014 that estimate the scale of distortions, market inefficiencies and development challenges faced by the agriculture sector at different points of the commodities' value chains.

MAFAP's database and methodology has been utilized to assess the incentives and disincentives faced by producers and consumers of agricultural commodities by providing best possible information and analysis on the effects of policies and public expenditure influencing food security within the country and in the region. Especially during times of high international food prices, policy measures are used by governments in order to protect highly vulnerable consumers. The policy instrument of choice (e.g. export restrictions) is commonly selected under time pressure and without considering the effects on other countries' agricultural sectors and food security. In return, countries affected by policy actions of their trading partners react by adjusting their own trade and agricultural policies. At the same time, governments often seek to increase self-sufficiency in staple foods through their own production capacities to become less reliant on imports. To support informed policy dialogue at national, regional and international levels, MAFAP provides sound evidence and analysis to help directing policy actions and reforms in the agricultural sector and beyond. Balancing sometimes conflicting policy priorities within a country, region and internationally is a challenging exercise that governments have to face and MAFAP provides adequate support.

Keywords: Policy support, price incentives, public expenditure, Sub Saharan Africa, MAFAP.

PAPER

1. Introduction

Most countries in the world adopt policies that impact their agricultural sector. In doing so, governments seek to influence behaviour of economic agents in agricultural value chains and especially farmers. Trade and domestic market policies intend to affect the prices farmers receive for their produce or the price of inputs they purchase. Governments typically also use budgetary transfers to support specific agents either directly or indirectly through investments in public goods (research, infrastructure, etc.).

While these policies and their incidence have long been monitored for member countries of the Organization for Economic Cooperation and Development (OECD), there is scarce literature on policies and policy monitoring efforts in developing countries and especially in Sub Saharan African (SSA) countries. This is largely because of the challenges in data availability and quality.

Throughout the past decades with many policy changes affecting the agricultural sector in high-income and developing countries, it has been difficult to assess the effectiveness of the various policy reforms in developing countries, as no monitoring system was in place to continuously measure the effects of policy interventions on the basis of comparable indicators across these countries and over time (Angelucci et al., 2013).

In this respect, the work undertaken by Anderson and Valenzuela (2008) as part of the World Bank's research project on Distortion to Agricultural Incentives (DAI) constituted a major breakthrough. It was then possible to observe whether SSA countries were gradually moving away from a situation of net taxation of agriculture by analysing the indicators over more than five decades. The study also allows to compare the evolution of policy indicators at different stages of countries' development and the impacts that policy reactions by large global players can have on other countries. This is important since in a global market one country's policy action can have a major effect on other countries agricultural sector.

In the same spirit and more recently, FAO's Monitoring and Analysing Food and Agricultural Policies (MAFAP) programme started in 2009 with the objective of establishing country owned and sustainable systems to monitor, analyse, and reform food and agricultural policies to enable more effective, efficient and inclusive policy frameworks in support of agricultural development in a growing number of developing and emerging economies.

This paper provides an overview of recent trends in policy support level and composition for a selection of SSA countries. The data available paint a picture of generalized heterogeneity across countries. Overall, the level of distortions seems to decline on average as the average aggregated NRP across countries and commodities is converging to zero or slightly above. The objective of the paper if is to provide an early snapshot from the emerging data and suggest how we should think about this picture.

The remainder of the paper is structured as follows. Part 2 presents the methods and data used. Part 3 proposes a discussion of the main results distinguishing the analysis of price incentives and the discussion of budgetary transfers in support of the sector. Part 4 concludes.

2 Method and data

This paper builds on two strands of methodologies commonly used to assess the extent of policy support in agriculture. On one side, a well-established methodology based on the price differential between domestic and reference markets, which is used to estimate price incentives. On the other side, an equally well established methodology is used to estimate the budgetary expenditures in support of producers and the agricultural sector as a whole to account for direct and indirect social transfers. Both components are necessary to undertake comprehensive policy analysis, including an assessment of policy coherence with respect to the development objectives stated by governments.

2.1 Price incentives analysis

Estimates of the nominal rates of protection (NRPs) are used in this paper as indicators of the policy effort through their impact on prices. Some of the most seminal applications of NRPs and related concepts include Krueger et al. (1988), Krueger et al. (1991), Monke and Pearson (1989), Tsakok (1990), and Anderson and Valenzuela (2008) and Anderson and Nelgen (2013). A detailed comparison of the applications of NRPs and related concepts can be found in Balié and Maetz (2011). Consistent with the approach proposed by Krueger et al. (1988, 1991), NRPs have mainly been used to examine two situations: (i) direct taxation (or support) of the agricultural sector or a specific value chain through direct sector-specific price policies (or interventions), and (ii) indirect taxation (or support) through trade policies, exchange rate and any other macroeconomic policies or non-agricultural sector specific policies.

In most cases, the expected direct policy effect is equivalent to a tax on exportable goods and to a subsidy for importable goods while the indirect effect also results in taxes on agriculture which generally dominates the direct effect. For example, Quiroz and Valdes (1993) argue that, in the case of Zambia and Zimbabwe during 1980-87, there was a negative trend in nominal protection rate that was the result of increasing transport costs due to deterioration of infrastructure, lack of spare parts, and other factors that could be due to both policy and market failures.

Some variations on NRPs found in the literature include the nominal protection coefficient (NPC), which expresses the result as a ratio rather than as percentage change.[1] The nominal rate of assistance (NRA) at the farm gate is the sum of the NRP plus subsidies paid to the farmer expressed as a percent of the border price. The subsidies also include the value of input subsidies whether provided as payments directly to the farmer or indirectly through policies which affect farm prices (Monke and Pearson, 1989). In a developed country context, NPCs are calculated by the OECD using the Producer Support Estimate data base (OECD, 2010).

[1] The NPC is the ratio of the domestic price to the border price. The NRP is the difference between the domestic price and the border price divided by the border price.

The point along the value chain where the NRP or any other such indicators are calculated plays a key role. As described by Tsakok (1990), the border price and domestic price need to be compared at the same point in the value chain. This leads to a number of challenges in real world applications in terms of data requirements but also makes the calculation of these indicators meaningful for policy. The methodology in this paper is closest to Tsakok (1990) with NRPs estimated at the farm gate, wholesale, and retail level, which helps locate market and policy failures along the value chain.

To compare prices in a wholesale market for an imported commodity, the border price that is used for comparison needs to be modified in such a way that it accounts for the costs incurred to take the commodity from a CIF position to sale in the wholesale market in question:

$$BP_w = P_b + TC_{b.w} + MM_{b.w} \quad \textbf{(1)}$$

where BP_w is the CIF price (or average unit value) of the commodity converted into domestic currency using an exchange rate;[2] TCb.w includes all handling costs at the border, transportation and any processing costs between CIF and placement of the commodity on the wholesale market; and MMb.w are the importers' normal marketing margins between the border and the wholesale market. The signs would be reversed in the case of an export and with the border price being a FOB price (or unit value).

Note that the border price does not include the tariff and tariff equivalent charges. Similarly TCb.w includes only the resource costs of moving the commodity between border and wholesale, and MMb.w is a 'normal' marketing margin. The adjusted border price at the farm gate would be

$$BP_f = BP_w - TC_{f.w} - MM_{f.w} \quad \textbf{(2)}$$

where $TCf._w$ include all handling costs at the border, transportation and any processing costs between the farm gate and placement of the commodity on the wholesale market; and $MMf._w$ are normal marketing margins between the wholesale market and the farm.

The NRP, expressed as a percentage, can then be calculated as the difference between the adjusted border price and the domestic price at wholesale and/or the farm gate:

$$NRP_w = 100\% \times (WP - BP_w)/BP_w \quad \textbf{(3)}$$

$$NRP_f = 100\% \times (FP - BP_f)/BP_f \quad \textbf{(4)}$$

As will be seen below, explicit trade of domestic policies are not always the main drivers of price incentives as captured by the NRP. In developing and emerging economies in particular, market imperfections and other factors (see below) play a substantial role wither exacerbating the effects of explicit policies or offsetting them. To illustrate this point, we refer to the simplest case where tariffs are the only market intervention and imperfection. Anderson and Valenzuela (2008) show that the NRP at the border is equivalent to a tariff if no other market interventions and imperfections are in place. In other words, in the absence of domestic market interventions and imperfections between the border and wholesale market, it can be shown that NRP at wholesale for an imported commodity is equal to the tariff and other tariff equivalent charges multiplied by the ratio of the border price to the border price used for reference at the wholesale level.

As a matter of fact, the calculated NRP, in addition to the effect of the tariff, includes the effects of market imperfections (asymmetric access to information, market power, etc.) as well as the effect of other policy measures (such as market regulations), other fees and levies, and other measures adopted by governments to generate revenue, address market failures or pursue other objectives, all of which distort price transmission between the border and the farmer. To account for that, MAFAP estimates an additional indicator, called the adjusted NRP. This measure aims to identify excessive access costs in comparison to a more efficient or ideally functioning value chain. If excessive costs are identified, they are excluded in the calculation of the adjusted costs that are used in the calculation of the family of adjusted indicators. The main concepts that are subject to revision in order to provide adjusted measurement are the exchange rate, the benchmark price and access costs at different points of the value chain.

To expand the analysis in order to particularly capture inefficient market functioning, such as poor infrastructure, high processing costs due to obsolete technology, government taxes and fees (excluding fees for services), high profit margins captured by various marketing agents, illegal bribes and other informal costs which are particularly relevant in developing countries, MAFAP introduces the indicator of the Market Development Gap (MDG). This indicator represents an aggregate estimate of the effect of excessive access costs within a given value chain on prices received by producers.

[2] The exchange rate used should reflect opportunity costs and should itself be adjusted in cases when the domestic currency is overvalued. African currencies have often been overvalued but most have been determined by market forces since about the 1980s. An exception is the CFA franc region in West Africa that has been tied to the French franc (and now the Euro) and Malawi for about 2008-10. Burkina Faso and Mali are included in the CFA franc region (Etta-Nkwellea et al., 2010).

These market imperfections can impede the transmission of world prices onto domestic markets, reflecting a bigger or lesser degree of immaturity. The more markets are integrated (i.e. the more the observed price gap is the effect of explicit trade and market support policies), the more the MAFAP MDG will resemble the total MDG in the country. In theory, the MDG reflects the opportunity costs that these inefficiencies represent for producers. It is the portion of the price gap that can be attributed to "excessive" or inefficient access costs within a given value chain (see Anyango, 1997) and imperfect functioning of markets.

2.2 Public expenditure analysis

Governments from developing countries often lack organized information that would enable them to systematically analyse the performance of expenditures affecting the food and agriculture sector (UN, 2014). Key actors at national level recognize the need for the availability of such information on a regular basis in order to make rational, evidence-based policy choices, and that the development of appropriate indicators is an important prerequisite for policy analysis and efficient budgetary processes.

The Public Expenditure in Agriculture (PEA) indicators proposed by MAFAP seek to keep track of both the level and composition of public expenditures in support of food and agricultural sector development, and to establish a link between aid allocations and national expenditures. The MAFAP-PEA indicators aim to assess whether resources are being allocated to priority areas, whether they address investment needs, and whether they are consistent with government policy objectives. They also reveal whether aid allocations are coherent with national priorities. Moreover, the detailed nature of the MAFAP indicators permits investigation into the incidence of PEA on agricultural growth, poverty reduction and other development variables, contributing to further research and analysis in that domain (, Hazell et al., 2010, Benin et al. , 2008, Benin et al., 2009).

The methodology proposes to capture all public expenditures in support of food and agricultural sector development, ideally going back a minimum of nine years. That includes expenditures from the national budget undertaken by either a central or regional government, regardless of the ministry or agency that implements the policy, and external aid provided either through local governments or specific projects and programmes conducted by development partners. Public expenditures considered in the MAFAP-PE methodology are those of the food and agricultural sector, including forestry and fisheries. In addition, the MAFAP-PE methodology includes all public expenditures in rural areas, as they may also play an important role in agricultural sector development, even if they are not specific to the sector. The information on public expenditures in rural areas also aims to establish a view of a country's general policy environment and whether there may be a pro or anti-rural bias in expenditures on such significant areas as infrastructure, health and education.

In order to capture all public expenditures in support of the food and agricultural sector, the MAFAP programme has established the following distinctions:

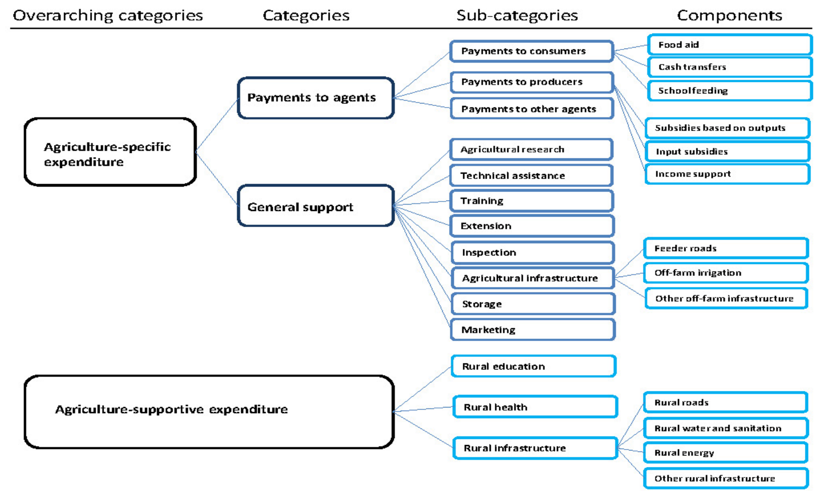
i. A broad distinction between expenditures that are agriculture-specific (direct support for the agricultural sector), agriculture-supportive (indirect support for the agricultural sector) and non-agricultural.

ii. Within the agriculture-specific category, a distinction between support for producers and other agents in the value chain (e.g. input subsidies), and general or collective support for the sector (e.g. research). The agents in the value chain include farmers (producers), input suppliers, processors, consumers, traders and transporters.

Agriculture-specific expenditures generate monetary transfers to agricultural agents or the sector as a whole. Those agents (or the sector as a whole) must be the only, or the principal recipient of the transfers generated by the expenditure measure. 6 Agriculture-supportive measures are not strictly specific to the agricultural sector but have a strong influence on agricultural sector development such as investment in rural education or rural health. All measures that meet these criteria are considered in the analysis, regardless their nature, objectives or perceived economic impacts. The detailed classification of support follows the OECD's principle of classifying policies according to their economic characteristics (i.e. the way they are implemented), which provides the basis for further policy analysis (OECD, 2008)[3].

[3] The fact that MAFAP classifies policies according to their economic characteristics should not be confused with the distinction made by the IMF between economic and functional classifications of expenses. In the IMF Government Finance Statistics (GFS) Manual (IMF, 2014, p.114), the following definitions are provided: "the economic classification of expense identifies the types of expense incurred according to the economic process involved" and "the functional classification of expense provides information on the purpose for which an expense was incurred". In this regard, the COFOG classification is functional in nature. However, the MAFAP classification considers policies and information on the way in which they are implemented (which can be both quantitative and qualitative) as the starting material for the attribution of the PEA categories. This is a consequence of the fact that the MAFAP classification is an analytical tool and not a reporting tool. Therefore, the distinction between functional and economic classifications in the sense given by IMF does not apply to the MAFAP classification, contrary to what could be suggested by the indication that policies are classified by function of their economic classification.

Figure 1 - Simplified MAFAP public expenditure categories



Source: MAFAP (2015). MAFAP Methodology working paper: Volume II. Analysis of Public Expenditure on Food and Agriculture. MAFAP Technical Notes Series, FAO, Rome, Italy.

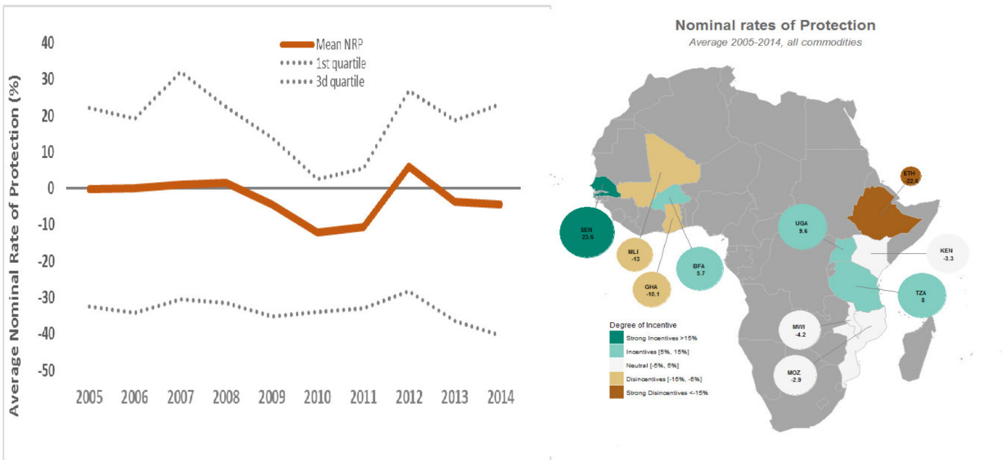
3 Results

3.1 Price incentive analysis

Results presented hereafter are based on Nominal Rates of Protection (NRP) estimates which serves as an indicator of incentives or disincentives to production and the Market Development Gap (MDG). The NRAP indicator is essentially based on the comparison between domestic market prices (observed prices) and reference prices free from domestic policy interventions (see above).

3.1.1 Aggregated results

Figure 2 - Nominal rates of protection, 10 African focus countries, unweighted average 2005-14



Source: Author calculations based on MAFAP, 2015.

The line representing the average NRP for all MAFAP countries in Figure 2 may give the impression that distortions are very low and almost negligible in the analysed time period from 2005 to 2014. The price distortion indicator is indeed close to zero on average for the analysed products and years, at least until the food price crises and then goes back to a value just under zero after the fluctuations caused by the crisis. However, the shown 1st and 3rd quantiles indicate that there is more to consider when analysing the price distortions affecting farmers in the observed countries.

The map in Figure 2 shows the important and substantial heterogeneity of the aggregated results across countries. Out of the ten countries analysed, we find that half exhibit average incentives for all commodities throughout the review period.

- The strongest incentives to farmers are to be found in Senegal with an NRA of 23.6%, followed by Uganda with 9.6%, Tanzania with 8%, Burkina Faso with 5.7% and Kenya with 5.5%.

- The strongest disincentives to farmers are observed in Ethiopia with an NRA of -22.6%. Mali has an NRA of -13% and Ghana -10.1%. Lower distortions are observed in, Mozambique with -2.9%, Kenya with -3.3 and Malawi with -4.2%.

It is important to keep in mind that the results are often driven by strong interventions for individual commodities that the governments pay particular attention to. The section on the commodity specific NRPs will provide more insight into these individual distortions by commodity.

Figure 3 - Market Development Gap, 11 African focus countries, unweighted average 2005-14

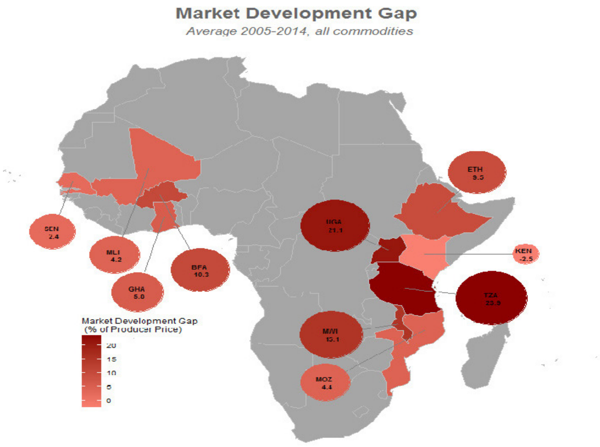


Figure 4 - Market Development Gap (total), NRP adjusted and observed (%), 11 African focus countries, unweighted average 2005-14

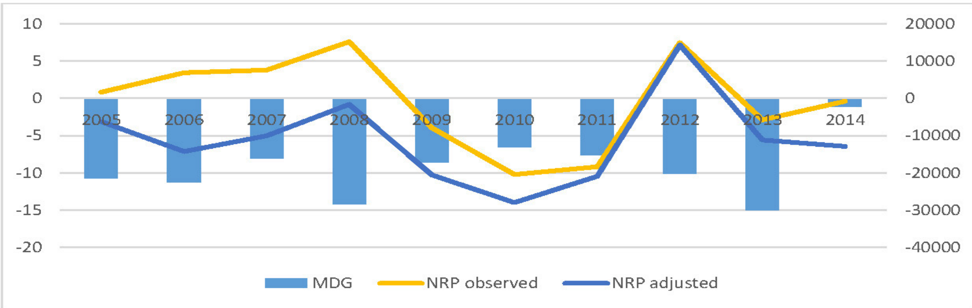


Figure 3 shows the Market Development Gap (MDG) indicator for the analysed countries. In Tanzania, the MDG is observed to be 23.9%, which means that market inefficiencies contribute highly to disincentives for farmers in Tanzania and therefore lead to overall disincentives for farmers, despite the positive observed NRP. In Uganda, the MDG is 21.1%, followed by Malawi with 15.1% Burkina Faso with 10.3%, Ethiopia with 9.5, Ghana 5.8%, Mozambique 4.4%, Mali 4.2%, Senegal 2.4%, and Kenya 2.5%.

The development of the MDG over the studied time period indicates the increasing role that market inefficiencies have in generating price incentives compared to trade, price or other market policies in all analysed countries. Reasons for these inefficiencies are mainly government taxes and fees, bribes, high transport and processing costs and the concentration of profits among intermediaries.

3.1.2 Cotton

This section reports the results analysed for cotton in seven countries: Burkina Faso, Kenya, Mali, Malawi, Mozambique, Tanzania and Uganda. Cotton is currently one of the most valuable cash crops despite the negative effect of subsidies and high levels of protection of many of the OECD countries on world prices (Baffes, 2002, Baffes et al., 2010; de Gorter, 2012). In 2010, cotton was by far the most important export crop in Burkina Faso and Mali, third most important and only slightly behind coffee and tobacco in Tanzania, fourth in Mozambique and Malawi, and seventh in Uganda.

In each country analysed, only a small number of companies, public or private, operate ginneries, each of which deals with a large number of small-holder farmers. All seven countries studied have one or more agencies or parastatal organizations charged with promoting the cotton sector, but the degree of centralized direction exercised varies considerably from country to country. However, in all countries studied ginneries operate well below capacity.

The private sector is now responsible for cotton ginning in all of the countries studied except for Mali and Burkina Faso where responsibility for cotton marketing is still vested in parastatals. Governments of both countries have set up regional companies that provide inputs to, and collect seed cotton from village level producer associations, process it in their ginneries and market the cotton lint, cottonseed and other by-products of the ginneries. They also play an important role in setting producer prices for seed cotton.

The industry is only slightly less concentrated in Mozambique. The Mozambique Cotton Institute (IAM) is the main cotton parastatal with responsibilities for the production of seed cotton, protection of stakeholders and fostering the development of the industry. It licenses eight ginneries which each have exclusive concessions to buy seed cotton in a specific region, fixes minimum pan-seasonal and pan-territorial prices and is the buyer of last resort if the ginneries are not willing to buy seed cotton from some producers.

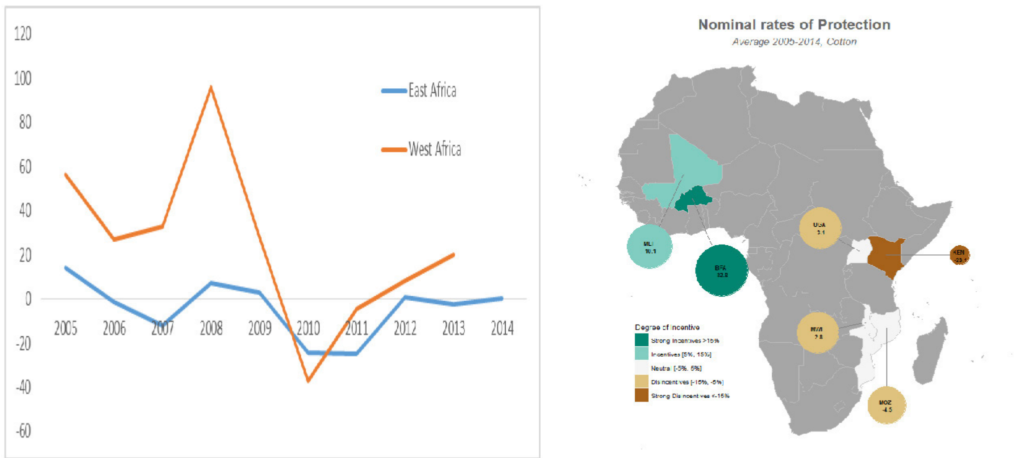
The cotton value chains in the other three countries are far more market-oriented. The Tanzania Cotton Board (TCB) is primarily a regulatory agency that promotes the development of the cotton sector through setting quality standards, licensing post-farm gate businesses involved in cotton trade and processing, farmer education and ensuring the seed cotton market is competitive. There are about 500,000 cotton farmers in Tanzania who sell their seed cotton to cotton traders or directly to one of the 40 to 60 ginneries. Since 2007, a new contract farming system has been made available in Tanzania in which farmers can get credit and other inputs from a ginnery and agree to sell their seed cotton to the ginnery according to the terms of the contract. The TCB also operates a network of about 8,000 'buying posts' for farmers not selling their seed cotton under contract.

The Ugandan cotton sector is organized much like that in Tanzania. Ginneries in Uganda are privately owned and operated companies that market the cotton lint and cottonseed they produce. The Government of Uganda mandated the Cotton Development Organization (CDO) to promote, monitor and regulate. The ginneries in Uganda are also required to provide a certain amount of cotton seed to the CDO which in turn provides good quality, treated seed to cotton farmers without charge.

Malawi's Cotton Development Trust (CDT) brings together all stakeholders in the value chain: farmers, input suppliers, ginners and the Malawi Ministry of Agriculture and Food Security. It recommends a minimum price for seed cotton each year to the government and advises on other aspects of policy for the cotton value chain.

In Kenya, despite the sector's decline in recent years, cotton is still considered one of the few cash crops with real potential for increasing employment opportunities and food security through income generation in the Arid and Semi-Arid Lands (ASALs) of Kenya (CODA, 2008). Kenya is endowed with a well-developed textile industry that requires a constant supply of cotton lint. The cotton market in Kenya has been fully liberalized and is now in the hands of the private sector. CODA as a regulatory body is charged with coordinating and regulating cotton marketing. Cotton marketing is facing difficulties due to the weak cotton cooperatives and organized farmer groups resulting in poor farmers bargaining power and lack of economies of scale (CODA, 2010). Despite a growth in exports, very few benefits have been realized by local cotton producers due to the fact that Kenya's textile industry continues to import most of its factory inputs rather than purchase domestic cotton lint. The ginnery industry appears to be operating at a 24 percent of its capacity due to short supply of cotton. As a result, the industry is highly dependent on imported inputs mainly from Uganda and Tanzania.

Figure 5 - Nominal rates of protection for cotton, unweighted average by region, 2005-2015



Source: Author calculations based on MAFAP, 2015.

Results presented in Figure 5 clearly show that the level of support to the cotton sub-sector is stronger in West Africa (Burkina Faso and Mali) than in Eastern and Southern Africa (Malawi, Mozambique, Kenya, Tanzania, and Uganda). Two periods can be easily distinguished. Between 2005 and last 2009, producers in West Africa received particularly strong price incentives to produce cotton while producers in Eastern and Southern Africa experienced only moderate incentives or disincentives. The cotton price crises of 2010 is visible in both West and East Africa regions with NRPs becoming substantially negative especially in the case of West Africa. The post crises period, when international prices of cotton started rise again, is characterised by the emergence of a common pattern of support in both regions although Western Africa started to diverge as of 2013 while price incentives remained neutral in East Africa.

Figure 6 - Nominal Rate of Protection for cotton seed in the MAFAP countries

Source: Author calculations based on MAFAP, 2015.

We observe that **Burkina Faso** is by far the country providing the highest level of support at roughly 33% while the average NRP is only 13% over the analysed period. Burkina Faso is the first cotton producer of West Africa with 766,000 tonnes of seed cotton produced in 2013-14. For the whole period analysed, producers have received strong price incentives while the main ginning company SOFITEX controlled by the State has been selling cotton at price lower than the international price which implies a substantial cost for the national budget especially when international prices are low.

In **Mali**, a similar price mechanism as the one observed in Burkina Faso operates. Although this stabilization fund creates incentives for production when international prices are low (2005-2009 period), this mechanism limits the transmission of prices and penalizes producers when prices are high (2010-2012). However, the incentives were not sufficient to stimulate the production of cotton, which declined between 2005 and 2008. In 2009, through direct support in the form on inputs subsidies, the government managed to boost production despite the price disincentives received by producers until 2012 when international prices were particularly high.

Contrary to the case of Burkina Faso and Mali, **Kenya** exhibits the highest level of disincentives at roughly -23% on average over the period. However, Kenya is a net importing country while Burkina Faso and Mali are both net exporters. The absence of production incentives may suggest an implicit support to the cotton processing industry in Kenya. The main driving factor for the price disincentives at the primary level of the cotton value chain is the distribution of the market power along the value chain which influences the cotton pricing. The minimum pricing model used by stakeholders appears to be an inadequate tool since it is based on FOB price rather than the CIF price of lint which is inappropriate for a net importing country.

In **Mozambique**, cotton producers have seen the level of support decline to pronounced negative levels in 2010. The situation improved as of 2011 to stabilize to moderate levels of either price incentives or disincentives depending on the years in a situation that seems to be characterized by instability. The minimum price policy allowed farmers to receive prices higher than what they should have received when international prices are low but this system has probably also be used to set low reference prices when international prices spike. The concession system has also made it easier for ginners to pay prices lower than what they should have paid to farmers when international prices are high. Over all the sector is affected by a low productivity, which increases the risk and limits the capability of the actors to respond effectively to changes in exchange rates and international prices.

In **Tanzania**, cotton producers have moved from a situation of net taxation until 2009 to a situation of support thereafter. Incentives to farmers at the farm gate have been increasing as the government has recently enacted further support projects including contract-farming solutions for farmers that guarantee higher prices. This has enabled further growth within the sector as more farmers are incentivized to grow seed cotton as assurance of price structures as well as marketplace to buy their lint is provided

In **Uganda**, producers have received price disincentives or moderate incentives for the most part of the analysed period except in 2012 when international prices were very high. The major driving force for the generally positive indicators is the cotton pricing system adopted which is based on world prices for lint prevailing at time of price announcement. The indicative price often becomes a price ceiling. However, the variability of the indicators is caused mainly by highly volatile world price of cotton and the difference in price between the price announcement and the realized export price for lint. Regardless of the price incentives to producers, the poor performance of the cotton sector In Uganda is related to factors including low productivity caused by the low use of purchased capital inputs and low profitability which is directly related to crop yields and output prices and inversely related to the cost of production.

Better policies and targeted public investments could help increase cotton productivity and production resulting in higher competitiveness of the cotton value chain across countries. Additional export opportunities could play an important role as a source of income and income diversification contributing to poverty reduction in these areas. It could also support the development of an African textile industry, in Kenya for example, to further integrate the economies of the East Africa Community (EAC).

3.1.3 Rice

This section reports the result for rice in nine countries: Burkina Faso, Burundi, Ghana, Kenya, Mali, Mozambique, Senegal, Tanzania, and Uganda. Most rice is produced using various irrigation systems although some rainfed rice production takes place in all the countries studied. There are a number of different irrigation systems in the Niger basin in Mali and Burkina Faso but irrigated rice production in other countries is mostly on irrigation schemes that were established by the governments concerned.

Although rice is mainly produced by small-scale farmers in the nine countries studied, it is not primarily a subsistence crop consumed on farm. Even in Mali with by the far the greatest consumption per capita, only 37 percent of the rice produced is consumed on-farm (Samake and Bélières, 2007). In general, rice is a cash crop produced in competition with imports and consumed in urban areas mainly by middle- and high-income consumers or on special occasions. The demand for rice is therefore expected to grow rapidly with rising incomes and urbanization.

The price spike in global commodity markets in 2007/08 was greater for rice than any other cereal (FAO, 2010; Headey and Fan, 2010). The price spike together with import dependence and the prospects of rapidly increasing domestic demand triggered concerns on rice policy in most of the countries studied. Policymakers in the countries studied also appeared to be convinced that there were good prospects to increase rice production by their small-scale farmers. It is this combination of factors that made rice a priority commodity for policymakers in the countries studied.

This priority given to rice by policy makers is illustrated in three policy areas: the National Rice Development Strategies (NRDS)[4], additional budgetary resources for infrastructure for rice production and the tariff regimes that appear to protect rice more than other staple commodities. Tanzania's objective, for instance, was to double rice production by 2018 to "develop the agricultural sector in order to attain the desired food security situation and growth for poverty reduction". Other countries included in this study have similar goals and ambitious targets.

Many of the countries studied also have parastatals for marketing major staple commodities. These generally have a dual function: to maintain a buffer stock that can be used to respond to exceptional shortfall in production resulting in a food security crisis for some segment of the population and to intervene when market prices for consumers rise above a ceiling level or fall below floor level for producers.[5]

Regional and local governments in all countries studied may also affect rice markets by charges they levy. In Tanzania, for instance, a district sales tax is charged on grain "exported" from the district to any destination. The tax rate varies from district to district between one and five percent. There are fees in some countries for grain transported through a district and for marketing it in local markets. Police checks along major transportation corridors are common and provide a venue for collecting district fees and an opportunity for extra-legal charges to avoid costly delays and/or avoid compliance with load limits and other regulations, all of which are a distributional inequity type of non-market failure.

4 All of the countries studied have prepared NRDSs in partnership with the Coalition for African Rice Development (CARD). CARD was established by the Japan International Cooperation Agency (JICA), the Alliance for a Green Revolution in Africa (AGRA) and the New Partnership for African Development (NEPAD). The CARD strategy focuses on strengthening the production and multiplication of certified seed, research, and agricultural extension, the development of agricultural land and water resources, and improved small-scale, post-harvest rice processing equipment.

5 The use of stocks to stabilize cereal prices has been criticized for at least three reasons: they replace private stocks, they were found to be poorly managed, and they distort market signals (Jane, 2011; Tangermann, 2011; Timmer, 2011; Demeke et al., 2014).

Burkina Faso and Mali have introduced new marketing policies or reverted to some pre-liberalization policies in response to the commodity price crisis of 2007/08. While it has been the case in Mali since 2003, Burkina Faso began including rice in its food security stocks in 2008. Both countries used a direct price control approach to stabilize prices rather than the indirect approach of buffer stocks. Mali established price ceilings at both wholesale and retail in 2008/09.

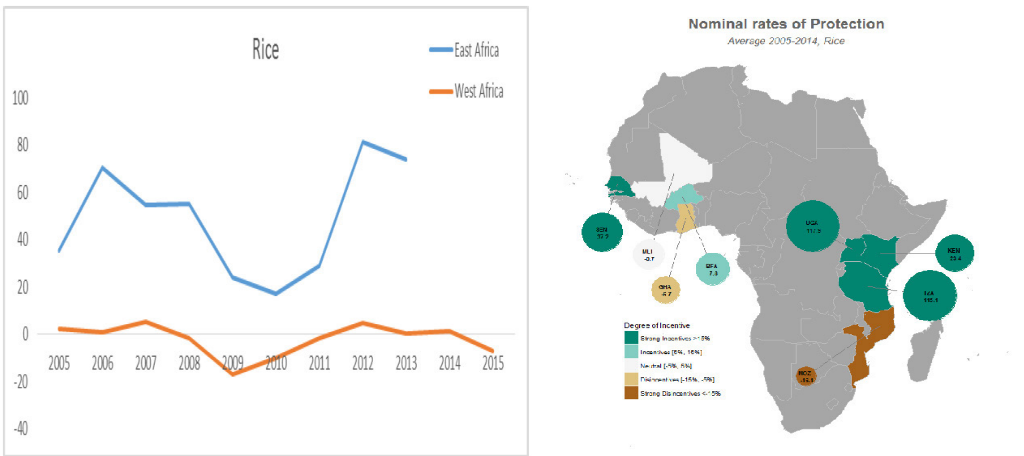
Burkina Faso prices were based on estimated costs of production plus a producer margin throughout 2008 -2010. They also set margins through the rest of the supply chain implicitly controlling prices at all levels.

All the countries studied belong to one or more preferential trade agreements (PTAs) which discipline their tariffs with each other and the rest of the world. They also seek to limit the effect of non-tariff barriers. Kenya, Uganda and Tanzania are members of the EAC. Kenya and Uganda are also members of the Common Market for Eastern and Southern Africa (COMESA). Tanzania and Mozambique were members of COMESA but withdrew. They are both members of the Southern African Development Community (SADC). All four West African countries are members of the Economic Community of West African States (ECOWAS). Burkina Faso and Mali are also members of WAEMU.

Results presented in Figure 7 show two different trends for East and West Africa. In both sub-regions we can observe the downward trend in support to production in 2009. This situation of depressed price received by producers appear to have lasted more for producer in eastern Africa than for those of West Africa.

The level of support to the rice sub-sector has been almost neutral on average in West Africa (Burkina Faso, Ghana Mali and Senegal). However, this result masks an important heterogeneity across countries. While producers in Senegal and to a lesser extent Burkina Faso received substantial price incentives on average over the period analysed (+16% and +8%), producers in Mali and even more so in Ghana received rice production disincentives of -1% and -5% respectively.

Figure 7 - Nominal rates of protection for rice, unweighted average by region, 2005-2015



Source: Author calculations based on MAFAP, 2015.

In **Senegal**, the strong production incentives are largely explained by the tariff set at 12.5% and the existence of an indicative producer price adopted by the Government.

The situation of **Burkina Faso** which is also a net importer is largely explained by the effect of the border protection (tariff of 14%) that dissipates partly between the wholesale and farm level due to market imperfections, the imposition of a floor price for rice, both of which are augmented by the natural protection for this landlocked country resulting in very high transportation costs.

For **Mali**, with the exception of 2009 and 2010, the situation of moderate price incentive or disincentives prevails over years. The government adjusts the its policy in support of either producer or consumers depending on the perceived food security situation of the population but the effects of the interventions are partially offset by huge market inefficiencies constraining price transmission.

In **Ghana**, rice imports are subject to an import duty of 20 percent (temporarily removed in 2008 and reinstated during the course of 2009) as well as other taxes and levies. Rice is one of the commodities, purchased by the National Buffer Stock Company (NAFCO), operating since 2010, to stabilize rice prices and build emergency stocks. The main driver of the huge price disincentives appears to be related to the important market failures, including market power exercised by NAFCO, and resulting in very high transport and other market access costs.

For Eastern and Southern Africa, Figure 7 shows that the level of support is generally much higher and could reach level as high as 80% in 2012 on average. However, in this region heterogeneity prevails too. Burundi, Kenya, Tanzania, and Uganda exhibit high levels of price incentives on average with 36%, 23%, 115% and 117% respectively.

In **Burundi**, the rice value chain is characterised by a strong demand that cannot be matched by domestic production and is consistently supplied by imports that represent 40% of the domestic consumption. The policy and market environment made of the external tariff set at 75% by the East Africa Community (EAC) and the high demand for rice explain the level of producer incentives. The fact that the average NRPs is below the tariff is explained by important market failures resulting in very high transportation costs and market power exercise by middle men.

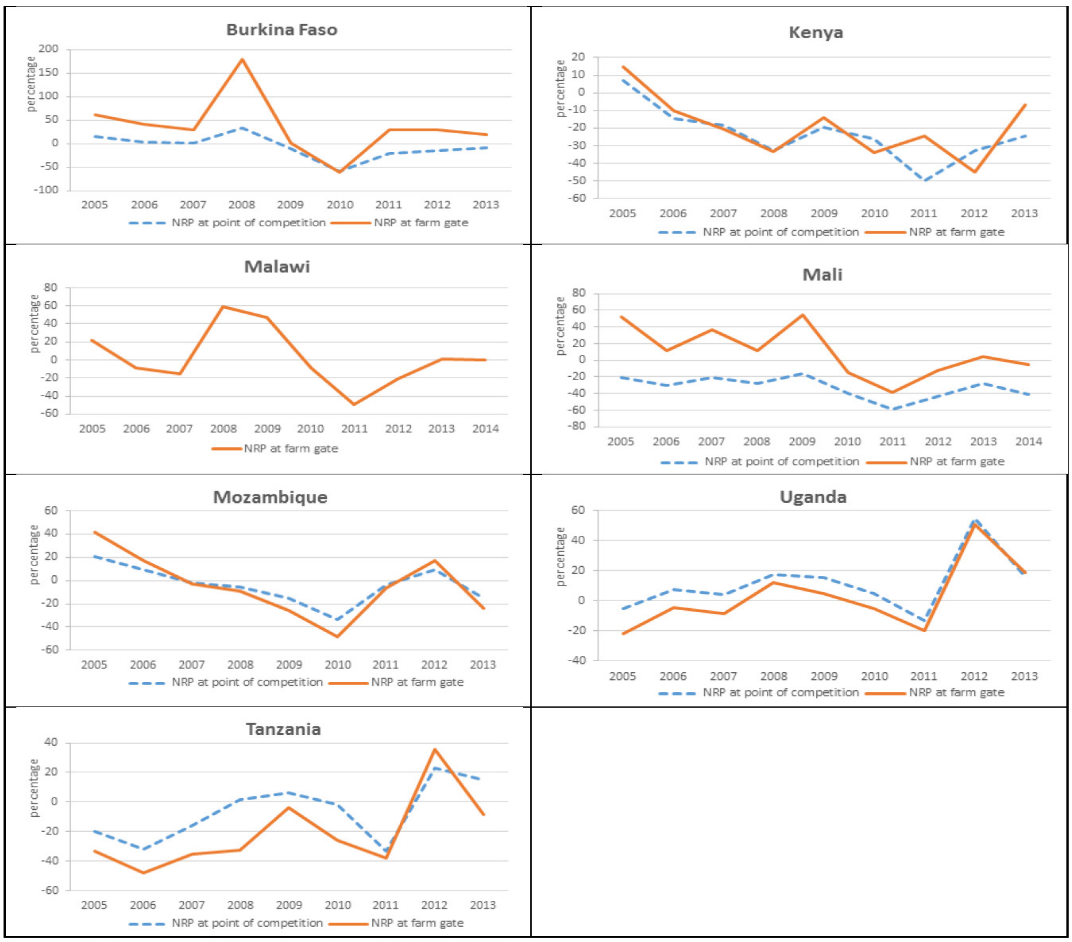
In **Kenya**, this result is due to the market failures affecting wholesale prices and producer prices at least as much as the external tariff. In addition, the Kenya government budgets in 2009 and 2010, for example, included new initiatives to rehabilitate and expand irrigation schemes that are mainly used for rice production.

In **Tanzania**, the Government's objective was to double rice production by 2018. As Tanzania also belongs to the EAC, rice producer benefit from the same high tariff. However, market inefficiencies as well as intervention by local government explain the reduced level of price incentives in Tanzania relative to the case of Kenya. For instance, a district sales tax is charged on grain "exported" from the district to any destination.

In **Uganda**, most of the commodity markets are fully liberalized and the average price incentives observed at farm level of 75% is basically the effect of the tariff adopted by the customs union of the EAC. Mozambique shows less favourable situation for rice producer with respectively - -16% NRPs on average for the period analysed.

In **Mozambique** where rice is also imported to match the demand, the level of price disincentives is largely explained by important market inefficiencies as the consumption region is around Maputo in the south while the production region is located in the north at quite long distance. The high transaction costs and market power exercise by traders explained the low prices received by producers.

Figure 8 - Nominal Rate of Protection for rice in the MAFAP countries



Source: Author calculations based on MAFAP, 2015.

3.1.4 Maize

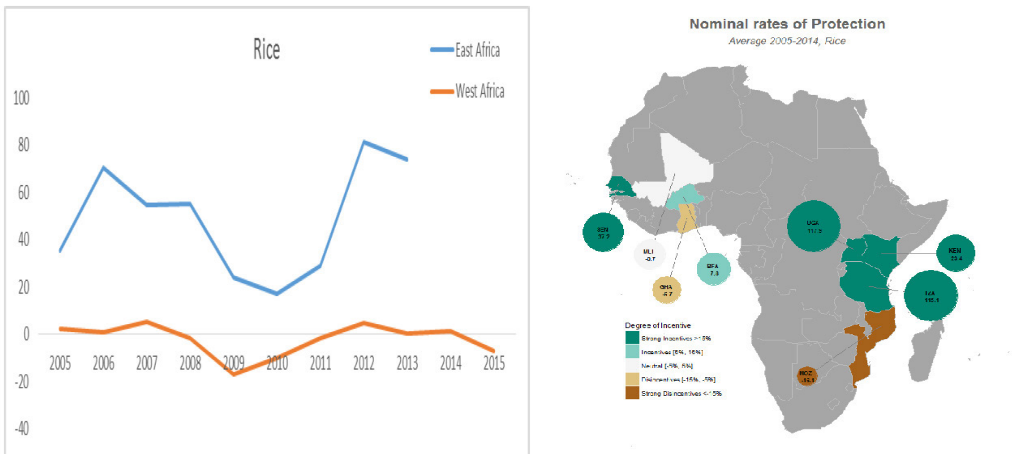
Maize is one of the most important crops in Africa by almost any measure. It is the biggest or nearly the biggest crop in terms of area and volume of production because it can be successfully grown in a wide range of African agro-ecological zones and because it is easy to cook. However maize plays a different role in each of the ten countries studied. In most countries, maize consumers have a strong preference for white maize, while yellow maize is generally regarded as animal feed. Malawi, Tanzania, and Kenya are the top three in terms of the domestic supply of maize in Kg/capita. Malawi for example stands out with 197 kg/capita, more than twice the level of the next largest figure. Uganda and Nigeria at 39 and 47 kg/capita, respectively, rely on a more diverse set of staple foods and have the lowest domestic supply levels with the other countries ranged between these extremes.

Maize is generally thinly marketed and traded. In all countries, there are networks of small traders who buy directly from farmers or in local markets. Maize is sold up the chain through larger market centres to larger wholesalers and ultimately the larger towns and cities and supply other maize deficit regions. Trade volumes are small relative to production and consumption so most of the countries analysed are near self-sufficiency in most years as shown in Table 1. In Malawi for example, which produces twice as much per capita as any other analysed country, only 5 – 10% of the crop produced by smallholders is marketed. Similarly in Kenya, only 32% of smallholder maize producers are net sellers. This is true too in countries like Mali and Burkina Faso where crops like rice, millet and sorghum are relatively more important than maize. Uganda is somewhat different because maize is also seen as an important export crop and, in some districts of Uganda, 75 – 95 percent of maize production is marketed. But even in Uganda, over 60% of maize is consumed within the country which can include informal trade and much of it on the farm. Some countries, like Tanzania, switch back and forth between net exporter and net importer status.

Prices in these countries are frequently both below import parity and above export parity relative to maize benchmark prices such as US Gulf and South African Futures Exchange (SAFEX). Consequently, trade often occurs with bordering countries.

As a result of the relatively small volume of international trade and the low share of production that is marketed internally, marketing channels are generally not well developed. This is also due to the fact that maize was a highly controlled and has often been a politically sensitive commodity in Eastern and Southern Africa, and the disbandment of parastatals has disorganized the marketing channels. There are few facilities for bulk grain handling and shipment that take advantage of economies of scale. It is frequently first transported to a nearby market in a 90 kg bag by the farmer that grew it. The most common form of transportation to large market centres is by 40 tonnes trucks rather than barges or by train in grain hopper cars. The existing marketing systems can cope with normal volumes and respond to small surpluses or shortfalls in production. Larger more widespread shortfalls create a crisis situation as seen in Kenya in 2008 – 2009, requiring atypical imports from world markets and straining logistics capacity.

Figure 9 - Nominal rates of protection for maize, unweighted average by region, 2005-2015



Source: Author calculations based on MAFAP, 2015.

The results for maize are strikingly different for the West Africa and East Africa regions. The aggregated NRPs behaves also symmetrically in opposite direction in the two regions. These very different patterns in the two regions suggest policy interventions moving in opposite directions. Once again, results vary a lot across countries and also within countries over years due to change in policy interventions.

Figure 10 - Nominal Rate of Protection for maize in the MAFAP countries

Source: Author calculations based on MAFAP, 2015.

Farmers in **Burkina Faso** have from price incentives with NRPs set at 20% on average over the period analysed. Burkina Faso is an exporter in all years except 2007 with trade happening with its neighbouring countries at zero tariff in all years. The farm level prices are quite lower than expected in all years given the wholesale prices and estimates of market access costs between the farm gate and wholesale. This result is consistent with inefficiencies affecting the value chain between farmers and wholesale markets. Illegal fees, some taxes often considered inefficient, excessive commercial margins by exporters and wholesalers accounted for a significant shortfall for farmers. This loss, reported in Franc CFA per tonne for the period 2008-2013, is ten times higher than the amount for input subsidies to maize distributed these years.

In **Mali**, Figure 9 indicates that the NRPs at farm level was close to -15 % on average over the period analysed. Producers have received by price disincentives largely explained by the poor connection of small farmers to domestic and regional markets where prices are generally higher than in Mali. Trade levels have been too low for producers to take advantage of potential market opportunities at regional and international levels. The apparent low correlation between domestic and international prices indicates a rather limited capacity of the economy to transmit price signals. Producers and wholesalers seem to have essentially reacted to signals emanating from the domestic market.

For **Ghana**, the right hand panel of Figure 9 shows that overall farmers have been substantially penalized by low prices with a NRPs of -45% on average over the period. Although the NRP at wholesale consistently stands at lower level of penalization both the farm and the wholesale levels have received substantial disincentives. Ghana has had a VAT and other levies amounting to a 17% charge on imports throughout the period analysed. In addition, there was a 20% tariff on maize in 2005-06 and 2009-10 that was reduced to zero in 2007-08. These charges cannot explain the very negative trend observed for the NRP throughout the period analysed. Clearly border protection should have played an important role in the opposite direction keeping domestic prices at wholesale and farm level well above the reference price. The main driver of the important price disincentives observed result from substantial market failure and primarily market power exercise by some agents in the value chain. High transport and handling costs contribute to exacerbate farmers' disconnection with wholesale markets

In **Ethiopia**, farmers have received very pronounced price disincentives at roughly -55% on average over the period analysed. Restrictive trade policy (export bans), overvalued exchange rate, high access costs and high international prices largely explain these disincentives to producers. For instance in 2010 and 2011, when the export ban was lifted and the exchange rate had improved after devaluation in 2011, disincentive declined, whereas in 2012 when the export ban was reinstated and the currency overvalued again and that a record level of domestic production coincided with a context of high international prices, the price disincentive was maximum. The low domestic demand during years of good harvest like in 2012 combined with fairly steady levels of imports between 2005 and 2011 (with the exception of 2012) are factors contributing to the decline in domestic price. Moreover, because Ethiopia is a landlocked country, transaction and transport costs are usually quite high which also contributes to high reference prices.

Uganda is an exporter in all years without export fees or other restrictions on trade. Farmers have benefited from fairly high level of NRPs at nearly 36% on average over the period. Farmers have revived higher incentives than wholesalers. This relatively high levels of incentives to maize producers has been driven by the liberalized policy environment in Uganda where farmers through traders have been able to seize market opportunities arising in the East Africa Community.

In **Tanzania** farmers have received no incentive on average over the reported period. Tanzania changed trade status regularly. It was an exporter in 2005, 2007 and 2009 and an importer in the other years. For the 2005-2013 period, farmers have received either small incentives or disincentives for maize production, but in an erratic and volatile way. Uncertain government policy and erratic interventions in form of export bans, public procurement, price setting, and subsidized distribution of maize is not only regarded as ineffective and destabilizing, but even penalized both farmers and consumers in some years. Careful review of the trade and market environment is required to make maize production more remunerative for farmers and the commodity more accessible to consumers. Substantial value chain inefficiencies are linked to high transport costs and the presence of local taxes, informal fees and rent-seeking practices by value chain agents. These inefficiencies represent a huge cost to the maize sector and should be addressed as a matter of priority if Tanzania is to succeed in its goal of developing a more commercial and export-oriented maize sector.

In **Kenya**, farmers have received moderate price disincentives to produce maize over the period analysed at (-3%). Maize is an import in all years. In normal years, 25-35 percent of total marketed maize is sold directly to the National Cereals and Produce Board (NCPB) by medium and large producers. Smallholder producers sell 96 percent of their maize to private traders/brokers or consuming households. NCPB is used by the government to regulate the market by purchasing maize (mainly from medium and large farms) and selling it below the cost of procurement to incentivize production, while keeping prices low for consumers. The main policy instrument used to affect market prices of maize and consequently the price incentives to producers in Kenya is the trading activities of the NCPB. It does this through purchasing grain and selling it to millers often at a subsidized price. Combined with the short-term adjustment of the tariff to increase imports during years of shortage, the purchase pricing of NCPB manifested itself as a maize price ceiling. Since the NCPB purchase price is not based on import parity of maize, the domestic price of maize in Kenya is isolated to some degree from aligning with world market price.

In **Burundi**, farmers have received quite high price incentives to produce maize at 42% on average over the analysed period. While Burundi is a net maize importer, domestic prices are heavily disconnected from prices on international markets. The majority of maize imports come from Uganda, Tanzania, Rwanda and, to a lesser extent, Zambia. During the study period, these countries were still members of a free trade area with the exception of Tanzania which between 2005 and 2008 was not a member of the Common Market for Eastern and Southern Africa (COMESA) while Burundi was. Since 2009, these two countries are members of the East African Community (EAC). The producer price increased steadily over the period, despite the falls in international prices. In 2010, the international price for maize fell more than 50 percent, but producer prices continued to rise explaining the peak in incentives for that year. These strong production incentives are likely attributable to both the existence of a monopsony on imports which limits the volume of maize flowing in the country to keep high prices in the domestic market and the significant disconnect between the regional market and the Burundian market due different barriers (logistic, administrative , etc.).

In **Malawi**, farmers have received relatively high price incentives to produce maize on average at 32%. Indicators reveal that, over the 2005-13 period, the domestic policy and market environment generated highly volatile price incentives to maize farmers. In a sector dominated by smallholders and subsistence farming practices, this instability represents a major issue, as producers are not able to plan appropriate production and marketing strategies. The inefficiencies between farm-gate and wholesale markets, owing to high marketing costs, have also contributed to penalize maize farmers. On the one hand, price incentives for farmers in several years (205-2007, 2009-2013, 2015) were driven by steady but higher maize prices in Malawi relative to the region. A policy context of limited trade restrictions prevailing before 2007 and in 2010 seems to have allowed for better price transmission and larger protection for maize producers. On the other hand, farm-gate price disincentives in some years (2008 and 2014) were primarily driven by lower producer prices due to bumper harvests and oversupply, coupled with large market inefficiencies between farm gate and wholesale markets generated by poor rural infrastructure and high traders' margins. Furthermore, lack of storage facilities prevent farmers to market their maize later in the season and take advantage of higher prices.

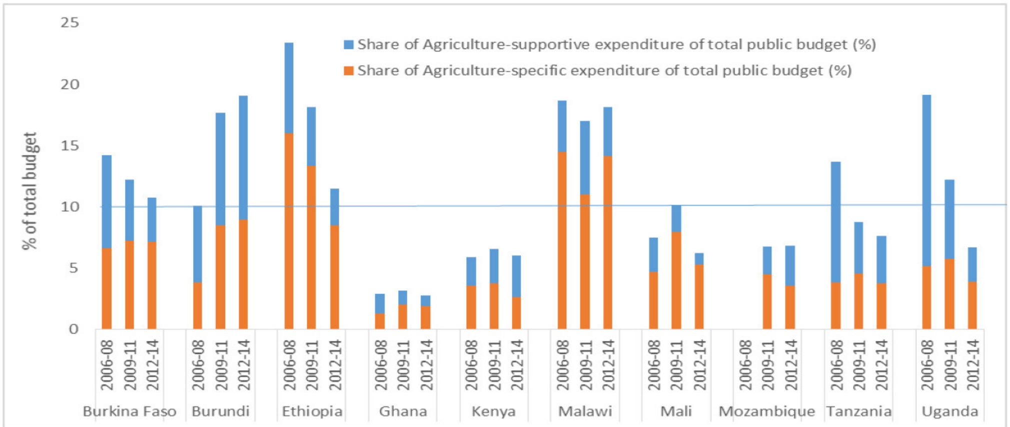
For **Mozambique**, wholesale prices are well above reference prices for all the years analysed, between 20 and 51% except in 2009 where they are only 5% as indicated by the NRPs (see Figure 10). NRPs in the 20 – 30% range at wholesale are consistent with Mozambique's tariff of 2.5% and VAT of 17% applied on imported maize only. The higher rate in 2008 is evidence of exceptional profits that importers could make in that year possibly due to restrictions or other problems of supply including the fact that Mozambique market is not really unified due to enormous transport constraints between the North and South. The 5% NRP in 2009 is consistent with measures to reduce the tariff or VAT in that year. Large scale importers are able to apply for a VAT rebate. Again, border policies appear to provide little incentive for farmers to produce maize. The NRPs at the farm gate should be at least as high as they are at the point of competition (wholesale) if the value chain were transmitting price incentives that exist at the border back to producers. But the NRPs at the farm gate are near zero in all years except 2008. Even in 2008, farmers did not receive the prices they were expected to receive considering the high NRP at wholesale. The wholesale-farm gate price gap suggests that internal market access costs, inclusive of excessive margins and any form of restrictions or exactions on transportation, are well above efficiency levels.

3.2 Public expenditure analysis

To pursue their policy objectives on growth and development, in addition to trade and pricing policy governments often use budgetary allocations in support of agriculture. In such a context, monitoring and analysing public expenditures in support of food and agriculture (PEA) is of the utmost importance for African governments and donors alike.

In July 2003, members of the African Union committed themselves to allocate at least 10% of their national budget to agriculture to achieve 6% growth of the sector. This commitment was renewed in the Malabo declaration of 2014 (AU, 2014). Figure 11 shows the trend in spending for 10 SSA countries. Figure 11 shows that agricultural specific expenditures dominate agricultural budgets. However, the wide variations across countries are also noticeable. While there is a controversy on what should exactly be accounted in the level of spending in reference to the Maputo declaration, most analysts have referred to specific on agriculture excluding spending categories related to rural development at large. According to this interpretation, out of the 10 countries analysed only Malawi exhibits a level of spending above the target. Burundi is quite close with an increasing trend. Ethiopia is also close but shows a declining trend. Even when we account for the agricultural supportive expenditures (i.e. spending on rural health, rural infrastructure, and rural education) only 4 country exhibit level of spending above the 10% threshold for the period 2012-14 (Burkina Faso, Burundi, Ethiopia, and Malawi). Most countries analysed exhibit a declining trend of support to their agricultural and rural sector.

Figure 11 - Share of Agriculture-supportive and Agriculture-Specific Expenditure of Total Public Budget, 2006-2014, three year averages, percent



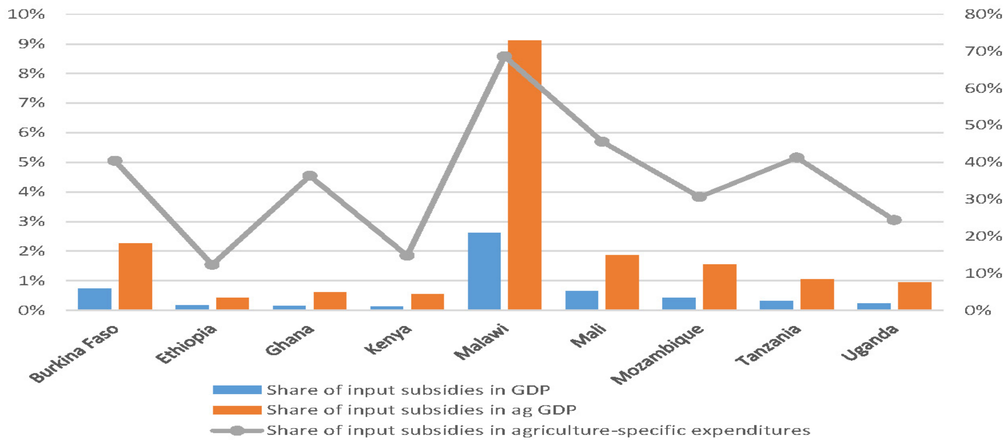
Source: Author calculations based on MAFAP, 2015.

Thanks to a fairly well desegregated MAFAP dataset it is possible to go beyond the level of monitoring public spending to focus on the composition of such expenditures in support of very specific categories such as payment to agents(producers, consumers, traders, ...), general support including agricultural research, technical assistance, extension storage, marketing and others. Payments to producers, for example, can include payments based on outputs, cash transfers, or input subsidies. The merits of spending on input subsidies as opposed to other spending categories such as research or infrastructure has been extensively discussed in the literature (Wiggins and Brooks, 2010). In this paper, we analyse input subsidies in more depth as one example of the type of analysis that can be done out of the MAFAP public expenditure database.

The MAFAP dataset reveals that over the period 2006-13, input subsidies have represented an average 35 % of agriculture-specific expenditures in the countries that were analysed. [6] This average masks three main groupings of countries. Low spenders are Ethiopia, Kenya and Uganda, with respective shares of 12, 15 and 24 %. Average spenders are Burkina Faso, Ghana, Mali, Mozambique and the United Republic of Tanzania (URT), with shares oscillating between 31 and 46 %. Malawi forms its own high-spending group, with a staggering share of 69 % (Figure 12).

The same pattern can be observed when considering the average shares of input subsidies in GDP and agricultural GDP (Figure 12Ghana is a specific case. Although input subsidies do constitute a large proportion of agricultural expenditures, at 36 %, they only account for 0,2 % of the country's GDP and 0,6 % of the agricultural GDP. There is indeed an important imbalance between public spending in the agricultural sector and the value added it produces.

Figure 12 - Share of input subsidies over agriculture-specific expenditures (right axis), agricultural GDP and overall GDP (left axis) in nine African countries, average 2006-13.

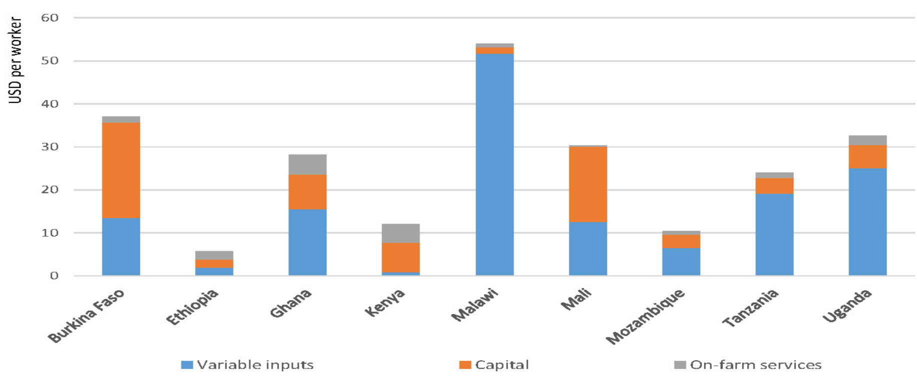


Source: MAFAP, 2016.

These results suggest to see the popular case of Malawi abundantly discussed in the literature (Chisinga, 2012; Jayne et al., 2013; Jayne and Rashid, 2013; Ricker-Gilbert et al., 2013) as an outlier rather than as an example of what is happening on input subsidies in SSA.

The composition of input subsidies is also more diversified than what is usually thought. Input subsidies are often equated to variable input subsidies for fertilizer and seeds. However, subsidized capital (on-farm equipment for instance) and subsidized on-farm services (inspection for instance) also represent a substantial share of the input subsidy category as can been see from. Although variable inputs have accounted for 59 % of input subsidies, capital and on-farm services have benefited, respectively, from 32 and 10 % of them. Burkina Faso and Mali have even subsidized capital, essentially on-farm irrigation, more than seeds and fertilizers (Figure 13). This is due to the geo-climatic characteristics of these countries, where access to water poses an important challenge. Kenya has also invested more in on-farm capital than in variable input subsidies.

Figure 13 - Expenditures in support of on-farm services, capital and variable inputs for nine African countries, average for the 2006-13 period, constant 2011 USD per farm.

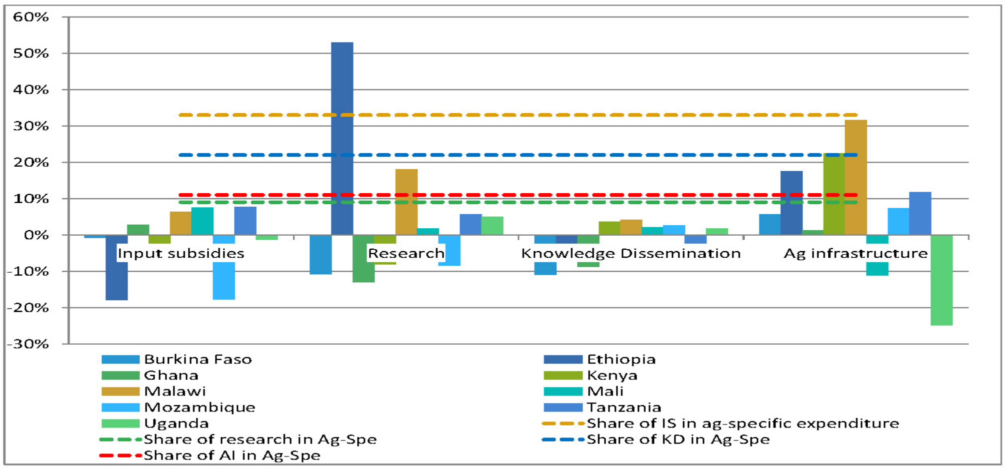


Source: MAFAP, 2016.

[6] The MAFAP methodology considers agriculture-specific and agricultural-supportive expenditures as PEA, which includes rural investments. See "methodology section".

Variable input subsidies have represented 23 % of agriculture specific expenditures on average for the nine countries over the analysed period, and 17 % if Malawi is not included. These results show that subsidies to seeds and fertilizers represent only a moderate fraction of agricultural budgets in all countries with the noticeable exception of Malawi. However, these variables input subsidy represent a substantial share of agricultural expenditures if taken jointly with subsidized capital and on-farm services, the three categories accounted for in the input subsidy category in MAFAP.

Figure 14 - Average exponential growth of the expenditures per farm on input subsidies, research, knowledge dissemination and agricultural infrastructure (in constant 2011 USD) in nine African countries, 2006-13 period, in %.



Source: MAFAP, 2016.

Figure 14 shows that input subsidies account for an average 36 % of agricultural expenditures, in the countries analysed and over the period. Input subsidies per farm, expressed in constant 2011 USD, grew at an average rate of 20.6 % during the period considered and across all countries reviewed. Agricultural research expenditure (ARE) per farm and agricultural infrastructure expenditure (AIE) per farm also grew positively, at about 26 % and 29 % respectively, but they only accounted for ten and 11 % of agricultural budgets respectively (Figure 14). Knowledge dissemination expenditure (KDE) per farm, which is recognized as a crucial area of expenditure to ensure effective uptake of research, increased at an average rate of about 21 %, which is about as much as expenditures on input subsidies per farm. In addition, ARE, AIE or KDE all represented less than 0.5 per cent of overall GDP or 1 per cent of agricultural GDP, on average for the reviewed period, considering all countries. By contrast, expenditures on input subsidies represented 0.6 % of overall GDP and 2.3 % of agricultural GDP, on average in all countries for the period considered here.

Overall, we find that the size and composition of input subsidies in budgets vary widely across countries (average 35%). Variable input subsidies do not always dominate agricultural spending. Other categories appear to be more attractive such as on-farm services, agricultural research/dissemination or agricultural infrastructures.

4 Conclusion

Governments in SSA are supportive of the idea that the agricultural sector in an engine of growth and plays a primary role in poverty reduction and improving food security. They therefore often decide to intervene in this sector through a variety of policy instruments ranging from trade and domestic policies, budgetary transfers or macroeconomic policies, or regulations. However, it also often the case that the governments' stated policy objectives, the policy measures implemented to achieve these objectives and the effects they generate are not in line.

This paper illustrate some of these policy gaps at regional and aggregated level as well as country and commodity disaggregated level.

First of all, while the overall level of price incentives is found to be generally low, the most striking result is the important heterogeneity of the results across countries and commodities analysed.

Second, when important disincentives are observed, the market failures and inefficiencies as captured by the market development gap indicator proposed by MAFAP appear to be playing a substantial if not primary role.

In addition, the problem of developing policy measures to mediate market failures poses difficulties that challenge the most sophisticated governments in developed countries: governments may not be able to accurately estimate costs to regulate prices in a market where one or more agent has excessive market power or evaluate the true value of an externality or public good.

Third, at commodity level based on the analysis of cotton, rice and maize, results also show a huge heterogeneity across countries and over time indicating that the situation is volatile and very much depends on conjectural factors and short term considerations by government leading to ad hoc policy interventions altering market signals and long term incentive structure.

Fourth, recognizing that government also use the budget as a tool to influence farmers' behaviour, MAFAP results indicate that the level of budgetary support to the agricultural sector as a whole for the fiscal year 2013/14 as reported by MAFAP is still below the Maputo target established in 2003. There are also clear signs of declining trends suggesting that the Maputo /Malabo target is not likely to be met in the near future.

Five, taking input subsidies as an example of desegregated result on public expenditure, MAFAP results show that here too heterogeneity prevails. Variable input subsidies for fertilizers and seeds do not always dominate the budget allocated to agriculture or even input subsidies as in some countries subsidies to capital in the form of irrigation or extension services on the use of variable input subsidies represent a non-negligible share of the total.

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THEMATIC SET C18

LAND STATISTICS

Session Organizer
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LIST OF PAPERS

The Tenure, Ownership, and Transition of Agricultural Land (TOTAL) Survey Conducted by the National Agricultural Statistics Service

H. Hamer, Jr. | National Agricultural Statistics Service United States Department of Agriculture | Washington, DC | USA

DOI: 10.1481/icasVII.2016.c18

Combining Administrative Data to Support Evidence-Based Land Policy Reform: Lessons from Ukraine

D. Nizalov | Capacity Development for Evidence-based Land and Agricultural Policy-Making in Ukraine | Kyiv | Ukraine

O. Niviyevskiy | Capacity Development for Evidence-based Land and Agricultural Policy-Making in Ukraine | Kyiv | Ukraine

S. Kubakh | Capacity Development for Evidence-based Land and Agricultural Policy-Making in Ukraine | Kyiv | Ukraine

K. Deininger | Development Research Group, World Bank | Washington | USA

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Competitive pressure and structural change in agriculture. Are larger farms more resilient? An analysis of Italian Census data

C. Cardillo | Council for the Research in Agriculture and analysis of Agricultural Economics | Rome | Italy

D. Fusco | National Institute of Statistics – Istat, Department of Economic Statistics | Rome | Italy

C. Russo | University of Cassino and Southern Lazio | Cassino | Italy

DOI: 10.1481/icasVII.2016.c18c

Cheaper, Faster and More Than Good Enough: Is GPS the new gold standard in land area measurement?

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C18

The Tenure, Ownership, and Transition of Agricultural Land (TOTAL) Survey Conducted by the National Agricultural Statistics Service

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DOI: 10.1481/icasVII.2016.c18

ABSTRACT

In 2015, the National Agricultural Statistics Service (NASS) of the United States Department of Agriculture (USDA) in partnership with USDA's Economic Research Service (ERS) conducted the 2014 Tenure, Ownership, and Transition of Agricultural Land (TOTAL) survey, which collected information about farmers and ranchers who rent agricultural land to other farmers and ranchers, as well as about agricultural landlords who do not farm. The TOTAL survey encompasses land ownership income, expense, debt, asset, demographic, and other landlord characteristics to provide detailed information from all agricultural landowners. As the only source of detailed information on agricultural land ownership characteristics and economic data, TOTAL provides important statistics to government, academia, the farming industry, and others who use agricultural land ownership data for planning, policymaking, research, and market analysis. This paper discusses both the major findings from the survey and some of the challenges and successes using this approach, and will highlight major changes in agricultural land ownership identified in the survey results, and lessons learned for future landlord surveys.

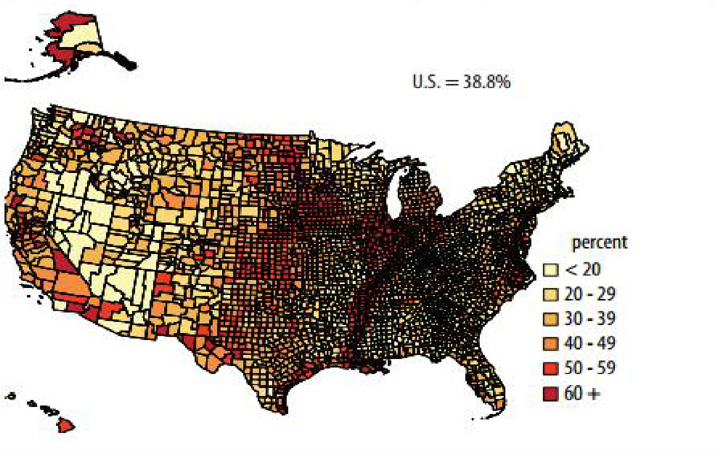
Keywords: Tenure, Ownership, and Transition of Agricultural Land; TOTAL; Land wnership; Landlord; United States Department of Agriculture; USDA; National Agricultural Statistics Service; NASS

PAPER

1. Introduction and Survey Overview

Nearly 40 percent of U.S. farmland is rented or leased from someone else, according to the 2012 United States Census of Agriculture. Moreover, the concentration of rented farmland varies significantly across the country (Figure 1). To learn more about the rented land and who owns it, USDA's National Agricultural Statistics Service (NASS) conducted a special study in cooperation with USDA's Economic Research Service (ERS) as part of the Census of Agriculture program. The 2014 Tenure, Ownership, and Transition of Agricultural Land (TOTAL) survey collected data in the 48 contiguous states about farmers and ranchers who rent agricultural land to others, as well as about agricultural landlords who do not operate a farm or ranch. The survey covers land ownership income, expense, debt, asset, demographic, and other landlord characteristics to provide detailed information from all agricultural landowners. TOTAL was the first landlord study conducted by NASS since 1999.

Figure 1
Percent of U.S. Farmland Rented or Leased, by County, 2012



Source: USDA NASS, 2012 Census of Agriculture.

NASS collected data by mail, personal interviews, and online from over 60,000 landowners across the United States. The agency mailed the forms in December 2014. NASS followed-up by phone with landlord owners who did not respond by mail to maximize response. In some special cases, NASS visited the landowners' operation. Data collection concluded in April 2015, with further analysis and review continuing until the results were published on August 31, 2015.

In order to customize data collection for different types of landlords, NASS used two versions of the TOTAL survey. One version focused on operator landlords (landlords who also farm agricultural land) and the other version focused on the non-operator landlords who are not involved in farming or ranching. The sample was designed to produce national data for the United States, plus state-level data for 25 states with the highest agricultural cash receipts over a three-year period, 2010 through 2012.

2. Landlord Ownership Arrangements

The survey results showed that, in 2014, more than 2 million landowners rented out 353.8 million acres of land for agricultural purposes. This is 39 percent of the 911 million acres of farmland in the surveyed states (and consistent with the 2012 Census findings).

Of these landowners, 13 percent were farmers and ranchers (operator landlords) and 87 percent were landlords who did not operate a farm (non-operator landlords). Non-operator landlords include those who rent out land individually or as participants in a variety of ownership arrangements (such as partnerships, trusts, corporations, municipalities, and limited liability companies or LLCs). A small number rent out land under more than one arrangement.

Table 1

Landlords and Acres Rented Out by Ownership Arrangements, 2014

	Landlord Arrangements[a]		Acres Rented Out	
	(number)	(percent)	(millions)	(percent)
Operator Landlord	**280,044**	**13**	**70.3**	**20**
Non-operator Landlord	**1,851,796**	**87**	**283.4**	**80**
Individual	1,092,551	51	138.2	39
Partnership	361,826	17	52.8	15
Trust	249,632	12	50.6	14
Corporation	91,011	4	31.5	9
Other	56,776	3	10.4	3
Total	**2,131,840**	**100.00**	**353.8**	**100.0**

[a] Landlords who rent out land under more than one arrangement are included in all relevant arrangements.

Numbers in this and other tables may not add due to rounding.

Source: USDA NASS, 2014 Tenure, Ownership, and Transition of Agricultural Land Survey.

Of the acres rented out, 20 percent were rented out by operator landlords, and 80 percent by non-operator landlords (Table 1). A similar survey in 1999, the Agricultural Economics and Land Ownership Survey (AELOS), found that 12 percent were operator landlords and 88 percent were non-operator landlords. Different methodologies between AELOS and TOTAL make direct comparisons difficult, but AELOS found that landlords rented out 394.3 million acres in 1999.

As far as income, in 2014, landlords received $31.2 billion in rent payments. Their expenses were $9.2 billion, and their debt related to the land they rented out was $32.8 billion. The value of the land and buildings they held on their rental acres was $1.1 trillion. Of the acres rented out, 89 percent of acres rented out by operator landlords, and 94 percent of acres rented out by non-operator landlords, were fully paid for.

3. Landlord Demographics

Of the 1.9 million non-operator landlords, 1.4 million can be called "principal landlords." They are either individual owners or the principal in a partnership arrangement.

The average age of principal landlords in 2014 was 66.5 years. Principal landlords are older than principal farm operators, whose average age was 58.3 years in 2012. (The 2012 Census of Agriculture defines a principal operator as the person who makes the day-to-day business decisions for a farming operation.) More than half (57 percent) of principal landlords were 65 years or older in 2014. They account for 67 percent of the rent received, 67 percent of the value of land and buildings, and 32 percent of the debt related to acres rented out. (Table 2)

Most principal landlords have college education; 25 percent have some college, and 38 percent have four or more years.

In terms of race, 97 percent of principal landlords are white. Two percent are Hispanic, regardless of race. Landlords who are white accounted for 98 percent of rent received, expenses, and the value of land and buildings, and 99 percent of debt, in 2014.

Of the principal landlords, 54 percent are not currently in the paid workforce; 41 percent are employed outside of farming. Also, 45 percent have never farmed.

Table 2

Principal Landlords: Income, Expenses, Assets, Debt, by Age
($ billions and percent)

	Number of Principal Landlords[a]	Rent Received	Expenses	Value of Land and Buildings	Debt
		($ billions)			
Total	**1,432,065**	**15.9**	**4.9**	**621.8**	**18.2**
	percent	percent			
< 55 years	18	11	14	12	34
55 to 64 years	25	22	22	21	34
65 to 74 years	29	30	29	31	18
75 to 84 years	19	25	24	24	12
85+ years	9	12	11	12	2
All ages	100	100	100	100	100

[a]Non-operator landlords who are individuals or the principal partner in a partnership.
Source: USDA NASS, 2014 Tenure, Ownership, and Transition of Agricultural Land Survey.

4. Land Uses and Economics

Of the total land rented out by operator and non-operator landlords, 63 percent was for cropland and 34 percent was for pasture. The remaining 3 percent was for other uses such as forest/woodland not pastured, buildings, ponds, ditches, and wasteland. In addition to renting out the land, landowners also lease or sell various rights, including mineral rights, recreational rights, development rights, and wind rights. Non-operator landlords leased oil and gas rights on 31.9 million acres and sold those rights on 4.1 million acres. Out of total farmland in the United States, oil and gas rights were leased on 61.0 million acres and sold on 11.3 million acres. (Table 3)

Table 3

Agricultural Land: Selected Rights Leased and Sold, 2014
(millions of acres)

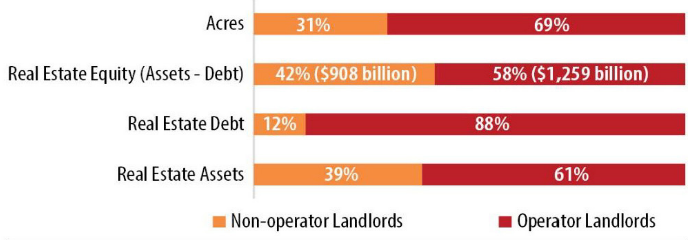
	Land Rented Out by Non-operator Landlord	All Farmland
Oil and gas rights leased	31.9	61.0
Other rights leased	14.9	35.6
Of which: wind rights [a]	3.5	
Oil and gas rights sold	4.1	11.3
Other rights sold	1.0	3.4
Of which: development rights [a]	0.7	

[a] Available for non-operator landlords only.
Source: USDA NASS, 2014 Tenure, Ownership, and Transition of Agricultural Land Survey.

Farm real estate financial statistics varied between non-operator landlords and operator landlords. Operator landlords held 69 percent of the acres, but 88 percent of the farm real estate debt and 61 percent of the farm real estate assets (Figure 2). Operator landlords held 58 percent of the farm real estate equity, or $1.259 trillion; non-operator landlords held 42 percent of the farm real estate equity, or $908 billion.

Figure 2

Farm Real Estate: Real Estate Debt, Assets and Equity



Source: Calculations based on TOTAL and USDA Economic Research Service, Farm Sector Balance Sheets.

5. Land Acquisition and Transition

Operator landlords purchased more than 60 percent of the land they rent out from a non-relative, a relative, or at auction. This is similar to the way all farmers in the United States acquired farmland. Non-operator landlords inherited or received as a gift more than 50 percent of the land they rent out.

The TOTAL survey asked landowners about their plans for transferring ownership in the next five years. Farmers were asked what they plan to do not only with the land they currently rent out for agricultural purposes but with all their land. In the next five years, operator landlords expect to transfer 15 percent, and non-operator landlords 14 percent, of the land they rent out. Operator landlords plan to transfer a larger percentage (70 percent) through trusts than non-operator landlords (40 percent). (Table 4)

In terms of their total land, not just acres rented out, landowners plan to transfer 91.5 million acres or 10 percent of all they own. These data do not included the 57.1 million acres landowners have put or plan to put into wills.

Table 4

Five-year Plan to Transfer Acres Rented Out and All Farmland
(millions of acres and percent)

	Operator Landlord		Non-operator Landlord		All Farmland	
	Acres (mil.)	%	Acres (mil.)	%	Acres (mil.)	%
Put/keep in trust	7.3	70	15.4	40	44.2	48
Sell to non-relative	1.7	17	10.5	27	21.1	23
Gift	0.5	5	8.0	21	12.6	14
Sell to relative	0.9	8	4.2	11	13.2	14
Other	-	-	0.5	1	0.5	1
Total to transfer	**10.4**	**100**	**38.5**	**100**	**91.5**	**100**

Source: USDA NASS, 2014 Tenure, Ownership, and Transition of Agricultural Land Survey.

6. Lessons Learned for Future Landlord Surveys

Conducting a new survey after 15 years presented many challenges. Some challenges were not easy to anticipate. Other challenges such as constructing a quality list of landlords to sample were anticipated challenges we addressed throughout the survey cycle. Some other lessons learned related to defining landlords, data collection for sub-leasing arrangements, and comparisons between the location of landlords and the land they rent. These specific challenges are described below.

One of the most significant lessons learned was that the definition of a landlord needed to be specified in more detail. There was no clear definition of who or what is a landlord. Depending on the goal, a landlord could be defined as the entity that is mailed a questionnaire, or it could be defined as all the individuals associated with all landlord arrangements within each entity. While tenants usually pay rent to one entity for each parcel of land, they don't necessarily know all the owners, especially if the landlord is a corporation. Obviously, counting all people with a connection to a corporate landownership arrangement as a landlord would be problematic. However, some measure of size of corporate landlords will become more important as corporate land ownership grows. As far as data collection, identifying the survey respondent for corporate partnerships will be an issue to further address in future surveys. Also, because the questionnaire contained three sections for the landlord arrangements – individual/partner, corporate/trust, and other, counting the entities with multiple arrangements created an issue when combining acreage data to landlord counts.

Sub-leasing arrangements created special data collection challenges. A small percentage (less than 1 percent) of farm operators rented land from others and also subleased at least a portion of the same land to other farmers. In order to be efficient, the questionnaires were used to collect all information for a farmer who is also a landlord. But with a sub-leasing arrangement an even more complex questionnaire would be needed.

Additional data on the location of the landlords would have been useful to data users. The data were summarized by the location of the land, which is appropriate for assigning expenses and land values to corresponding states and regions. However, summarizing the number of landlords by where they reside might produce results that are also valuable for analysis.

7. Conclusion

The TOTAL Survey provides valuable data that were not available in 15 years, and will be used for many years in the future. The data are a comprehensive view of all land, including agricultural land owned by non-operator landlords, as a follow on component of the United States Census of Agriculture program.

NASS conducted the TOTAL survey in collaboration with the USDA Economic Research Service (ERS). Many stakeholders have used these data, and many more will use the data in years to come. As future surveys are planned, the need for landlord data by more and more stakeholders will only continue to grow. There is already a growing list of requests for more detailed data on topics such as future transition to agricultural land, corporate landlord characteristics, and barriers to land ownership by new and beginning farmers. In 2014, the TOTAL survey provided a start into understanding the changes and complexities of land ownership in the United States. More information on the survey, methodology, data collection and results and other products can be found on the USDA NASS website at: www.agcensus.usda.gov/Publications/TOTAL.

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Combining Administrative Data to Support Evidence-Based Land Policy Reform: Lessons from Ukraine [1]

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ABSTRACT

The lack of reliable and up to date data on land governance is a common issue for countries in developing and developed world. A new approach for generating land data is related to utilization of existing administrative records of government agencies. The case of Ukraine demonstrates how the data from the State Land Cadaster, Registry of Rights, Tax Authority, Court Administration and other agencies can be linked together to produce a comprehensive description of land governance at regionally disaggregated level. A pilot implementation of the Monitoring system was completed in 2015. Results demonstrate a significant diversity in quality of land governance across the sub-national administrative units (rural rayons and cities) and can be used as a base-line for assessment of performance of relevant local authorities and some of the recent reforms in the sector. These differences are unrelated to the common national legislation and are related to factors at the local level such as resource endowment, infrastructure and local government decision making. The results demonstrate that the key challenge to development of land market in Ukraine is related to access to finance, a temporary ban (Moratorium) on sales of agricultural land and non-transparent practices at the local level.

A data set with more than 140 characteristics for the universe of over 600 sub-national administrative units was generated as a result of pilot implementation of the Monitoring system. For most indicators, the data covers period 2014-15 and reported quarterly. This data set is available in public domain and was used to establish a comparative ranking of land governance at the local level. Pilot implementation of the Monitoring in Ukraine faced several challenges including: i) the quality of generated land statistics is conditional on completeness of administrative records (combination of data from different sources helps to assess the gap); ii) most of the authorities do not follow the standards for classification of administrative units, as boundaries of service areas do not always coincide with administrative boundaries; iii) rigidities with data access are related to flexibility of design of the software used for processing and maintenance of administrative records. Development of a comprehensive reporting system allows addressing several practical issues (e.g., assessment of tax gap, mass valuation of land, design and assessment of land reform). To sustain the system, normative acts with reporting requirements and software need to be developed. Land governance monitoring reduces information asymmetry regarding the land use, land availability and performance of local government, and, thus, helps to reduce the moral hazard effect in government decision making.

Keywords: land governance; Ukraine; monitoring; administrative data, transparency, accountability, land reform

PAPER

1. Introduction and motivation

Land is an important factor of production, mean of asset accumulation and development of urban and rural areas. Thus, imperfections in governance of land resources have far-reaching consequences including stagnation of local economic development, poverty trap, low investment attractiveness, low access to capital, conflicts, eviction, land grabbing, etc.

Most of these problems, however, have common roots: information about land rights, land use, land availability and government decision making is asymmetric and protection of land related rights is weak.

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The overall results of these information imperfections are related to underdeveloped land markets, low transferability of land, low prices for land, inefficient distribution of land resources and imperfections on the interlinked markets (e.g. credit), rent on information (corruption, speculation), lack of productivity growth and technology transfer. The information asymmetry is also a reason for inefficient design of land reforms and lack of their implementation. Thus, reducing this asymmetry would have a profound impact on growth of urban and rural areas and governance of land resources.

Various national and international programs and policies were designed and implemented to reduce the information asymmetry regarding the land rights, their transfer and dispute resolution. Land cadasters and land titling programs in some countries exist for hundreds of years, while in many others they were introduced only recently. Development of the information technologies (including remote sensing) have greatly facilitated this progress. Nevertheless, the causal effect of introducing such systems on improvements in land allocation and investments are yet to be assessed (as many of such innovations were introduced to replace some already existed traditional systems of identification and protection of rights to land).

The issues of non-transparent land use and land allocation remain current for many countries. They are particularly important for governance of state and communal land. But, the same issues are also relevant for private land, where cases of non-formalized land use, violations in zoning and designated use, informal transfers and outdated cadastral records are not uncommon.

As land is an immobile asset, land markets are geographically fragmented and local governments in many countries play an important role in governing land resources. However, information on performance of such local markets and government decisions are not available (with rare exceptions), which provides room for non-transparent practices, opportunistic behavior and sometime market failures.

A response to this challenge belongs to a more general field of efficiency of local governments, institutional arrangements of land market and establishment of information revelation mechanisms and better contract design.

Talking specifically about the governance of land resources, the need for better access to information and use of information for monitoring and evaluation of land policies is clearly recognized by UN as it is stipulated in the Voluntary Guideline for Governance of Tenure (FAO 2012).

Several initiative to address the issue of access to information and transparency of land governance were taken by other international organizations. Starting 2010, The World Bank has developed a diagnostic tool – Land Governance Assessment Framework (LGAF) - for assessment the state of land governance at national level (Deininger et al, 2012). By 2016, this tool was used in more than 45 countries. It helped to reveal the state of land governance and provided recommendations for improvement. One of the common recommendation for these countries was to improve access to information on land governance, to provide regular updates and to reveal the relevant information at subnational level. In some countries (e.g. India, Brazil) LGAF was implemented at sub-national level.

Among other international initiatives are Land Matrix/ Global Observatory (http://www.landmatrix.org/), which collects information about large-scale land acquisitions. LandMark (http://www.landmarkmap.org/) collects and disseminates critical information on the collective land and natural resource rights of Indigenous Peoples and local communities around the world. While providing very important information, these sources are likely to be non-representative and non-comprehensive. Thus, they would have a limited use for design and monitoring of national policies.

There are also international surveys (e.g. Doing Business, Enabling Business for Agriculture), which include some characteristic of land governance as a part of broader investment attractiveness and business climate. While results of these surveys are wildly used as country promotion tools, they are not regionally disaggregated, impossible to scale down and update frequently, and are expensive to collect data.

Finally, there are several local and national pilots for spatial data infrastructure (NSDI) development, which by design should be comprehensive and contain many details. Unfortunately, local pilots are not always scalable as data availability is not universal, have high implementation cost and may be limited to a narrow set of characteristics available to national or local land cadasters.

This brief review points out to a need for a new institutional infrastructure that would reveal information on the state of land governance at the level of local land markets (e.g. districts or provinces) where most land use and land allocation decisions are made.

At least three options for design of such infrastructure are available. Among them are:

- Establishment of a regular survey or reporting system including interviews and focus groups of key informants. While such approach is standard, it also has standard limitations: cost, time, selection and accessibility. As the size of local land market could be anywhere between 50,000 sq. km and 300,000 sq. km (an area within which a buyer, investor or a tenant would consider options if she decides to acquire or rent land in a particular region), establishing characteristics of all local markets using the survey tools becomes difficult for medium and large size countries. A regular updating of characteristics of local markets becomes practically non-feasible;

- Remote sensing becomes a popular and accessible tool for assessment of land use, changes in land use and several other physical characteristics. However, this tool cannot provide information on social characteristics such as ownership, conflicts, taxation, values.

- Administrative records of government authorities dealing with different functional areas of land governance become a new alternative source of information as most of such records become available in electronic form. For example, tax declarations, cadastral records, court cases, - they all cover the universe of all relevant transactions or characteristics that belong to the formal side of land governance. Such individual records can be used as a source for regionally disaggregated statistics and can be updated regularly at almost no cost. It is not clear, however, if such approach is feasible and what institutional arrangement is necessary to sustain land governance monitoring system based on administrative records.

In this paper we describe the design of Land Governance Monitoring System – an infrastructure that helps to reduce asymmetry of information regarding the state of land governance at local and national level, ...- and demonstrate the case of Ukraine where the biggest progress up to date is made in establishing of such system. Ukrainian system is relies on administrative data from six different government authorities. This case demonstrates some feasible institutional arrangements, issues with linking administrative data across government institutions and options for dissemination and use of information on land governance for decision making by private and public sector at local and national levels. It also presents tools that can be used to overcome a moral hazard problem with local government decision making.

The rest of this paper is structured as follows. Section 2 presents the concept of Land Governance Monitoring System, its goals structure and stakeholders and relates it to moral hazard problem in local government decision making. Section 3 describes the case of establishment of monitoring system in Ukraine, example of institutional arrangement, monitoring results and describes implementation issues. Section 4 demonstrates how the monitoring data can be used analysis of the state of land governance by employing ranking and benchmarking of local land governance. In conclusions, we compare the case of Ukraine with several other examples and draw recommendations for other countries and development of land governance from a broader perspective.

2. Land Governance Monitoring as an infrastructure for information revelation

Regionally disaggregated Land Governance Monitoring System is considered as an institution to reveal the information on the actual state of formal land governance based on administrative data. It includes normative acts, institutional arrangement, methodology and software for collecting, processing and disseminating data on key indicators that describe the state of land governance at local land markets. The fundamental principal of the system is that it reports on the spatial/administrative units that coincide with geographic boundaries for local decision-making authorities in different functional areas of land governance (e.g. courts, tax authorities).

The institutional arrangement of the local land governance that currently exists in many countries can be described in a framework of standard principal-agent problem. Local government authority is appointed or elected to perform functions related to governance of land resources (e.g. to provide for registration of land parcels and related rights, manage state or communal land, collect taxes, resolve conflicts). In terms of outcomes and efforts of performing these functions, we face a dual problem with asymmetric information. First, the outcome for each local authority is not perfectly observable as the performance is often reported at aggregated national level (e.g. number of registered parcels or collected land tax) or at a level of individual parcel (a common situation with several cadastral or tax reporting systems). Second, the effort level of local authority is not perfectly observable as the outcomes depend on factors not observable to outsiders (e.g. number of applicants, quality of applications). The optimal behavior of the local government authority in such a setup is also standard – the authority would exert a minimal effort and extract a maximum rent on private information (including use of public resources for individual benefits).

This model for socially optimal land governance can be formalized in the following way. Consider a universe of N land parcels (with individual parcels $i \in N$) with some characteristics x_i. Such characteristics could include a state of formal registration, status of land tax payment, pending dispute, land investment etc. For simplicity x_i takes is binary (tax is paid or not, parcel is registered in the cadaster or not). Each such parcel locates in one of the local areas j ($j \in J$) where the land governance function is performed by a local authority.

Assume that a social utility function for land governance is $U = \sum_{i=1}^{N} x_i$ and local authorities are employed to maximize it (or minimize in case of conflicts) within the boundaries of a local area j. Thus, $U = \sum_{j=1}^{J} u_j$. The probability that a given parcel has desired properties $x_i=1$ (e.g. is registered) is affected by several parcel specific (k_i) (e.g. availability of historical records on ownership, owner's attitude or preference) and regional (r_j) (e.g. demand for land) factors. One of such regional factors is an effort level of local authority (e_j), which is not observable to outsiders. For simplification, we assume that the market transaction cost (e.g. for registration or dispute resolution) is an inverse of the efforts.

$$(1)\ P(x_i=1)=P(k_i, r_j, e_j)$$

It is a common situation that the reward of local government officials (l_j) for performing their functions (e.g. registration of land rights) is a fixed wage and is not dependent on the outcome (moreover on unobservable effort). It could be region specific to adjust for the local cost of labor or could be the same nationwide. The utility of local government officials that performs a specific governance function (e.g. registration) can be expressed in the most general form as $v_j=V(l_j, e_j)$, which is increasing in l_j and decreasing in e_j. As l_j is independent of e_j we face a standard moral hazard problem with an optimal outcome $e_j=0$ (and, thus, the registration transaction cost taken the maximum possible value and U becomes sub-optimal).

As the above principal-agent (PA) problem is structured in a standard way, the solutions to this problem would be also standard: to establish either a franchise contract with local government authorities or to make the reword (l_j) being conditional on the observed regional outcome $\sum_{i=1}^{N_J} x_{ij}$. The problem becomes interesting when one starts considering feasible implementation strategies for such contracts.

Franchising contracts makes the respective government authorities a residual claimant of the better land governance. There are two possible implementations of such contract:

i) *Decentralization* of land governance function (as currently considered in Ukraine), which means that local government receives authority to manage all state and communal land within the respective boundaries of their geographical area, collect land tax and stamp fees and other land transaction revenues as well as other benefits of better land market and better investment climate. While such contract allows resolving the PA problem in relationships between the central and local government authorities, the PA problem persists in the relationships between the local government and the individual government officers. Thus, there is a chance for preserving the lower equilibrium with ej=0 when the individual benefits from corrupted or low quality service provision remain higher than the benefits from the onset behavior. Unavoidably, the contracts of local government officials responsible for land would require modification that makes the reward conditional on the service outcomes (either in a form of bonuses or penalties) lj=L(xj).

ii) *Self sustainable services for land governance* is yet another option for franchising contracts with a functional government authorities. An example of such arrangement was practiced in Georgia between 2010 and 2014. With such arrangement, the functional authority (e.g. registration) becomes a residual claimant for all land transaction and registration fees or other service revenue as well as services provided to other government authorities (e.g. tax administration). Such arrangement provides incentives to the authority to establish performance based contracts with individual officers and to monitor their performance, which makes the operations of government authority similar to business operations.

An important issue that needs to be considered while designing the above contracts is the relative degree of risk averseness of local governments or the functional authority vs. central government.

The performance based contract becomes unavoidable whether we talk about local governments or individual government officers responsible for land governance decision making. Such contract would condition the reward on the observed outcomes for a given area xj (e.g. completeness or currency of registration). Establishment of such contracts would require knowledge of distribution of xij conditional on ej and, thus, access to reliable information on xij, ki, rj, and a proxy for ej is necessary for implementation.

A performance based contract for local authorities may take many different forms. One of them, with a moderate information requirements would be a benchmarking contract, where the benchmark would be either an individual past performance or the performance of "similar" (peer) government authorities or the combination of the two. The peer group may include either the authorities in a close proximity or authorities with similar characteristics of land resources (rj,) (e.g. structure of land ownership and land use, conditions of related markets).

Thus, overcoming the PA problem in land governance unavoidably would require access to regionally disaggregated information on land governance outcomes xij, conditions of land resources and related markets rj, and on distribution of individual characteristics of land owners and land users ki.

Establishment of Land Governance Monitoring System with regular reporting on key indicators at the level of local government authorities can change the contract arrangement in two ways. First, it would allow associating the outcomes for specific local area with activities of specific local authority. In many cases, such performance indicators could come from the sources independent of a particular authority. For example, quality and completeness of cadastral registration (area of responsibility of registration authority) could be characterized with a number of boundary disputes (recorded by a court authority). Second, data on the performance indicators can establish a benchmarking system for performance evaluation for local authorities. Such benchmarks could include previous period outcomes for the same authorities and/or performance of neighboring or similar authorities for the same period. For example, land tax revenue in one district could be comparable to the revenue in the previous period for the same authority or for a similar authority (normalized in per hectare terms).

It is expected, that introduction of the monitoring system and enforcement of new contracts based on performance outcomes could improve the quality of land governance at local and national levels, and increase effectiveness of use of public and private land resources. However, like in many theoretical models, the main question is what would be a feasible design and implementation arrangement for such monitoring system and how to sustain it.

2.1. Design of Land Governance Monitoring System

The primary goal of the monitoring system is to improve transparency and accountability of decision-making at local and national level. It also allows supporting evidence based policy making and keeping track of progress with reform implementation and their evaluation. Besides, better information on the state of local land markets provides for decision making in private sector, improves business climate and investment attractiveness, stimulates effective use of land resources and economic development at local and national levels.

The monitoring system includes a set of indicators that describe key functional areas of land governance (Figure 1). Among such functional areas are:

1. Formal registration of land parcels and related rights;

2. Formal land transactions of different types (sales, rent, inheritance, exchange, mortgage, etc);

3. Land tax;

4. Expropriation and privatization;

5. Land-related conflicts;

6. Equality of land related rights and their exercising by women, men, legal entities, national and ethnic minorities, and other potentially vulnerable groups of land owners and users.

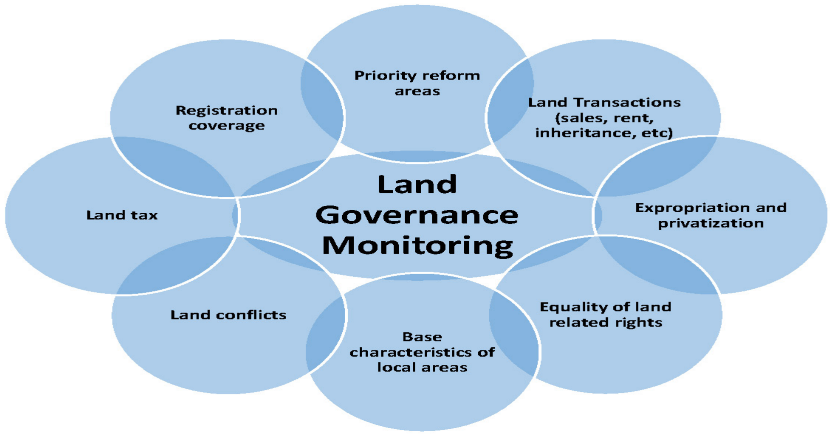
Besides the functional areas, the monitoring system may include two additional groups of key indicators:

7. Country priority reform areas (country specific);

8. Base characteristics of local areas (total land area, total number of land parcels, population, distribution of land ownership and land use).

The monitoring indicators for each of the functional areas could be further disaggregated by type of land use (e.g. agricultural/ non-agricultural) and form of property (state, private, communal, collective/ group).

Figure 1 - Structure of land governance monitoring indicators



The motivation and examples of specific indicators for each of the above groups are the following:

1. The formal registration of land parcels and related rights

Proportions of land resources of different ownership types are qualitative characteristics that determine the resource base for economic development and investment attractiveness. In contrast, the share of land that is formally registered by state is a measure of security of property rights and a factor that influences market activity and productivity of land use. Often, communal land without clear demarcation is highly vulnerable to encroachment by powerful outsiders leading to major conflicts. These indicators highlight the importance of land inventory and registration for state/community/public lands and related assets, which in turn is crucial for effective land management.

Indicators included to this group are: the number and area of land parcels (total and by use type and form of ownership), which are formally registered according to the national legislation in the Land Cadaster and/or Registry vs. total area of a relevant local area. The number of primary registrations is an indicator that shows the currency of the cadastral records and refers to previously unregistered parcels, merged and split parcels. Share of formally registered land is both a measure of completeness of administrative records and a quality of formal protection of rights.

Two *Data sources* are required for these indicators. First are the Land Cadaster or Registry data bases on registered parcels, which are used to generate the number of parcels and area of land formally registered for each local district by land use and form of property. Second, as a base for comparison several sources of data can be used. Among them could be results of inventory or a survey (e.g. in Georgia), statistical surveys or reports (e.g. in Ukraine) or results of remote sensing (e.g. in Vietnam). In some countries (e.g. Croatia) completeness of the Cadaster is not an issue, however accessibility of the records and their currency are. For cases like this, other indicators may be more informative. For example, the share of records that were updated during the last 5 years, the share of records entered into the electronic data base or accessible by a central authority, records that are entered into European systems (e.g. ARKOD - System for Registration of Agricultural Parcels).

Reporting Frequency depends on the stage of development and completeness of the cadaster in a particular country. In established and complete systems, annual updates may be sufficient, while in cases where some active reform of land governance is in progress, some more frequent updates may be necessary.

Use for decision making would vary depending on the country priorities and context. Among the examples are the need assessment for inventory and registration of state and communal land, identification of target areas for interventions related to formal registration, assessment of tax base, assessment of risks of investments in local area, assessment of potential costs of investments, etc.

2. Formal land transactions of different types

The information on transactions indicates how the market reacts to micro- and macroeconomic factors, government programs, etc. These indicators also reveal the market capacity and flexibility, and they are the most sensitive to changes to the quality of land governance. Comparisons by transaction types, land use categories, types of ownership and regions helps to reveal market imperfections that should become a subject to public regulation/ de-regulations or administrative actions. The completeness of public registry affects the quality of such conclusions to a great extent.

Reporting indicators include the quantity of registered market transactions for land (sales, bequests, gifts, mortgages, rentals, exchange) – total number, area, prices and payments (including rental) per ha. The indicators are disaggregated by land use category. Comparison of transactions across geographic areas requires normalization in per hectare or per capita terms.

Data sources include administrative records of State Registrars, Cadasters, Courts, notaries or other authorities responsible for keeping track of land transactions. Accessibility of these records, ability to link them to cadastral records and reliability of information (particularly on price) is one of the biggest challenges in the countries we worked with over the last 3 years. On the other hand, resolving this issues and publishing information on prices makes the biggest breakthrough in terms of transparency of land markets.

Reporting Frequency depends on the frequency of transactions. Monthly reporting would serve the purpose in most of the cases. There are, however, examples when the data on individual transactions is published and could be updated in the real time or quarterly.

Use for decision making would include assessment of market capacity, mass valuation (appraisal) of property, identification of market imperfections and sources of inequality.

3. Land Tax

Taxes on land and other real estate objects, as well as related fees are among the few sources of revenue available to local governments. As actual receipts depend on coverage, assessed values, tax rates and collection efficiency, among other factors, comparison across local areas could provide for a better design of land tax system. Land and property taxes may play an important role in stimulating the productive utilization of resources and sustainable development of rural areas. Such taxes can also foster investment in infrastructure, improvement of land quality and real estate as well as to prevent a non-effective use of land parcels (brownfields and idle property).

Reporting indicators include the number of tax payers, declared area, the revenue and a number of tax exemptions for the different categories of land and land tax.

Data sources for these indicators include relevant administrative records of tax authorities or municipalities. An ability to access the records (including local tax rates) from the central level and institutional capacity to link the tax and cadastral records (e.g. consistent use of cadastral and tax numbers) is a target for institutional development of tax system on its own right.

Reporting Frequency depends on frequency of tax declaration and payment. In most cases annual or semi-annual reporting is sufficient.

Use for decision making would include assessment of the tax gap, design and evaluation of changes in tax system, assessment of elasticities of tax revenue to various intervention, identification of target area for policy and administrative interventions.

4. Expropriation and Privatization

Privatization and expropriation can play both positive and negative role in stimulating economic development. Land acquisition for public purposes with fair compensation is unavoidable to provide public services (e.g. infrastructure) effectively. However, low levels or failure to pay compensation and use of excessive administrative power to acquire land can easily undermine good governance and the respect for due process. In contrast, transparent procedures (e.g. auction), divestiture of public land (e.g. brownfields in urban areas) can be a driver of private sector development and revenue generation for the public sector. Therefore, information about these transactions is an important indicator of the quality of land resource management, it can also indicate possible directions for improvements of the system.

Reporting indicators include the number, area of land parcels by use type that were expropriated (taken, purchased) for public needs and value of compensation paid, and the number and area of land parcels by use type transferred to private ownership (privatized) (separately via auction and free of charge) and relevant revenue.

Data source for these indicators may represent a challenge. While the records on privatization can be maintained by a state land authority, local municipalities, state agency for privatization, records on expropriation may be identified only partially in some contexts. In most cases authorities responsible for decisions on expropriation are well defined (e.g. courts, central government authorities, President of a country). However, many decisions on alienation of private land for the public purposes are made in amicable way via buyouts by municipalities or infrastructure development companies (e.g. rail roads or transportation authorities, project implementation authorities). Thus, identification of sources of information would require some additional investigation in a context of a specific country.

Reporting Frequency depends greatly on data accessibility. In most cases annual reporting is the only option.

Use for decision making would include assessment of risk of expropriation and fairness of payments.

5. The Number of Land-Related Conflicts

A large number of cases in court points to either drawbacks in regulatory and legal environment, or an under-developed conflict resolution system. In both cases reduction in the number of conflicts should coincide with an increase in number of formally registered land plots. Thus, this indicator can be used not only to track changes in the legal and regulatory environment, but also to justify further improvements of the system of State land cadaster and land inventory. It could also indicate the quality of decision-making by local authorities regarding land allocation and other land governance and land management issues.

Reporting indicators include the number of cases, for which there are court disputes filed or pending. The cases could be disaggregated by court authority (administrative, commercial or civil) and type of disputes (boundary, misuse, encroachment, registration of property rights, distribution of land, valuation, payments, etc.) between different categories of participants (individuals, legal entities, government bodies) by state of cases in the dispute process (filed, resolved: granted/declined) and length of the process.

Data sources depend on the specific institutional setting and could include State Court Administration, Ministry of Justice or individual courts.

Reporting Frequency is annual as the number of formal disputes is relatively low in most cases when disaggregated regionally.

Use for decision making would include assessment of reforms and changes in other areas of land governance and targeting local areas. Analysis of frequency of different types of disputes and length of disputes helps to identify the areas where legal and procedural changes are needed. Frequency of disputes is yet another measure of security of rights and quality their protection.

6. Share of land and real estate registered in the State Land Cadastre in women's, men's name or as a joint property and in legal entities' ownership

Although the legislation of most countries has no gender-related limitations for acquisition or use of land parcels (or other assets), the practice of exercising these rights may reveal certain evidences of discrimination. It may be related to some traditional practices of intra-household distribution of rights. Such inequalities may also happen when women or minorities have less negotiation power, access to information (e.g. in native language) or means to protect their rights, which can influence the rental and sale pricing, the number of conflicts, etc. The discrimination may also take place at the stage of divorce or bequest. Therefore, consideration of gender and minority status in land relations and prevention of possible discrimination can have a significant positive impact on the quality of land governance, economic development and human rights protection. Moreover, FAO Voluntary Guidelines, Global Land Indicators Initiative (GLII) and Global Development Goals focus on guarantying equal rights of men and women and other land users.

Reporting indicators include the number of private land plots, total area and prices by use type registered on women's name, men's name or as a joint property, in property of legal entities or minorities.

Identification of the data sources often represent a challenge as too often it is not recorded on the titles or in other records. However, gender indicator may be added as a mandatory field to the registration forms as it was recently done in Georgia or India. As an alternative, a name comparison against the male and female name dictionary can be performed for the registered property. Finally, the registration data may be merged with tax registry or civil status records where gender and nationality is recorded.

Reporting Frequency is annual as this indicator is not likely to change fast.

Use for decision making would include identification of inequalities, design and implementation of legal changes and programs to protect vulnerable groups of land owners or land users.

7. State of Land Reforms

This group of indicators reflects on key reform priorities in each specific country and helps to assess the scope of reforms and keep track of their implementation. As priorities differ from country to country, the following examples are just for illustration. In case of Georgia, Eastern European countries, such indicators include the number and are of land parcels owned by foreigners. In case of Ukraine, they include the number and prices for renal rights sold via auctions and the number of errors corrected in the State Land Cadaster. Other countries may focus on large-scale land acquisition, land conversion, etc.

The data sources, indicators and reporting frequency would also be country specific.

8. Base characteristics of local areas.

Comparison of the data for reporting units (local areas) of different size requires normalization (e.g., per unit area, per capita) or statistical weighting by size of administrative units.

Reported indicators included into this group are the area and the number of plots (total and by land use and ownership types), population, number of business entities.

Data sources are the State Statistics or National Census authorities (data on population and business entities as well as on land ownership and use). Land inventory, cartographical base (with identification of boundaries) could serve as a source of data on land area and types.

Reporting frequency is annual. However, less frequent updates would also fit the purpose.

2.2. Administrative data

The use of administrative records from government authorities involved with land governance is considered as a feasible strategy for providing regular regionally disaggregated data for the purpose of Monitoring. However, administrative data has some specifics that has to be taken into account at the stage of interpretation of the Monitoring results and features, which can contribute to sustainability of the Monitoring system.

First, completeness and currency of administrative data determines the quality and reliability of the resulted monitoring indicators. For example, if the land cadastre covers only a relatively small share of land, it could not provide a reliable information on land use, distribution of ownership and other characteristics of land. Thus, other sources for such characteristics have to be considered. On the other hand, completeness of the cadaster is an important characteristic of land governance on its own rights and is included as an indicator of quality of protection of land related rights.

Second, the use of administrative data from multiple sources creates mutual benefits to all the agencies involved. It allows assessing gaps and technical errors across the data sets, which cannot be revealed otherwise. For example, joint use of cadastral and tax records helps to verify the currency of information in the cadaster. The cadaster records can improve the tax base. Thus, participation in the monitoring helps authorities to improve the quality of their administrative records and, thus, the quality of their service. However, to fully benefit from such data exchange, the relevant authorities need to upgrade their internal data sharing and error correction procedures. Too often, the government agencies may know about errors but do not have rights, a functional responsibility or procedures to correct them. For example, the area of land parcel recorded during a transaction may not coincide with cadastral records. But, verification and correction may be initiated only by the owner.

Third, administrative data have several important benefits in comparison to alternative sources of information that can be used to create the indicators and sustain the monitoring system. Among them are:

- *Low cost of data collection* – government authorities collect and store the administrative records as a part of their regular operations. Thus, only some small initial investments are needed to develop a reporting software that would generate the reporting indicators out of records with a pre-designed frequency or on demand.
- Promptness – administrative data requires minimum processing, allows construction and publication of monitoring indicators on a regular base with virtually no delay after the reporting period;
- *Regular update of information* – as the reporting software were developed, the reporting can be done with any frequency. The option for generation of retrospective values is also feasible;
- *Accuracy of information* – the authorities keep records on the universe of formal transactions, land parcels and other relevant objects. Thus, selection is not an issue for producing characteristics of formal side of the land governance. Also, the authorities are interested in and have responsibilities for having their records accurate and they employ different quality control and back up practices; they should be interested to address any known gaps in data as well.

Fourth, there are some common challenges of working with administrative data that need to be anticipated and addresses with normative acts and procedures. Among them are the rigidity of current software (property and access rights, formally approved procedures, etc.) which does not have functionality for generating necessary statistics out of data and does not provide access to the raw data. Another challenge is the lack of common standards among the authorities in terms of definition of land use and land cover types, boundaries of reporting areas, etc. Finally, some administrative data (or a part of it) are yet stored in hard copies only (or in form of scanned copies). Resolving these issues is often time consuming and require solutions tailored to each specific case. However, the solutions do provide for not only the monitoring function, but they also help to improve the overall quality of government services in the field of land governance.

2.3. Motivation for implementation of Land Governance Monitoring

Besides the theoretical and strategic benefits of more transparent and more efficient governance of land resources, establishment of the monitoring system can bring several short-term tangible benefits to different groups of stakeholders. Central government authorities and policy makers can use the information on monitoring indicators as an evidence base for their decision making, policy design, monitoring and evaluation of reforms, programs and policies, need assessment for public intervention. Authorities responsible for delivering public services receive a tool that helps to reveal errors, improve coverage, assess the gaps in delivering of the relevant services. They also can monitor and assess performance of various local branches and service centers to identify the best practices and targets for improvements. Private sector receives a source of information necessary for risk assessment, valuation and planning in all industries where land is used as an important production factor. Finally, land owners, public activists and media can rely on publicly available monitoring results to understand the impact of various government decisions on wellbeing, to assess the performance of elected local authorities or to set agenda for improvements on local level.

There are also groups of stakeholders that would face losses because of better availability of information on land, and, thus, would oppose the introduction of monitoring. To this group would belong the local and central authorities involved in non-transparent management of state and communal land. The land users, which currently enjoy a monopolistic market power on the local markets and producers that use land informally would likely to oppose the introduction of the monitoring too as better information and higher competition will likely to reduce their rent on non-transparent use of land.

However, the most important motivation and factor of success for the monitoring system is the support from top government authorities, which coordinate land reform activities among different functional areas of land governance. Three factors may play a role in supporting the introduction of land Governance monitoring. These are political agenda (if transparent land governance is already a part of priorities), legal requirements (if monitoring is stipulated by law as for example in Columbia and Vietnam), and development projects by various international donors (for example, the World Bank supports pre-project or relevant implementation activities in Georgia, Ukraine, India, Croatia, Peru, Philippines, Rwanda).

The motivation of various stakeholder groups is taken into account when institutional and implementation arrangement is developed for introduction of the monitoring system.

2.4. Dissemination mechanisms

The degree to which the benefits of the Monitoring system can be realized by different stakeholder groups depends on the dissemination channels for the monitoring results. Online publications of the regionally disaggregated data would fit this purpose only partially. In addition to that, supplementary products such as regional rankings, benchmarking, policy briefs on the selected topics would help to communicate the results to the relevant audience. However, one of the most important dissemination tool would be the distribution of the local area profiles, which would make the results of the local authorities' practices perfectly observable and comparable with other peers and over time. The local landowners and land users should be aware of such profile and monitor the performance of the local authorities.

2.5. Institutional arrangement

As it follows from the motivation of different interest groups, a successful implementation of the monitoring system requires arrangements at three different levels: policy, coordination and technical implementation.

Policy level includes establishing a policy agenda where increasing transparency of land governance is included as a priority. The key players in this process could be the reform-oriented government or political parties representing interests of landowners. International organizations and donors could be instrumental in this process by providing financial support for initial investments and methodological help. However, without political support and political leader, the process of improving transparency of land governance and implementation of the monitoring is not feasible.

Coordination of development and implementation activities among the key government authorities involved with the land governance is an important factor of success. Such coordination could be done in form of a land reform steering committee or other body, which includes top decision makers from the relevant government authorities (e.g. Land Cadaster, Ministry of Justice, Tax Authority, Ministry of Agriculture, Ministry of Regional Development, Ministry of Land and Natural resources). The primary task of such coordination body is to agree on the need for the joint work to establish the monitoring system in order to achieve a political goal or a legal requirement for better transparency of land governance. The members of this coordination body would also authorize the relevant departments to engaged into development and implementation work, and to authorize the information sharing for the purpose of monitoring.

Technical implementation or a working group would include technical experts from the relevant government institutions that are in charge for management of administrative records. The tasks of this group include organization and implementation of data exchange and data processing, development and testing relevant procedures and methodology. At the implementation stage, the experts from this group would also organize and supervise development of software that generates monitoring indicators out of administrative records.

In terms of institutional arrangement, there is also a need for a task force, which would actually do all the day-to-day development and coordination work across the institutional levels and among the government authorities.

The effective institutional arrangement is a key element of successful implementation of the monitoring system. The case of Ukraine demonstrates an example of such arrangement and illustrates some first implementation results.

3. Case of Ukraine: indicators, sources and results

Different elements of the land governance monitoring can be found in many countries and are implemented by several authorities as a part of their regular duties. For example, most of the land cadasters publish regular information on the total number of registrations, extracts or complaints. Similarly, information on land transaction and prices are often available to the public at regional level and at a level of individual transactions. The case of Ukraine, however, is informative as it represents an example of successful institutional arrangement for a comprehensive monitoring system based on administrative records from six different government authorities and where synergy effect from linking the data from different sources is observed. This system produces all monitoring indicators consistently for all rayons (districts) and cities of Ukraine. So far, Ukraine represents the first case where such comprehensive system is established and where the benefits of improved transparency can be expected in a near term.

3.1. Timeline and institutional arrangement

Development of the Land Governance Monitoring System in Ukraine started in 2015 with a coincidence of several events. After the Parliamentary election in the fall of 2014, a new pro-reform government was formed, and land reform was included as one of the reform priorities. It followed by a development of Comprehensive Strategy for Agricultural Development 2015-20 by the Ministry of Agrarian Policy and Food of Ukraine (MoA) and experts from private sector and professional associations. This strategy has established a clear set of priorities for land reform and was supported by the National Reform Council. Monitoring of land governance was included to this strategy as a necessary condition for transparency and accountability of the land reform.

At the same time, the World Bank has established a new project to support the government and to upgrade the government's capacity for evidence-based policy making in area of agriculture and governance of land resources. The project has provided methodology and implementation support for establishment of the Monitoring system. To coordinate the Project's efforts, the MoA has established a Steering Committee, which includes representatives of six central government authorities at a level of Deputy Ministers, Members of Parliament, representatives of professional associations and international organizations. The Steering Committee supervised the progress with development of the Monitoring system and made some key decisions regarding the distribution of functional responsibilities among the government authorities with respect to Monitoring. Its functions also include a review of normative acts related to the land governance monitoring that were proposed to the Cabinet of Ministers and other central government authorities.

The MoA has also established a Monitoring Working Group, which included technical experts from the government authorities involved with land governance and maintenance of administrative records. The responsibilities of the working group include organization of data supply, development of methodology, coordination of joint implementation work, liaison with corresponding government authority, interpretation of the monitoring results, feedback and administrative actions.

Establishment of the working group marked a start for the pilot implementation of Land Governance Monitoring system in Ukraine. The pilot implementation took about eight months, from April to December of 2015, and included development of monitoring indicators, identification of the data sources, sample data collection, data cleaning and construction of the sample monitoring indicators for the period 2013-2015. The pilot implementation has also identified gaps in existing administrative data in terms of data quality, availability and data collection procedures, and suggest approaches for bridging some of these gaps. The pilot implementation resulted in the following outputs:

- The first set of monitoring indicators for 2013-2015 at rayon (district) level were published online on the Project web site (land.kse.org.ua). This data establishes a base-line for designing and monitoring further land reform and for development of the monitoring system;

- A yearbook "Land Governance Monitoring 2014-2015" was presented to the stakeholders and published online. It provided a description of the monitoring result to the expert community and policy makers;

- Normative acts for establishing the Monitoring system and methodology ware drafted as well as the terms of reference for monitoring software.

Currently, a permanent automated system of land governance monitoring is at a stage of development and implementation. It is expected that the fully operational system can be established within six months after adopting the necessary normative acts. Besides the above outputs, the system would also generate maps and charts, local area profiles, and a list of detected errors in administrative data.

3.2. Sources of data

During the pilot implementation, the administrative data on land parcels, related rights, land tax and other functional areas of land governance was provided by the following state authorities at the level of rayons and cities of Ukraine:

- State Service of Ukraine for Geodesy, Cartography and Cadastre (2014-2015);
- Ministry of Justice of Ukraine (provided by the "National Information Systems" State Company) (2013-2015);
- State Fiscal Service of Ukraine (2015);
- State Court Administration of Ukraine (2013-2014);
- State Statistics Service of Ukraine (2011-2015); and
- State Water Resources Agency of Ukraine (2014).

Based on these data sources, more than 140 indicators for land governance performance were constructed. However, some areas and time periods were not covered as the data was unavailable during the pilot implementation. In particular, the gender of landowners and data on expropriation remained non-accessible. Some examples of the monitoring results are provided below.

3.3. Pilot results

Administrative structure

The territory of Ukraine is 60.3 mln ha and includes 27 primary administrative units (of national subordination): 24 regions (oblast), the Autonomous Republic of Crimea, cities of Kyiv and Sevastopol[2]. These units are further subdivided into the secondary administrative units: rural rayons (districts) and cities of regional subordination. There are 490 rayons and 182 cities, which are the units of reporting for the Monitoring system. These units have elected local governments (councils), and most of the public (government) cervices have local branches (service delivery units) at this level (e.g. Fiscal Service, State Geocadastre, Courts). Thus, most of the decisions on governance of land resources are made at this level and the administrative reports (besides those generated from a parcel level data bases) are available at rayon/city level and higher levels. The average size of rayon is 119,530 ha (ranging from 30,874 ha to 361,615 ha) while the cities occupy on average 10,000 ha (ranging from 202 ha to 86,400 ha). The average population of rayon is 41,226 and of city is 143,333 people. As basic characteristics, land prices, land use and quality of land governance are different between rural rayons and cities, most of the descriptive analysis of the monitoring results is presented separately for cities and rayons.

There are also administrative units below rayon/city level. These are village councils and urban rayon councils. There are 10,798 of such units. There are also 29,772 settlements (villages, towns, cities) in Ukraine. As one of the monitoring indicators, the System reports on the number of village councils and settlements with clearly established and formally registered boundaries. The monitoring reports that only 50 such units have registered boundaries as of 2015. Undefined formal boundaries was a reason for boundary conflicts in several areas. The unclear situation with boundaries and the fact that Ukraine is currently going through an administrative reform (village councils are aggregated into larger units) were the reasons for selection of rayons and cities as the primary reporting units for the Monitoring system.

Main characteristics of rayons and cities of Ukraine

The Monitoring system includes both, the indicators on the functional areas of land governance and some basic characteristics of the reporting units. Table 1 present some of these characteristics to illustrate the diversity of property distribution and land use structure.

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[2] Since March 2014, the City of Sevastopol and Crimea Autonomous Republic are temporary occupied by Russian Federation and several districts of Donetsk and Lugansk region are regulated by regime of anti-terrorist operation and information on these regions may be unavailable.

Table 1 - Main characteristics of rayons and cities of Ukraine, 2014

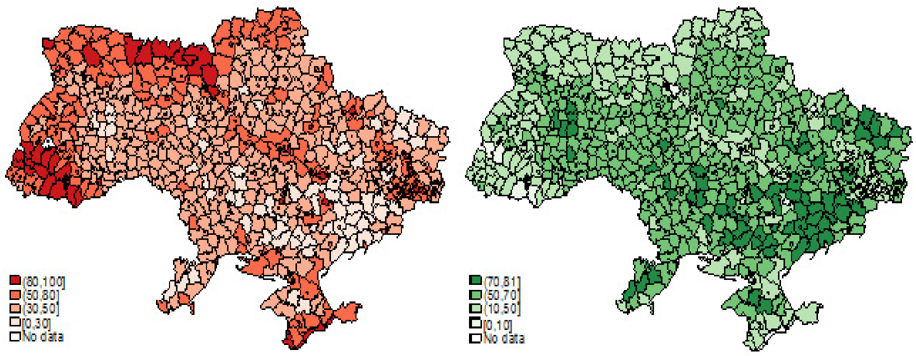
	Total	West	East	North	South	West	East	North	South
		Rayon				City			
Population per ha[a]	**0.7**	0.5	0.3	0.3	0.3	16.6	23.3	21.0	17.1
Agricultural land[b], %	**68.7**	58.6	78.5	70.6	77.4	26.1	39.8	27.0	26.0
Developed land[b], %	**4.2**	3.4	3.4	3.3	2.9	34.4	37.9	44.8	25.4
State owned[b], %	**47.9**	56.5	38.4	47.4	40.1	82.6	76.0	81.3	83.0
Privately owned[b], %	**52.1**	43.8	61.3	52.5	59.8	16.4	23.2	18.3	12.5
Average size of private plot[b], ha	**2.4**	1.3	3.5	2.3	3.4	0.7	1.0	0.2	1.2
Average size of state owned plot[b], ha	**10.1**	13.3	7.6	10.1	9.0	2.3	2.7	3.9	2.6
Average farm size[a], ha	**481.7**	318.1	643.5	706.2	300.9	132.8	803.0	1111.3	266.8

Data: a) State Statistics Service; b) State Service of Ukraine for Geodesy, Cartography and Cadastre

The primary land use in rural rayons is agriculture, which occupies about 70% of total rayon area with some regional variation. Less agricultural land is available in Western part of Ukraine as about 30% of rayons in this part of the country are covered with forests. The largest share of land used for agriculture is in the Eastern part. Cities have on average 32% of land used for agriculture as many cities include into their administrative boundaries also adjacent villages and village councils. About 35% of the territory of cities is developed and the rest of city territory is covered with water and forests. Only 3.3% of rural rayons territory is developed. A small share of territory is classified as mountainous areas (Crimean and Carpathian mountains), desert (in Kherson oblast) or swamps (in Northern part).

About 52% of land in Ukraine is privately owned with private ownership being lower in urban area (19% on average). State owns 47.87% of the land (of them 10 mln ha is agricultural land). The rest of land is in communal property. The share of state property in rural rayons ranges from 94.7% (primarily in mountainous and forested areas) to 19.6% (see Map 1). In cities, this range is from 99.1% to 36.9. The management of state land is a responsibility of various state enterprises and ministries. Most of agricultural land is managed by the State Service for Geodesy, Cartography and Cadaster. It has to be mentioned, that Ukraine started a process of transferring land within the boundaries of settlements from state to the communal property. However, the formal registration of this new communal property is incomplete. The monitoring will be able to show the progress with this process. Also, a reform related to state ownership of agricultural land is in a process of design and is likely to start in 2017. It is anticipated that a part of state agricultural land will be transferred to communal property while another part will be privatized via auctions. The monitoring system will help to keep track of implementation of this reform and to evaluate its effect on productivity, prices and investments.

Map 1 - The share of land area of the state (left) and private (right) form of ownership by rayons, 2014



Ukraine is a large agricultural producer and exporter. There are 52,543 agricultural producers (State Statistics 2015). Of them, 44,968 commercial producers are involved with cultivation of land (total area of cultivated land is 21.5 mln ha in 2014). The rest of private agricultural land is cultivated by individual owners. The average size of a commercial farm in Ukraine is 481.7 ha. The farms are larger on average in Eastern and Northern parts of the country (643.5 ha and 706.2 ha respectively).

A specific of Ukrainian farmland market is that a ban to sale agricultural land (Moratorium) was established in 2001. As a result, rent is the primary mode for transferring use rights and more than 4.6 mln rental agreements for about 16.6 mln ha of private land are signed as of 2015. Such a large number of rental agreement is a result of land distribution during the privatization of 1990s. During this process, 27.72 mln ha of agricultural land of former collective enterprises was equally distributed among 6.91 mln of employees of these enterprises. As a result, an average enterprise has to sign and maintain about 130 (primarily short term) rental agreements which imposes a significant transaction cost and puts a downward pressure on the size of rental payments.

Lifting the Moratorium is considered as one of the top priorities for the land reform in Ukraine. Land Governance Monitoring System will help to demonstrate the progress with opening up of the sales market and its impact on land consolidation, number and prices of rental agreements as well as other characteristics of land governance.

The quality of land governance is also associated with a cost of land transactions and security of land related rights and is the primary focus area of the monitoring.

4. State of land governance in Ukraine, 2014-2015

As it was mentioned above, access to information on the state of land governance at the level of decision making is a necessary condition for overcoming the moral hazard problem in relationships between central and local government and between the individual bureaucrats and government authorities. To address this issue, the monitoring system includes a large number of indicators on six functional areas of land governance. Each of these areas contains one or two aggregated indicators, which are presented in Table 2.

Table 2 - State of Land Governance, 2014-2015

		West	East	North	South	West	East	North	South
	Total	Rayon				City			
Registered in the Land Cadaster - private, %	**70.9**	64.5	72.7	73.3	74.2	81.1	74.3	81.9	85.9
Registered in the Land Cadaster - state, %	**24.0**	18.8	31.4	23.5	25.9	15.5	28.1	11.6	26.0
Number of rental agreements per 000 landowners	**40.8**	41.3	37.2	56.1	30.7	1.3	2.8	1.2	0.4
Number of non-rental transactions per 000 landowners	**1.2**	1.1	0.5	2.0	1.2	0.5	0.3	0.9	1.0
Number of sales per 000 landowners	**0.1**	0.1	0.1	0.1	0.1	0.2	0.1	0.2	0.7
Number of exchanges per 000 landowners	**0.1**	0.1	0.1	0.2	0.04	0.1	0.03	0.1	0.1
Number of inheritance per 000 landowners	**1.0**	1.0	0.3	1.6	1.0	0.2	0.1	0.6	0.2
Tax by Individual taxpayers per ha of private land	**36.3**	8.9	9.7	7.5	12.6	346.3	2,129.9	2,114.5	1,653.6
Tax by Corporate taxpayers per ha of private land	**458.1**	27.5	21.4	25.2	14.7	6,859.3	19,546.2	32,039.8	40,330.0
Administrative court cases per 000 landowners	**0.05**	0.06	0.03	0.05	0.05	0.38	0.01	0.13	0.02
Civil court cases per 000 landowners	**0.4**	0.3	0.5	0.4	0.4	0.6	0.03	0.3	0.1
Use of privatization rights, %	**87.9**	92.7	78.1	94.5	82.7	93.7	73.9	91.4	76.1
State of land governance, average rank	-	**289.8**	**372.1**	**200.6**	**310.2**	**251.5**	**243.7**	**226.7**	**167.3**

4.1. Completeness of formal registration

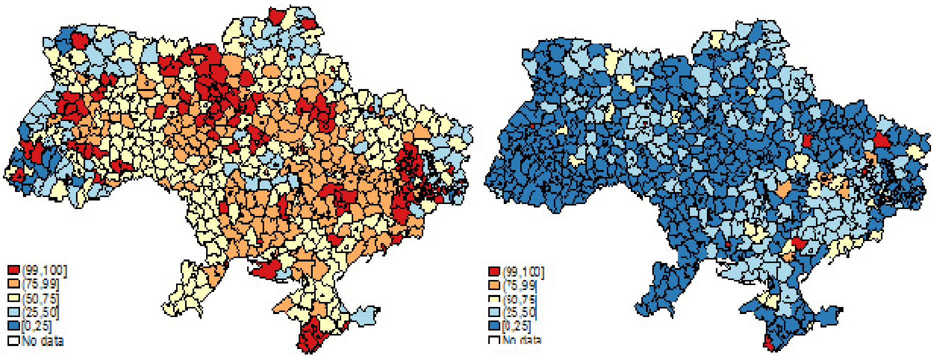
Formal state registration of land plots and related rights is an important institution for protecting rights of owners, users and other stakeholders. There are two institutions in Ukraine performing the registration function. The State Service of Ukraine for Geodesy, Cartography and Cadastre is responsible for management of State Land Cadaster, which contain records of physical characteristics of land plots (geographic coordinates of boundaries, area, designated land use, etc.). All rights and encumbrances, related to these parcels, are registered by the State Registry of Rights for Immobile Property administered by the Ministry of Justice of Ukraine. Completeness and currency of the Land Cadastre and Registry is a characteristics of quality of protection of land rights.

As of December 1, 2015, there were 16,661,051 plots registered in the State Land Cadastre with a total area of 41,812,127.76 hectares, representing 69% of Ukraine's territory. However, the completeness of registration is different across the forms of property and geography. There was only 24.0% of state-owned land registered in the Cadaster, while the completeness of registration of private property is 70.9% (Table 2). The level of registration of private property is higher in cities (average for cities is 79.9% vs 70.6% for rayons). The completeness of registration of private property for rural rayons ranges from 7.8% to 98.7%. For cities, this range is from 21.0% to 99.6% (Map 2, left panel). For state property these ranges are from 0.03% to 95.2% and from 0.35% to 88.8% correspondingly (Map 2, right panel). In several rayons, the area of registered land turned out to be above the total area of land of corresponding form of property. Such cases were reported to the administrators of relevant data sets and were top coded for further analysis.

The difference in the level of registration between the state and private land points to a significantly lower level of protection of ownership rights of state, which provides opportunities for land grabbing and other forms for poor land management. Better contractual arrangements (e.g. benchmarking) for land registration and governance of state land can bring significant benefits to Ukraine.

The total number of registrations of land rights in the State Register as of September 2015 is 3,485,630, which corresponds to 20.9% of the land plots registered in the Cadaster with significant regional variation in terms of coverage.

Map 2 - Share of land registered in the State Cadaster in private (left) and state (right) property.



The observed spatial variation in formal registration coverage demonstrates that despite the common legal environment, rayon specific factors play a significant role in determining the level of protection of property rights. Among such factors could be professional skills and motivation of the registration personal, awareness of land owners, level of corruption, commitment of the local government to improve the governance of land resources, value of land. Most of these factors are non-observable to central government and local landowners. Thus, publication of the monitoring indicators on cadastral and registry registrations would provide the information for comparison across time periods and with neighboring or similar communities. Such information can be used by central government authorities to assess the performance of local personnel and by local activists, media and politicians and makes the local registration authorities accountable for their performance.

Improvements in registration coverage bring several important benefits to local governments, landowners, and land users. It is safer, faster and easier to transact (including renting) the parcels, which are already registered. With lower transaction costs, local markets become more active, which increases sales and rental price for land. As the registered parcels establish a tax base for land tax and single tax for agricultural producers, local governments are the direct beneficiaries of more complete tax base.

4.2. Transactions

The total number of transactions with the change of the owner or user of land that are formally registered by the State Registry varies between 2,167 in the first quarter to 2013 to 208,735 in the fourth 2014 (Figure 2).

Figure 2 - Total number of transactions with the change of land ownership\user in Ukraine, 2013 - 3rd quarter 2015

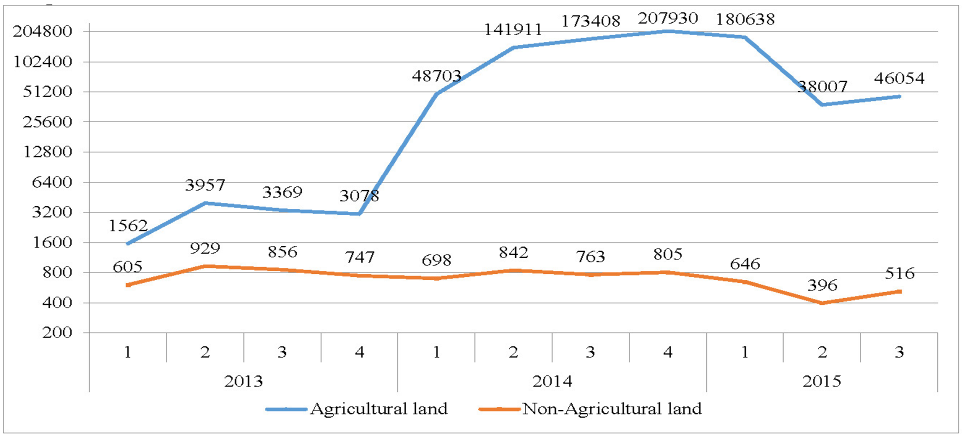
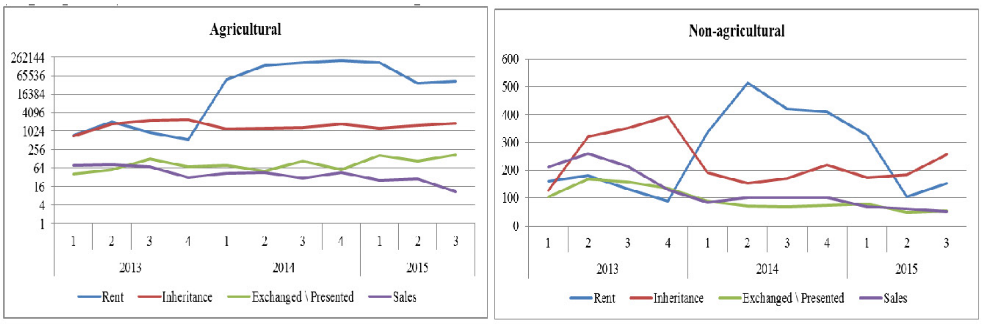


Figure 3 - Number of transactions of different types for agricultural (left panel) and non-agricultural (right panel) land in Ukraine, 2013 - 3rd quarter 2015

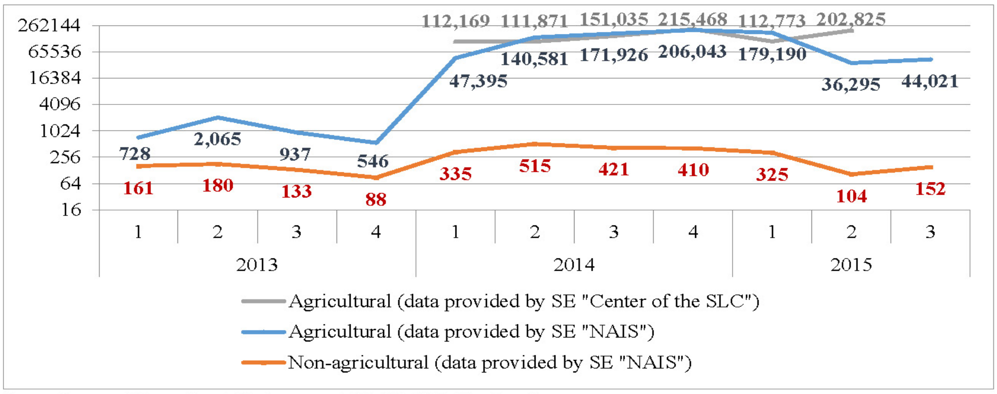


Most of these transactions are the rent of agricultural land (Figure 3). The second type of transactions in terms of frequency is inheritance. There were 1,077 land sales in 2013, 560 in 2014, and 262 during the first three quarters of 2015 with corresponding total area of 2,943.49 ha, 177.38 ha and 3,094.89 ha. The very small number of sales (total area of private land is 31.4 mln ha) points to significant barriers on the sales market for land. While for agricultural land the main barrier is Moratorium for sales, for non-agricultural land the reason is different. Comparison of the number of sales with the number of mortgages indicates that mortgages almost not used in Ukraine, which may be the primary reason for slow development of the land sales market in the country. In 2013, there were 19 mortgages for total area of 7.69 ha; in 2014, these were 58 mortgages for 42.03 ha; there were 14 mortgages for 3.24 ha during the first three quarters of 2015. In other countries the number of sales ranges from 0.5% to 3% of the number of property per year and mortgages are the main source of funding.

In the absence of sales market for agricultural land in Ukraine, rent became the primary type of land transfers. As of 01.07.2015, about 4,671.5 thousand rental contracts for private agricultural land (shares of privatized state farms) were signed in Ukraine for the total area of 16,597.0 thousand hectares (43% of privately owned land). During 2013-2015, transfer of use (rental) rights were registered for 832,551 land plots with total area of 3.5 mln ha (about 16% of land under rental

agreements) (Figure 4). The average rent payment was 786 UAH/ha per year in 2015. Also, 56,053 rental contracts for state-owned land were established with an average rental payment of 1351.6 UAH/ha per year with a significant difference in rental price across the regions.

Figure 4 - Number of registered rental agreements



Data: Center of State Land Cadastre and SE "NAIS" (Registry)

The variation in the number of formal transactions across time periods is related to several policy changes and, thus, the monitoring results can be used for evaluation of such policy effects on various land governance characteristics. For example, in the first quarter of 2015, new restriction on the minimum term of rental contracts for agricultural land was imposed, which coincides with a drop of formal registration of rental agreements from 179 thousand cases in the 1st quarter of 2015 to only 36 thousand in the 2nd quarter 2015. This change is unrelated to seasonality (as no such change was observed before).

For comparison across regions, the number of transactions is weighted by the number of landowners. Table 2 demonstrates that except for rental agreements, number of transactions is distributed relatively universally across the regions. However, if compared across rayons some outliers can be identifies. Such outliers would require a closer analysis and targeted inspection as they may reflect technical errors, cases of best practice or wrongdoing.

4.3. Land tax

The land tax in Ukraine is a local tax paid by land owners and land users (individual and corporate). Starting 2015, the rate of tax and tax exemptions are determined by local councils based on normative value of land. The total amount of land tax collected in 2015 was 3,651 mln. UAH, of which 86% were paid by corporate tax payers. About 70% of land tax revenue was collected in cities (reflecting difference in value of land). For some rural rayons, however, land tax constitute more than 80% of local budget revenue. Thus, improvements in administration of land tax would make a significant contribution to self-sufficiency and independence of local governments.

In 2015, the were 7,826,787 land tax payers, among them 98.5% were individuals (the rest are corporate). This number represents 46% of the total number of landowners, registered by the State Land Cadastre, which points to some significant tax gap.

This statistic does not reflect the payments of single agricultural tax (which includes land tax payment) as the data was not available.

Example of land tax is a good illustration of how closely different areas of land governance are interlinked and how the monitoring results can be used for analysis of land tax. Table 3 presents the regression results for relationship between the tax revenue per hectare of private land, and completeness of cadastral registration controlling for characteristics of local land resources (distribution of land use, forms of property and oblast fixed effect – for more details see Annex 1). The results show that an increase in registration coverage of private land by 10 percentage points would correspond to about 1% increase in average tax revenue per hectare in cities for both individual and corporate tax payers corresponding respectively to 15 and 243 additional UAH per hectare of private land. These benefit outweigh the registration cost many times meaning that local government would have a net gain if they invest in better registration of private land. Expectedly, the registration of state land does not affect land tax. Thus, a privatization of state land via open and transparent auctions may benefit local communities in a short (via sales revenue) and long run (via tax revenue).

Table 3 - Link between the formal land registration and land tax revenue

	Tax per ha of private land paid by			
	Corporate		Individuals	
	In cities	In rayons	In cities	In rayons
	(1)	(2)	(3)	(4)
Share of **private** land registered in Cadaster, %	0.016*	0.002	0.011*	0.001
	(0.008)	(0.002)	(0.006)	(0.002)
Share of **state** land registered in Cadaster, %	0.009	-0.003	0.009	-0.002
	(0.007)	(0.003)	(0.007)	(0.002)
Other controls	yes	yes	yes	yes
Obs	110	436	110	435
R^2	0.806	0.646	0.825	0.575

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; oblast FE are controlled for. Details in Annex 1.

4.4. Other indicators

The Monitoring system includes indicators on other areas of land governance. Some of them are presented as examples in Table 2 (disputes, privatization). The diversity of indicators opens opportunity for detailed analysis of land governance and for development of policy recommendations to improve security of land rights and land transferability. More importantly, availability of detailed regionally disaggregated information provides an opportunity for design of better contractual arrangements with local authorities for delivery of land governance functions. The monitoring indicators could serve as a measure of performance as well as benchmarks in such contracts.

4.5. Ranking of Land Governance

By its nature, land governance includes activities and decisions that target multiple objectives. Thus, assessment of land governance should incorporate all these different objectives and have tool for a simple instrument for comparison of the quality of land governance across the administrative units.

There is a large literature on operational research and in several other field that provide various tools for multi-objective assessment. Ranking is one of the simplest tools that allows aggregate performance along multiple dimensions into a simple index. Below, we demonstrate how the monitoring results can be used for comparison of quality of land governance across administrative units. Such comparison is necessary when performance of neighboring communities or other peer groups is used as a benchmark for assessment the quality of land governance in a given administrative unit.

Ranking represents a position (rank) of a specific city or rayon in comparison to the rest of administrative units in a range from the first (the best value of a specific indicator) to the last with the lowest value for a particular indicator of land governance (e.g. tax revenue per hectare). Ranking for each individual indicator can be combined into an aggregate ranking of land governance. Such ranking is proposed to assess the quality of land governance for each rayon and city of Ukraine. It is based on monitoring results for 2013-2015. One or two indicators were selected to represent each functional area of land governance. A rank of rayon/city was calculated for all of the indicators separately. To assess the total rank, an average across all functional areas was taken. This approach effectively provides equal weight for each functional area as there is no theoretical ground to set priorities among the functional areas differently. In case two sub-indicators represented a functional area (e.g. share of registered state and private land), an average of the two ranks was used to represent the functional area in the final computation. The distribution of weights among the sub-indicators can potentially be adjusted to the share of the sub-components in the total (e.g. share of private vs state land). However, such adjustment may unnecessary complicate the practical implementation of the ranking. The following indicators are used for five functional areas:

1. Share of land registered in the State Land Cadaster (50% of weight is given for registration of private and 50% for registration of state land);
2. Number of transactions per thousand landowners (50% - rental agreements (change of land user) and 50% - other transactions with change of ownership: sales, inheritance, exchange);
3. Land Tax paid per ha of private land;
4. Share of individuals, who claimed their privatization rights for land;

5. Number of court cases related to land per thousand landowners (50% - in Administrative courts and 50% - in Civil courts).

The ranking was performed for all sub-regional administrative units of Ukraine, Map 2. In case several administrative units have the same value of indicator, they receive the same rank, that correspond the highest rank in the group (standard competition ranking). The presentation of results, however, is done separately for cities and rayons (Table 2). The Autonomous Republic of Crimea, Donetsk and Lukhansk regions are excluded from ranking as mentioned above, thus, the lowest rank is 557, which corresponds to the number of cities and rayons used for establishing the ranking.

For example, Barskiy rayon of Vinnitsa oblast has 12.46% of state land registered in the Land Cadaster and 70.56% of registered private land. It is ranked respectively 354 and 294 among cities and rayons participated in ranking (Table 4). As Indicator 1 "Share of land registered in the State Land Cadaster" includes two sub-indicators, the average of them is 324 and is included in computation of the overall ranking. Ranking for other functional areas of land governance are performed similarly and their total equals to 1363. As the sum of ranks gets larger, the overall position of rayon or city in terms of quality of land governance is getting lower. The overall rank for Barskiy rayon is 293. Dubenskiy rayon of Rivne oblast is in the first palace.

Table 4 - Calculation of ranking for state of land governance: case of Barskiy rayon of Vinnitsa oblast, 2015

Monitoring indicator	Sub-indicator	Value of indicator	Rank
1.Share of land registered in the State Land Cadaster, %	State	12.46	354
	Private	70.56	294
2. Number of transactions per thousand landowners	Rental (change of user)	43.89	201
	Change of owner	0.07	367
3. Land Tax paid per ha of private land, UAH/ha	-	43.02	179
4. Share of individuals, who claimed their privatization rights for land, %	-	91.03	337
5. Number of court cases related to land per thousand landowners	Civil	0.22	218
	Administrative	0.04	260
Sum of ranks			***1363***
Overall rank of land governance			***293***

There are also 8 administrative units with missing data for one or more indicators used for ranking. One of such units is the city of Prypiat', which is de-populated after Chernobyl nuclear disaster. This observation is excluded from ranking. The rest of missing data was replaced with average values for respective oblast rayon/city clusters.

Comparison between the cities and rayons shows that there is a statistically significant difference in terms of the ranking and across the regions. The oblasts with the highest average rank is Zaporizhzha (average rank across rayons and cities is 88), Rivne (103) and Poltava (average rank is 104). The lowest rank is in Kharkiv (466), Zakarpatska (461) and Odessa (447) and oblasts. The lowest and highest ranks for individual cities and rayons is presented in Table 5.

Map 3 - Rank of land governance at local level

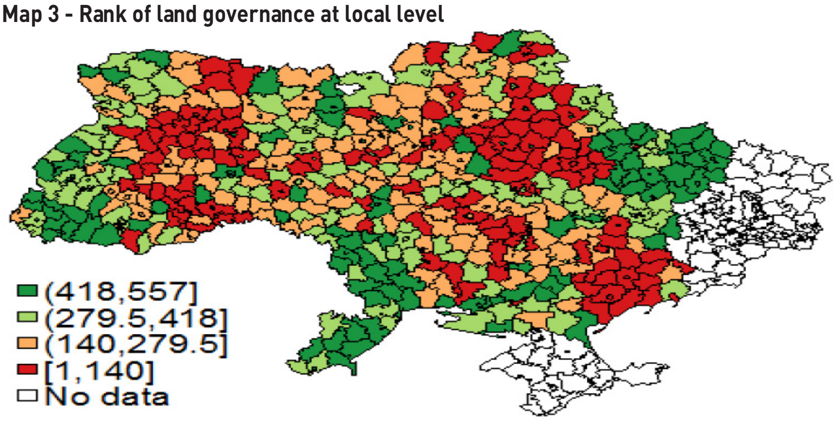


Table 5 - Ranking of land governance for selected rayons and cities

	Top ranking	Lowest ranking
Cities	(12) Znamianka, Kirovograd oblast (17,5) Kalush, Ivano-Frankivsk oblast (23) Polrava, Poltava oblast	(555) Bucha, Kyiv oblast (556) Kotovsk, Odessa oblast (557) Bilgorod-Dnistrovskiy, Odessa oblast
Rayons	(1) Dubenetskiy, Rivne oblast (2) Grebinkivskiy, Poltava oblast (3) Karlivskiy, Poltava oblast	(547) Irshavskiy, Zakarpatska oblast (549) Velykolepetyskiy, Kherson oblast (553) Dvorichanskiy, Kharkivska oblast

As demonstrated, the ranking provides a simple measure of relative position of the land governance at the local level and can show if improvements takes place over time. The potential users of the ranking results include policy makers, government administrators, land owners, land users, journalists and general public.

4.6. Benchmarking

The ranking, presented above, can be a useful tool for the overall comparison. However, for practical recommendations how to improve the ranking and for establishing contracts with local governments, the ranking can be complimented with clear benchmarks for overall performance and for each component and sub-component as presented below.

Figure 5 presents a graphical comparison of ranking for Barskiy rayon (Vinnitsa oblast) along each of the ranking sub-indicators with average performance of two peer groups for this rayon: its immediate neighbors and all rayons and cities in Vinnitsa oblast. We can see that Barskiy rayon outperforms its neighbors in terms of registration of private land and land tax revenue. In terms of registration of state land and the number of transactions with change of ownership, the rayon is significantly below its peers. Thus, efforts for improvements in land governance in Barskiy rayon should target better registration of state land (e.g. by allocating the budget for land registration, bringing state land to the auctions with registration of land parcels as a part of auction preparation procedure). In terms of establishing the performance indicator, Barskiy rayon should target an increase in registration of state land from current 12.46% to 22%, which is an average for Vinnitsa oblast (Table 6). The improvements in number of land transactions can be achieved via improvements in registration practices (e.g., improving performance of registration personnel, increasing their qualification), improving access to finance and improving awareness of population regarding the procedures for land transaction registration. The reasons for the relatively low number of transactions should be investigated further and the reviled barriers should be target with specific administrative actions.

Figure 5 - Benchmarking results for Barskiy rayon of Vinnitsa oblast, 2015

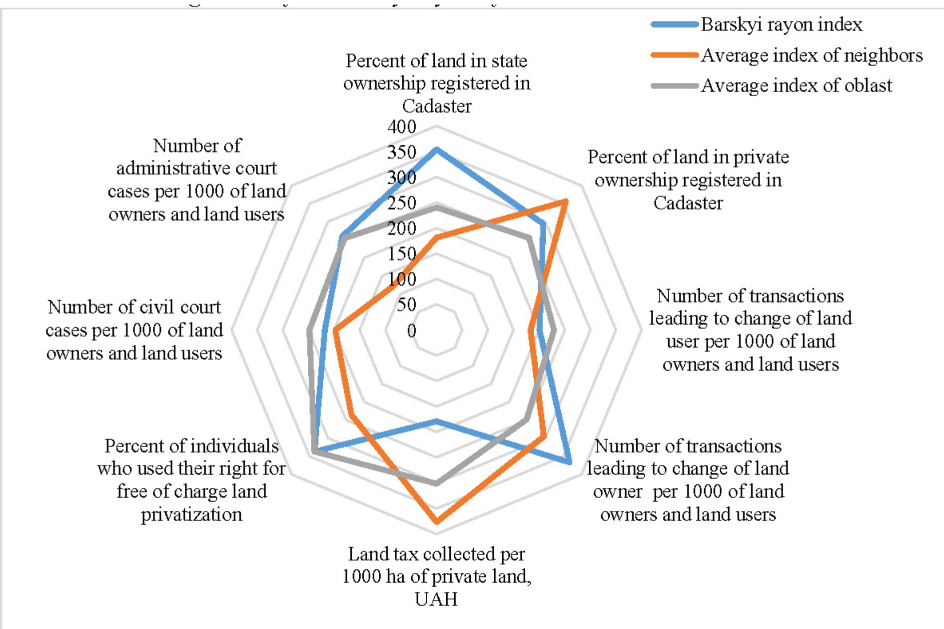


Table 6 - Comparison of ranking results with peer groups.

		Percent of in state land registered in the Cadaster	Percent of private land registered in Cadaster	Number of transactions leading to change of land user per 1000 of land owners and land users	Number of transactions leading to change of land owner per 1000 of land owners and land users	Land tax collected per 1000 ha of private land, UAH	Percent of individuals who used their right for free of charge land privatization	Number of civil court cases per 1000 of land owners and land users	Number of administrative court cases per 1000 of land owners and land users
Barskyi rayon	Rank	354	294	201	367	179	337	218	260
	Value	12.46	70.56	43.89	0.07	0.04	91.03	0.22	0.04
Neighbors	Average Rank	181.0	356.5	183.3	295.5	376.5	235.0	197.8	120.8
	Value	26.32	64.48	51.75	1.82	0.02	92.88	0.32	0.02
Vinnytsia oblast	Average Rank	240.1	255.5	228.9	248.3	301.4	337.0	248.2	254.4
	Value	22.06	74.88	51.61	3.18	1.18	91.03	0.34	0.06

As demonstrated, land governance monitoring helps to address the issue with unobservable performance of local government authorities and establish clear targets for improvements in land governance functions.

4.7. Difficulties with practical implementation

One of the results of the pilot implementation of Land Governance Monitoring in Ukraine is identification of issues, which require normative changes or development of procedures in order to implement a full scale automated monitoring. First, there were issues with delays in data supply and lack of common structure for reporting. Besides, there are cases when data important for policy making is not recorded and/or is not provided in the form of regular reports (e.g. number and characteristics of the land plots that were expropriated for public use, gender of land owners, prices for rental and sales transactions, etc.). Overcoming these issues requires adoption of new regulations.

Second, several government agencies have corresponding service areas that do not match the administrative territorial structure of Ukraine. Most common case is that one local office serves several administrative units (e.g. city and an adjacent rural rayon). As a temporary solution, the reporting statistics was distributed among the administrative units proportionally to population. A permanent solution would be a requirement to report separately for each administrative unit.

Third, there are inconsistencies in standards used by authorities for land use categories and other characteristics of land governance. Thus, establishment of common standards would improve the performance of land governance functions by providing for better data exchange among the government authorities.

Fourth, several errors were detected in administrative records. A clear procedure is yet to be established for errors correction for each relevant agency. Among the solutions would be an establishment of procedures for automated control at data entry, linking the administrative data at parcel level and eliminating the duplication of information across the government authorities, and simplifying procedures for error correction.

Fifth, several authorities use licensed and certified software for management of administrative data which does not have functionality for producing regular, regionally disaggregated reporting on a selected set of indicators. Thus, development and certification of reporting software is required. This also implies that terms of reference for development of new software in different areas of land governance should, by default, include the reporting function.

Finally, data exchange procedures across the government authorities need to be improved. It requires adoption of normative acts that stipulate requirements for regular reporting and data exchange.

5. Implications and Conclusions

Introduction of the monitoring system allows testing several hypothesis regarding the state of local governance of land resources and its impact on growth and development. For example, effect of better protection of property rights for land on investments and productivity growth. It also provides information for design of policy intervention, monitoring their introduction and evaluation of impact. Moreover, monitoring provides for transparency and accountability of local government decision making, which to a large degree would decries the room for moral hazard in local government decision making.

The case of Ukraine demonstrates only some core features and possible extensions of Land governance monitoring. Examples of overlaying spatial data (including remote sensing of satellite images) can provide additional functionality to the monitoring system. Among additional tools that would extend the functionality of the monitoring system could be mass valuation of land and real estate, modelling and assessment changes in land tax, etc. The monitoring can also be extended to monitoring of forestry, water, urban land and real estate.

Monitoring provides evidence regarding the actual state of land governance at national and local levels and allows to reduce information asymmetry regarding the administration of land resources. It helps to reduce political speculation regarding land and enhances practice of evidence based policy making. Moreover, by improving one of the key resource market it improves the investment attractiveness of agriculture and rural areas.

The results of Monitoring point to a significant difference in the characteristics of land resources and land governance at the local level. Therefore, the land reform must take into account the diversity of local conditions and capacity for implementation of reforms at the local level and provides input to various international rankings.

Case of Ukraine demonstrates an example of successful institutional arrangements for implementation of the land governance monitoring. Comparison with monitoring experience of several other countries demonstrates the importance of establishing a working group within government at the level of decision makers and the need for normative regulation of the monitoring function. Also, the comparison of the presented case with examples of parcel level pilots in selected regions demonstrate that the presented approach of establishing the national system with reporting at the level of local governments can solve a significant problem with asymmetric information and can be extended if necessary in terms of additional indicators and reporting scale. On the other hand, very detailed pilots in most cases lack capacity for extension to the national level.

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Annex 1 - Land tax revenue

	Tax per ha of private land paid by			
	Legal entities		Individuals	
	In cities	In rayons	In cities	In rayons
	(1)	(2)	(3)	(4)
Share of **private** land registered in Cadaster, %	0.016*	0.002	0.011*	0.001
	(0.008)	(0.002)	(0.006)	(0.002)
Share of **state** land registered in Cadaster, %	0.009	-0.003	0.009	-0.002
	(0.007)	(0.003)	(0.007)	(0.002)
Log(Total area)	0.232	0.338**	0.319	-0.045
	(0.302)	(0.131)	(0.231)	(0.104)
Unemployment, %	0.008	-0.102***	-0.041	-0.020
	(0.214)	(0.028)	(0.169)	(0.019)
Log(Wage)	4.171***	1.326***	1.131**	0.639***
	(0.823)	(0.291)	(0.504)	(0.187)
Landowners per ha	0.135	1.202***	0.116	1.365***
	(0.126)	(0.357)	(0.097)	(0.216)
Forests, %	0.035	0.017**	0.014	-0.003
	(0.025)	(0.008)	(0.018)	(0.006)
Developed, %	0.008	0.195***	0.010	0.003
	(0.016)	(0.064)	(0.011)	(0.023)
Water, %	0.034	0.023**	0.011	0.011
	(0.037)	(0.010)	(0.030)	(0.007)
Other land, %	-0.034	0.016	-0.001	-0.029*
	(0.034)	(0.017)	(0.033)	(0.015)
Contaminated, %		-0.109***		-0.067
		(0.019)		(0.042)
Pasture & Hayland, %	-0.044	-0.023**	-0.002	-0.007
	(0.069)	(0.011)	(0.049)	(0.008)
State owned, %	0.005	0.010	0.004	0.002
	(0.018)	(0.008)	(0.013)	(0.005)
Collective, %	0.936**	0.151	0.662*	-0.024
	(0.412)	(0.136)	(0.341)	(0.104)
Communal, %	0.160	0.972*	0.177	0.012
	(0.240)	(0.563)	(0.193)	(0.427)
Retirees, %	-0.129*	-0.011	-0.120**	-0.017
	(0.065)	(0.012)	(0.056)	(0.010)
Urban population, %	0.057	0.001	0.052*	-0.000
	(0.036)	(0.003)	(0.028)	(0.002)
Log(Average farm size)	-0.121	-0.045	-0.102	-0.147***
	(0.127)	(0.058)	(0.095)	(0.054)
Regional center	1.569***		1.601***	
	(0.578)		(0.503)	
Constant	-37.820***	-19.313***	-16.998***	-8.173***
	(7.961)	(2.439)	(5.878)	(1.787)
Obs	110	436	110	435
R^2	0.806	0.646	0.825	0.575

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; oblast FE are controlled for

C18

Competitive pressure and structural change in agriculture. Are larger farms more resilient? An analysis of Italian Census data

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ABSTRACT

This paper provides an example of application of massive farm-level panel data for agricultural economic studies. We used a panel data of 1,008,310 farms from the V and VI Italian agricultural censuses and we described the adjustment in land use at farm level, in order to observe the changes in the economic and production behavior at individual level.

Changes in market structure, such as the consolidation of downstream and upstream industries, global sourcing, price volatility, increase in reservation wage of family labor increase the socio-economic pressure on farmers and call for adjustment in strategies and operation (Russo, Sabbatini 2010).

The most evident consequence of the severe challenge was the sharp decrease in the number of farms (-32.4% between 2000 and 2010) and the decline of utilized area (-2.5%). The combined result of these trends determined a relevant increase the average size of a farm: from 5.5 to 7.9 hectares. These aggregate data were interpreted at first as a consolidation of the farm system: the selection operated by the competitive pressure made the surviving farms larger and somehow more competitive.

We use our panel data to provide a more in-depth analysis. In particular, we test the hypothesis that larger farms are more likely to survive the competitive pressure.

Keywords: Resilience, Agriculture, Performance

PAPER

1. Introduction

In the decade 2000-2010 Italian (and European) agriculture underwent a process of consolidation (i.e., the growth of farm size aiming at exploiting economies of scale). Census data registered a remarkable decrease in the number of farms and, simultaneously, an increase in the average farm size.

The consolidation process is the result of dramatic changes in farmers' social and economic environment (Sabbatini 2011). A mix of social and economic factors (such as increasing competition, decreasing public intervention, demographic changes, technology, etc.) resulted in a non-negligible 'squeeze' on farming profit margins (van der Ploeg 2006). Facing the increasing pressure, farmers implement a set of strategies defining new paths in rural development (van der Ploeg et al. 2002). Consolidation is often considered the mainstream approach to competitiveness (van der Ploeg et al. 2016), although it is not the only one. The rationale of consolidation is straightforward: given the declining per-unit margins and the increasing fixed costs, farmers must achieve much higher production in order to break-even. A minimum scale is considered a prerequisite for profitable capital investments, and even multi-functional oriented investments are assumed to be fully justified only if the farm is 'large enough' (van der Ploeg et al. 2016).

In this paper, we test if larger farms are more resilient than smaller ones. The study question is relevant because agricultural policy supports farm consolidation and cooperation in order to foster competitiveness and ensure surviving of farm businesses. If farm size proved to be inconsequential, then such policy measures should be reconsidered.

In our study, we measure the farm size with arable land and we use econometric models to link the initial endowment of utilized land (year 2000) to the probability that a farm is still active at the end of the period (year 2010).

In our analysis, we build a panel dataset to identify the surviving farms (i.e., firms from the 2000 Census that are in the 2010 Census). A Logit regression is used to calculate the conditional probability of belonging to the subset of surviving firms. We found a significant and positive impact of farm size on such probability.

2. The dataset

The Database used for this study was obtained combining three independent data sources via statistical matching: the V and VI General Agricultural Censuses and Integrated Administration and Control System (IACS).

The General Agricultural Censuses (Reg. EC 1166/2008) provide complete information based on the structure of the agricultural and livestock system on a national, regional and local level. The dataset of the V Census refers to the year 2000 with 2,396,274 farms and dataset of the VI Census refers to the year 2010 with 1,620,884 farms.

IACS (Reg. EC 73/2009) is the most important system for the management and control of payments to farmers made by the Member States in application of the Common Agricultural Policy.

IACS consists of a number of computerized and interconnected databases that are used to receive and process subsidy applications and respective data. In this study is considered the year 2013 reporting 1,915,560 farms.

We linked the datasets and matched the units having the same person as head of operations from year 2000.,. This approach underestimates the number of surviving farms because units with a passage of an inheritance or a change in legal form have been excluded from the dataset.

In order to integrate the three datasets we applied statistical matching model (also known as data fusion, data merging or synthetic matching) that is a model-based approach for providing joint statistical information based on variables and indicators collected through two or more sources (Leulescu A., Agafitei M., 2013).

Statistical matching relies on certain pre-requisites of harmonization and coherence of data sources to be matched, in particular the choice of matching keys.

For the linkage of the two Censuses three variable which identify the farms are chosen:

1. Unique Code Farm (UCF).
2. Address of the headquarter.
3. Name of the farm.

UCF is represented by the personal code in the individual companies and the Value Added Tax (VAT) in the companies, it is a stable variable along the time and allows a deterministic linkage of the two universes. In both censuses, this variable was not subject to control procedures, so it was applied a standardization procedure before the linking activities.

Related to the addresses a fundamental issue is related to the existence of multiple ways to express the location qualifiers, (e.g. Piazza and P.zza) or parts of the proper name of the street (such as Santa, or S. or S or S.ta). To validate the addresses was used a software to validate the addresses and standardize them to the official format (www.egon.com).

The farm name or the holder name (depend on the UCF) is the variable potentially wrong for the presence of transcription errors and for the possibility that during the period each farm might changed its name.

The first step of the matching model selected for the linkage was linking the Unique Code applying a deterministic model of equality, combining the frame of V and VI agricultural censuses. In this way has been obtained a panel of 816,319 farms existing at 2000 Census and still active at 2010 Agricultural Census. We excluded approximately 20,000 farms existent in the lists of both censuses, because they result inactive in 2010 year.

804,565 farms detected at VI census and 1,579,955 farms of 2000 census result un-matched. A comparison function1 is used to compute the distance between records on the values of the chosen matching variables, name and address. It is requested to choose a threshold, between 0 and 1. The higher distance for two strings is, the more similar the strings are. The threshold chosen is 0.69 for both variables. The distance function was used combined with a deterministic merge.

With the deterministic merge with variable name 130,455 farms have coupled. According to the threshold of distance function applied on the address of these farms, just 783 have similar addresses.

The same procedure was applied on residuals, making a deterministic match on the variable address combining to the comparison function on the variable name. 47,657 have the same address, but only 6,669 also the same name.

The result was a panel of 823,771 farms that are present in the censuses of 2000 and 2010.

We checked the residual 2000 census farms with IACS. It was done a deterministic linkage between IACS database and 2000 census residual farms using the Unique Code as merge key. In this way it was been identify other 184,539 of 2000 Census still "alive" based on IACS source.

Totally we can considered 1,008,310 farms detected at V General Agricultural Censuses still-existing after 10 years.

[1] The function distance calculated is $d(\delta, \theta) = \begin{cases} 1 & se\ \delta = \theta \\ 0 & or \end{cases}$

3. Farmland distribution a comparison between 2000 and 2010 Censuses

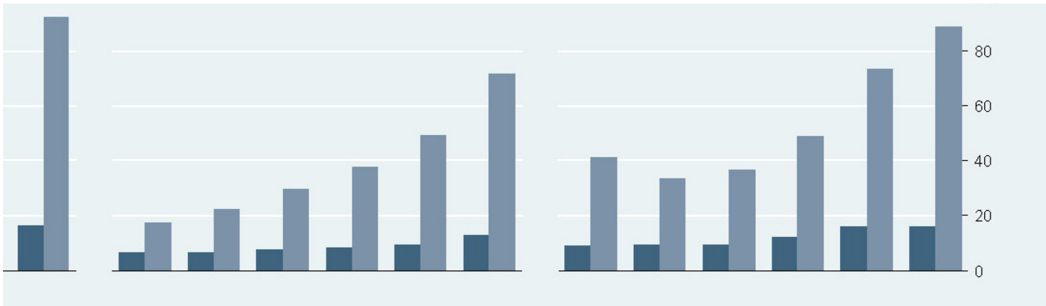
Aggregate descriptive statistics from the two Censuses show that, the agricultural sector has been characterized by a deep restructuring due to competitive pressure (Spinelli, Fanfani 2012; Sotte, Arzeni 2013). Between 2000 and 2010 the number of farms declined by 32.4% while the average tillable area increased by 30.4%. More than half of the farms in the panel is located in the hills, about a third in the plains and the rest in the mountain. In terms of Utilized Agricultural Area (UAA) the farms in the panel registered an increase of 22%, but they have values slightly higher than the total number of farms in 2010, with an average UAA of 8.9 hectares against 7.9 hectares of the total, and an average Total Agricultural Area (TAA) of 12 hectares against 10.5. However the distribution and the increase in the UAA varies across regions, indeed the average values vary from less than 2.5 hectares of Liguria to more than 20 hectares in Lombardy and Sardinia. Almost all regions recorded an increase in the area, the highest value is recorded in the Province of Trento (+70%), followed by Abruzzo (+42%) and Lazio (+33%), the lowest values in Molise and Liguria (+12% and +10%, respectively), the only region that recorded a decrease is the Valle d'Aosta (-11%). Average size varies with altitude. The value reaches 12.4 hectares in mountainous areas, generally characterized by the presence of large area of pasture and meadows, 9.3 hectares in the plains and 7.6 hectares in hilly areas. Also the change in UAA is affected by altitude. Censuses registers an increase of the UAA in the mountainous part of the country (+34.2%) followed by about 20% in the plain area while in the hilly the rise were smaller (+17.3%).

At national level the most common form of land tenure is still the property, with 66% of the UAA, although it is down compared to 2000 (70%), while the rented area slightly increases (from 25% to 27%) and even more the area used for free, that is almost doubled, although it remains marginal (from 4.6 to 7.2%). This situation varies across Regions, in fact, even if the property remains the most prevalent form of tenures, the percentages vary from region to region.

4. Farm size and resilience

The panel data described in section 2 can be used to address the first study question: are larger farms more resilient? The question has theoretical implications. The hypothesis that larger farms are more resilient implies that the incentive to selling out operation decreases with farm size. The Figure 1 summarizes the problem. From an economic standpoint, a farmer should sell his/her farm if the present value of future cash flows (the thick line in Figure 1.) is lower than the sum of the sale price of land (and operations) plus the value of any alternative revenue (e.g., a reservation salary).

Figure 1 - Farm size and the decision of selling operations out



The Figure 1 presents two illustrative examples of the comparison between the Present value of future cash flows (PVFC) and sale price plus outside option (SPOO). In the graph, we depicted two SPOO lines: one refers to the outside option (reservation salary) for the farmer, the other refers to the outside option for the family member who can take charge of operation after the farmer's retirement (for example, a son or daughter), which has been assumed to be greater than farmers' one (for example, because of more education, etc.). The graph identifies three areas: when PVFC is lower than farmer's SPOO, the rational behavior is Competitive pressure and structural change in agriculture. Are larger farms more resilient? An analysis of Italian Census data to sell operation immediately. If PVFC is lower than family's SPOO but higher than farmer's SPOO, the rational decision is to sell after the farmer's retirement. Finally if PVFC is greater than any SPOO, the optimal behavior is to keep farming and the family member should take over at farmer's retirement.

The two panels in Figure 1 depict opposite cases. In case a) small farms are more likely to be sold; in case b) large farmers are more likely to be sold. The difference between the two panels is in the curvature of the PVFC curve. If the PVFC increases faster than SPOO, then large farms are more likely to survive. In this case, our simple framework suggests that the price of land is not able to capture the increase in PVFC. Such result might be due to scale economies: the marginal value product of land changes depending the amount of factor. Vice-versa, case b) suggests the presence of declining marginal value product of land (scale diseconomies).

In order to test the hypothesis, we developed an econometric model assessing if farm size (measured as hectares of utilized agricultural area) is a statistically significant variable affecting the probability of surviving in the competitive agro-food sector. The test is structured as a logit regression estimating the probability that a farmer detected in the 2000 census is still active in 2010. We built a binary variable yr that is equal to 1 if a given farmer belongs to the panel of 1,008,310 surviving farms (described in section 2) and it is equal to zero otherwise. The logit regression of yr on a set of explanatory variables, including farm size, can provide an answer to the study question.

The independent variable yr is subject to measurement error due to the construction of the panel data. The linkage procedure is designed to minimize the probability of including non-surviving firms in the panel (type I error). Yet among the set of excluded firms might still include surviving firms that for several reasons (data collection errors, changes in management or in address, etc.) have not been identified in the 2010 census (type II error). The low power of the linkage procedure might introduce a bias in the estimation of significant variables affecting the surviving probability, because the control group (i.e., the non-surviving firms) might include unidentified surviving firms. We run our analysis under the assumption that misidentification of surviving firms depends on non-systematic, random factors so that model still provides unbiased estimates.

In order to assess the statistical significance of farmland size on the surviving probability of a farm, we regressed yr on a set of variables describing the structural characteristics of the farm, the social and demographic characteristics of the farmer and his/her family, and the marketing approach. This reduced model approach is based on the assumption that the surviving probability is somehow affected by four drivers: the resource endowment (measured in terms of land, livestock, and machinery), the working effort of the farming family (measured in terms of farmer's age, working days, number of family members working on farm), human capital (measured by farmer's education) and market opportunities (measured in terms of share of self-consumed products, presence of value-added productions, differentiation and horizontal coordination). In theory, we expect a positive pairwise-correlation between each driver and the probability of surviving. Table 1 reports the regression results. The odds ratio in the logistic regression output summarizes the relationship between the explanatory and the dependent variables: an odds value ratio greater than 1 means that an increase in the explanatory variable is associated with an increase in the probability that the observation belongs to the panel of surviving farms, holding everything else constant (i.e., the regression coefficient is positive). A lower-than-1 odds ratio indicates a negative association (i.e., the regression coefficient is negative). The z-score and the p-value of a t-test on the statistical significance of the regression coefficients are also investigated.

The sign of the regression coefficients is consistent with expectations. Market access, participation to associations (such as cooperatives or producer associations), and processing activities are associated with higher probability of belonging to the surviving panel. The variables are associated with higher PVFC, while have a weak link with SPOO. Consequently, we expect that the probability of selling the operations is smaller.

The share of rented land has a positive impact (although the confidence level is only 10%). Land rental is profitable only if the farming activities are profitable enough to pay the rent. Therefore, we expect that land rental is a proxy of high PVFC. The association with SPOO is weak, because the value of rented land usually is not captured in the sale value of operations.

Multi-functional activities, measured with the presence of agri-tourism and the location in a natural park, are not statistically significant. However, the complexity of multifunctional agriculture is hardly captured by the available variables and measurement errors might reduce the efficiency of estimates.

The personal characteristics of the farmer are expected to affect both the PVFC (because of higher farming profits) and the SPOO value (because of better outside working opportunities). The regression results support the conclusion that better human capital increases the probability of being in the panel of surviving firms. Such conclusions are consistent with a wide literature about human capital in agriculture (e.g., Idda and Pulina 2011). Young, educated and full-time farmers have higher probability of being in the panel of surviving farms than otherwise. Noticeably, female gender is positively associated with yr. This result might be explained by the lower value of the outside option for women in agriculture (e.g., Sabbatini et al. 2011).

The role of family members is ambiguous. On one hand, the presence of 'family members working on farm' increases the probability of being in the surviving panel. The presence of family workers is associated to the ability to sustain the family with farm profits. Both factors are associated to higher PVCF. Furthermore, family members are assumed to be working on farm because the value of outside options is low, depressing the SPOO value. The combined effect of the two drivers results in higher probability of yr =1.

On the other hand, when an additional variable discriminating the presence of full time family members, a negative effect emerges. The interaction of the two variables results in a negative and statistically significant coefficient (the 2(2) test statistic is 65,443, which allows us to reject the null hypothesis of no joint significance at 1% confidence level). The result might be explained considering that a full time position by a family member might be associated to a planned turnover in management (e.g., Cardillo et al. 2010). In this case, the full-time member might act as apprentice, learning specific skills, with the objective of taking over.

The farm's factor endowment is associated with a negative impact on the probability of belonging in the surviving panel. Capital investments in irrigation, machinery and livestock present negative coefficients (although significance is at 10% confidence level). In part, this result might be due to the crisis of cattle farming that struck Italy after the 2003 dairy quota reform. Nevertheless, the data suggest that markets are efficient in capturing the value of investments in the sale price of the farm.

Finally, land size shows a positive and statistically significant coefficient. Data support the conclusion that larger farms have higher probability of being in the surviving panel. Yet, the quadratic term in the regression shows that the relationship is not linear and the impact of land increase is decreasing. This conclusion might explain why empirical studies have reached mixed conclusion when looking at the relationship between land size and farm surviving.

6. Conclusions

In this paper we tested the hypothesis that larger farms are more successful in surviving the increasing competitive pressure. This assumption is the rationale for agricultural policies fostering consolidation in the agricultural sector as a key driver for competitiveness. Yet, academic literature has not reached a consensus about the link between size and resilience.

We contributed to the debate using a unique dataset composed of observation from two censuses (2000 and 2010). The comparison between the two censuses allowed us to identify the subset of farms that are in both surveys. We considered this set as the group of 'surviving farms'. A Competitive pressure and structural change in agriculture. Are larger farms more resilient? An analysis of Italian Census data simple logit regression allowed us to establish that larger farms have higher probability of being in the surviving group. We conclude that large farm, holding everything else constant, are more likely to survive the competitive pressure.

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Table 1 - Regression results

Variable	Description	Type	Odds ratio	Std. error	z-score	p-value
Dependent variable: y_r (observation belongs to the panel of surviving farms) Log-likelihood: -736.532 Area under the receiver operating curve (AROC): 0,7639 N. of observations: 2.396.274 Unconditional probability of y_r: 0,42						
RentS	Rented land/arable land	Continuous	1,001	0,000	1,896	0,058
SALES	Value of market production /total production	Discrete				0,000
SALES1	*0<SALES<0,5*		2,393	0,192	10,873	0,000
SALES2	*0,5≤SALES*		2,980	0,262	12,405	0,000
SALES3	*SALES=0 (base)*		1,	0,		
ORG	participation to associations	Binary	1,705	0,056	16,138	0,000
PARK	farm is located in a natural park	Binary	0,983	0,043	-0,395	0,693
LIVES	livestock	Continuous	1,000	0,000	-1,661	0,097
AGTUR	Agri-tourism activities	Binary	0,972	0,042	-0,653	0,514
PROCES	processing activities	Binary	1,175	0,051	3,695	0,000
WFAM	Family members working on farm	Binary	1,144	0,03	5,204	0,000
WFAM_FT	Family members working on farm full time	Binary	0,793	0,027	-6,792	0,000
GEND	Farmer's gender is female	Binary	1,145	0,037	4,169	0,000
WD	On farm working days of farmer	Continuous	1,042	0,001	41,458	0,000
YEAR	Farmer's year of birth	Continuous	1,004	0,000	25,54	0,000
EDUC	Farmer's education	Discrete				0,000
HE	*Higher education degree*		1,143	0,053	2,901	0,004
HS	*High school diploma*		1,070	0,030	2,433	0,015
MS	*Middle school diploma*		1,189	0,028	7,406	0,000
ES	*Elementary school*		1,291	0,024	13,487	0,000
N	*None (base)*		1,	0,		0,000
HP_AL	Machinery hp/arable land	Continuous	1,000	0,000	-1,677	0,094
SO_AL	Standard output / arable land	Continuous	1,000	0,000	-0,827	0,408
ALT	Altitude	Discrete				0,000
M	*Mountain*		0,704	0,058	-4,289	0,000
H	*Hill*		0,888	0,052	-2,011	0,044
P	*Plains (base)*		1,	0,		
UAA	Utilized agricultural area	Continuous	1,005	0,001	5,263	0,000
UAA²	Utilized agricultural area squared	Continuous	1,000	0,000	-3,048	0,002
IRR	Presence of irrigated land	Binary	0,981	0,032	-0,594	0,000

Cheaper, Faster and More Than Good Enough: Is GPS the new gold standard in land area measurement?

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ABSTRACT

In rural societies of low- and middle-income countries land is a major measure of wealth, a critical input in agricultural production, and a key variable for assessing agricultural performance and productivity. In the absence of cadastral information to refer to, measures of land plots have historically been taken with one of two approaches: traversing (accurate, but cumbersome), and farmers" self-report (cheap, but marred by measurement error). Recently, the advent of cheap handheld GPS devices has held promise of balancing cost and precision.Guided by purposely collected primary data from Ethiopia, Nigeria, and Tanzania (Zanzibar), and with consideration for practical household survey implementation, the paper assesses the nature and magnitude of measurement error under different measurement methods and proposes a set of recommendations for plot area measurement. Results largely point to the support of GPS measurement, with simultaneous collection of farmer self-reported areas.

Keywords: Land, Agriculture, Measurement, Surveys.

PAPER

1. Introduction

Land is a key measure of absolute and relative farmer wealth, a critical input in production, and a key variable for normalizing agricultural input use and output measures. Although easily overlooked by analysts, the quality of land area measurement can have non-trivial implications for agricultural statistics, economics, and policy analysis. The methodological menu for collecting land area measurements is diverse and selection of the appropriate method depends on several factors. This paper focuses on the methods that hold relevance for agricultural and household surveys. For the analysis of household level processes and outcomes it is vital that the land area being measured can then be linked to other variables concerning the agricultural production, or welfare outcomes, or other variables of interest for the same household or holding. The main types of surveys for which these measurements are relevant are agricultural sample surveys, agricultural censuses, multi-topic surveys that cover agriculture (such as most Living Standard Measurement Study (LSMS) surveys), and smaller scale household surveys carried out for research purposes. This paper aims to provide some elements to inform the selection of measurement methods, based on empirical evidence gathered by the Living Standard Measurement Study – Integrated Surveys on Agriculture (LSMS-ISA) team of the World Bank in Ethiopia, Tanzania, and Nigeria during methodological fieldwork aimed at understanding the relationship between the three primary methodological options: farmer estimate, GPS measurement, and the traditional compass and rope method.

2. Methods

The first step in analyzing the different methods is comparing the measurements obtained. To that end we construct two measures of deviation between the GPS and CR measures, defined as follows:

$$Bias = GPS - CR$$

$$Relative\ Bias = \frac{GPS - CR}{CR} * 100$$

The bias is the simple difference between the GPS measure and the CR measure, expressed in acres. The relative bias is the simple difference between the GPS measure and the CR measure, in acres, divided by the CR measure, expressed in percentage terms. The absolute value of both measures is also used in the analysis. Although the main focus on what follows will be on the deviation of the GPS from the CR measure, we will occasionally employ measures of deviation of the self-reported (SR) from the CR measure, employing a terminology analogous to the one just described for the deviation of GPS from CR measures.

The analysis will be based initially on a bivariate comparison of the means of the above variables for particular portions of the sample cross-tabulated with a broad range of variables of interest. The second part of the analysis will explore the determinants of the different measures of bias. We will estimate two main regression models. The first model is an OLS regression specified as:

$$(1) \qquad Y_i = L_i + C_i + S_i + SAT_i + T_i + W_i + e_i$$

Where *Y* is one of the four measures of bias defined above, L is the measure of the plot taken using CR, *C* is the closing error of the CR measure, *S* is a vector of proxies for the shape of the plot (including the number of corners and the ratio of the perimeter/area, *SAT* is the number of satellites the GPS device was fixed on at the time of measurement, *T* is a vector of dummy variables related to tree canopy cover (the reference being no canopy cover), *W* is a vector of dummy variables related to weather conditions at the time of the measurement (the reference being clear or partly cloudy sky), and e is a random error with the usual desirable characteristics.

To focus specifically on plots for which large deviations are observed between GPS and CR we then estimate a probit model to capture the factors likely to increase the probability that a plot be measured with arelative bias larger than ten percent (in absolute value). The model is specified as follows:

$$(2) \Pr(Y_i = 1|X_i) = \Phi(X_i\beta)$$

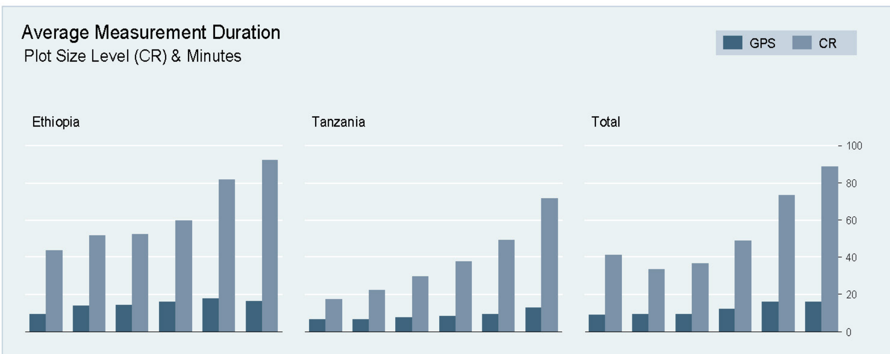
where $X_i = (C_i, s_i, SAT, T, W_i)$ and Φ is the standard cumulative distribution function. In equation (2), Y_i is one of three outcomes: a plot having absolute relative bias greater than 10%; a plot having relative bias greater than 10%; a plot having relative bias smaller than -10%.

3. Results

From the perspective of survey practitioners and national statistical offices, considerations about accuracy need to be accompanied by considerations related to time (and hence cost) of each methods implementation.The reason why the choice of method should matter for survey practitioners is compellingly conveyed by Figure 1, which shows the measurement time for GPS and compass and rope measurements by plot size classes, moving from small plots on the left to large plots on the right. Compass and rope requires significantly more time than GPS with time increasing exponentially with plot size, while the additional time required for GPS measurement for plots of the size included in these studies is negligible. In Ethiopia, GPS required 13.9 minutes on average, while the compass and rope measurement on the same plots required an average of 57 minutes. In Tanzania, the duration averages were 7.4 minutes and 29.3 minutes for GPS and compass and rope respectively. These findings are consistent with previous studies such as Schoning et al.(2005) and Keita and Carfagna (2009) who find that compass and rope takes approximately 3.5 times as long as GPS on average.

To put the time considerations into context, given the sample size and average measurement urations in Ethiopia, the field teams spent a total of 416 hours measuring plots with GPS (1797 plots * 13.89 minutes) and 1,707 hours measuring with compass and rope. Using GPS instead of compass and rope, therefore, saved 1,291 hours of labor – over 160 person/days (at 8 hours per day).

Figure 1 - Time taken for GPS and CR measurement



A. Comparison of competing measurements

1.Compass and Rope vs. GPS

In the literature, the main reservation regarding the use of GPS measurement in surveys is its performance on small plots. Table 1 presents descriptive statistics on the GPS and compass and rope area measurements completed as part of the methodological studies. Mean plot size is small in all countries, ranging from 0.38 acres in Ethiopia to 1.30 acres in Nigeria. The mean difference between compass and rope and GPS measurement is very small. The sample mean bias in all three countries is plus or minus 0.01 acre, which translates in a 1 to 3 percent difference when expressed in relative terms (note that the values are not expressed in absolute value and as such negative and positive figures are averaged). Notably, GPS and CR measurements on the smallest plots (level 1) are not found to be significantly different in Ethiopia, Tanzania or the pooled data. While some literature suggests that plots smaller than 0.5 hectares (1.24 acres) have significantly different GPS and compass and rope measurementswith much lower correlation (Schoning et al., 2005), results from the methodological validation experiments suggest otherwise. In the pooled data, the difference between the average GPS measurement and average compass and rope measurement for plots ranging from 0.05 – 0.15 acreswas less than 0.001 acres or 3% of the average compass and rope area. Even for the smallest plots, those less than 0.05 acres (202.3 square meters or 0.02 hectares), the average measurements are extremely consistent. In Ethiopia, the average GPS measurement of 390 plots in this size range is 0.0216 while the average compass and rope measurement for the same plots is 0.0215 acres.

The differences that are recorded do not appear to bear any clear trend with plot size. In Tanzania, the smallest and largest plot classes have the smallest and largest average relative bias, but the figures are not large, and the number of observations in these two classes fairly small. The correlation coefficients between GPS and CR are in excess of 0.99 in all three studies, and 0.87 or larger in all classes with n larger than 50.

Table 1 - GPS vs Compass and Rope (CR) measures, by plot size classes

Means; Acres

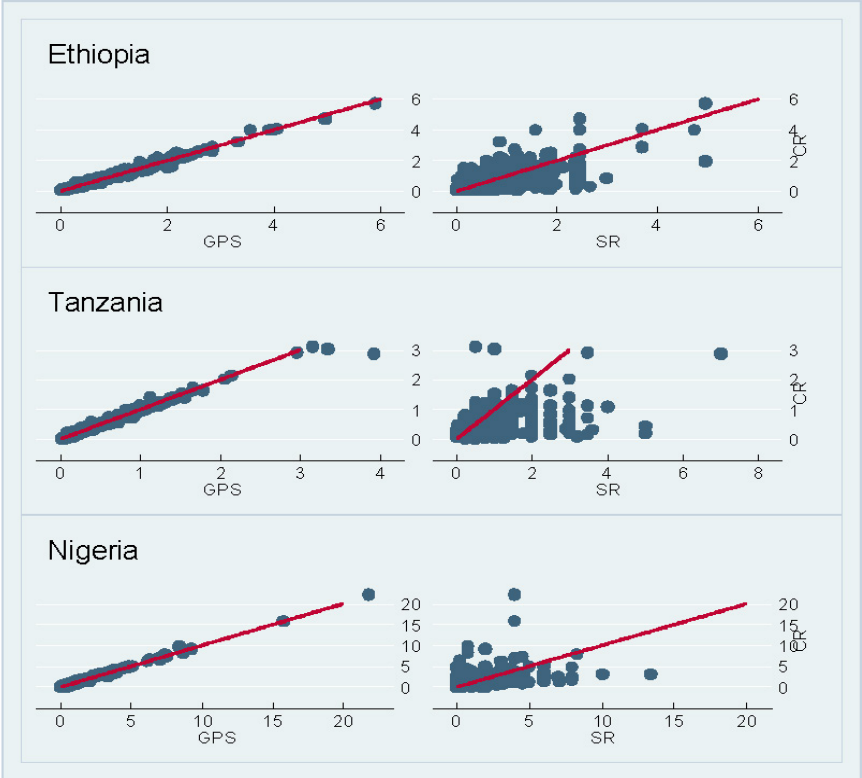
Level (CR)	Ethiopia						Tanzania					
	N	GPS	CR	Bias	Mean Bias / Mean CR	Difference in means	N	GPS	CR	Bias	Mean Bias / Mean CR	Difference in means
1 (<0.05 acres)	390	0.02	0.02	0.00	0%	-	45	0.04	0.04	0.00	-3%	-
2 (<0.15 acres)	400	0.10	0.09	0.00	2%	***	631	0.11	0.11	0.00	2%	***
3 (<0.35 acres)	365	0.24	0.24	0.01	3%	***	823	0.23	0.23	0.01	2%	***
4 (<0.75 acres)	328	0.52	0.51	0.01	2%	***	326	0.51	0.49	0.02	4%	***
5 (<1.25 acres)	182	0.98	0.96	0.02	2%	***	63	0.94	0.92	0.02	2%	***
6 (>=1.25 acres)	100	1.91	1.89	0.02	1%	-	20	1.91	1.81	0.09	5%	-
Total	1765	0.38	0.38	0.01	2%	***	1908	0.28	0.27	0.01	3%	***

Level (CR)	Nigeria						Pooled					
	N	GPS	CR	Bias	Mean Bias / Mean CR	Difference in means	N	GPS	CR	Bias	Mean Bias / Mean CR	Difference in means
1 (<0.05 acres)	-	-	-	-	-	-	436	0.02	0.02	0.00	-1%	-
2 (<0.15 acres)	21	0.11	0.11	-0.01	-7%	***	1052	0.10	0.10	0.00	2%	***
3 (<0.35 acres)	73	0.24	0.25	-0.01	-4%	***	1261	0.24	0.23	0.01	2%	***
4 (<0.75 acres)	129	0.52	0.53	-0.01	-2%	**	783	0.51	0.50	0.01	2%	***
5 (<1.25 acres)	108	0.97	0.99	-0.02	-2%	***	353	0.97	0.96	0.01	1%	-
6 (>=1.25 acres)	153	2.86	2.87	-0.01	0%	-	273	2.44	2.43	0.01	0%	-
Total	485	1.30	1.31	-0.01	-1%	*	4158	0.44	0.44	0.00	1%	***

*p<.1; ** p<.05; *** p<.01

The results presented here suggest that average GPS measures are not much different from compass and rope even for very small plots, and even from a fairly small n, and that is despite the difference in enumerator skill levels and plot characteristics of the different studies. This is confirmed by an inspection of the scatter plots in the left side of Figure 2, where GPS measures are plotted against compass and rope with measures tightly clustered around the equality line. This alllends support to the argument that GPS is an acceptable substitute of compass and rope measures across the range of plot sizes in our samples, at least if the goal is that of estimating average plot size for groups with sufficient numerosity.

Figure 2 - Scatter plots of Compass and Rope vs GPS (left) and Self-Reported (right) land area measures, acres

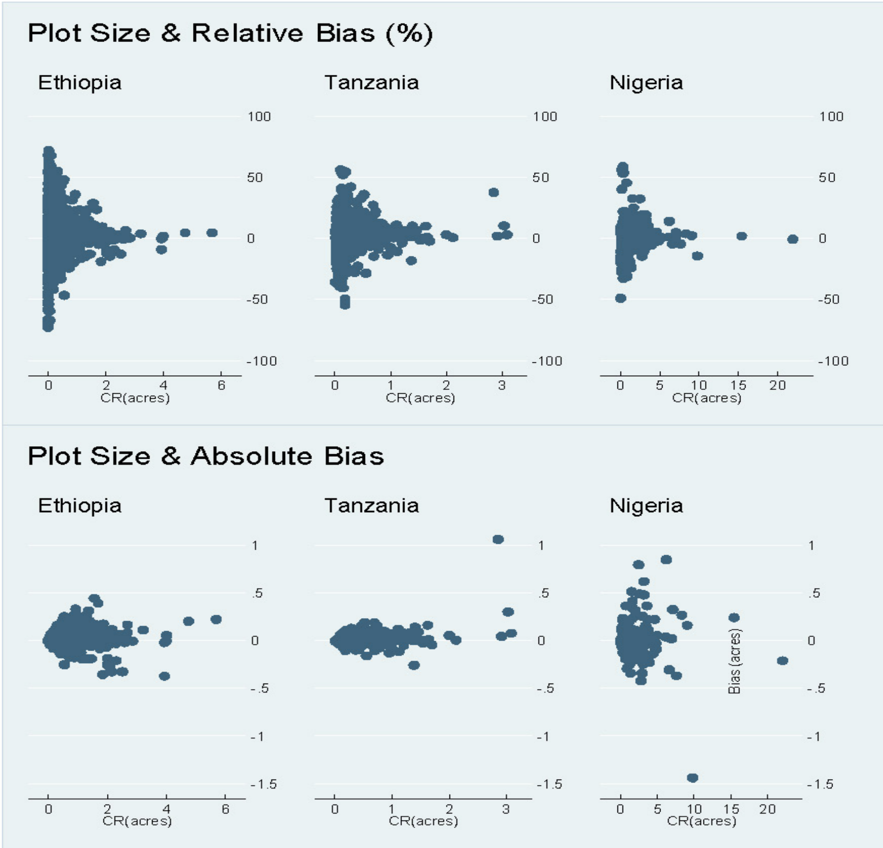


2.GPS measures: Exploring deviations from the gold-standard

Previous studies have also raised the issue of how factors other than plot size may affect the quality of GPS measures. None of the studies have provided compelling, conclusive evidence on the impact of these factors on measurement quality. Some have explicitly called for further research to systematically investigate this matter. Our data allow for analysis on a number of factors including plot shape, slope, and tree cover, weather conditions, and number of GPS satellites acquired at the time of measurement, via a comparison of the GPS measurement to the „gold standard" of CR measurement.

The global navigation system requires, at a minimum, the acquisition of four satellites to triangulate the 3D position of the GPS receiver. Descriptive statistics suggest that the difference between GPS and CR measurement tends to decline the higher the number of satellites, but average difference remain small across all the distribution of plot areas. In Ethiopia, the difference between measurements is 1.6% (but not statistically significant) on the plots with less than 16 satellites and 1.2% on plots with the 20 or more satellites, though the trend is not linear as the middle category has an average of 1.8% bias. In Tanzania, the differences are 2.9% and 2.6%, respectively.Dense canopy cover and weather conditions at the time of measurement have been found or argued to impair the precision of the GPS measurement. Contrary to expectations, descriptive analysis reveals that the relative difference between the GPS and CR measurements was slightly higher on plots with no tree cover, with the level of bias decreasing with increasing canopy density. In Ethiopia and Nigeria, there was no statistically significant difference in measurements found on plots reported with partial or heavy tree cover.The lack of statistical significance in the groups with canopy cover is also likely linked to the smaller sample size for these groupings.This could also be attributable to plot size, enumerator characteristics or other factors, which are not controlled for in these simple descriptive statistics. The sections below will further explore the influence of tree cover on measurement.No clear trend emerges in terms of systematic association of the differences between the two measures and weather conditions.
Having ascertained that the average difference between GPS and CR is small does not rule out that for individual measurements, there may be observations with errors of significant magnitude. To investigate this aspect we plot the percentage and absolute differences between GPS and CR measures over plot area (Figure 3). A number of considerations emerge from a visual analysis of these graphs. First, the GPS measurement error in percentage terms is often far from negligible, in some instances larger than plus or minus 50 percent. Second, large percentage errors appear to be roughly equally distributed above or below the zero line, which explains why we do not observe differences in the means for the two measures.Thirdly, the magnitude of the percentage errors is much larger for the small size classes, and decreases rapidly as plot size increase. Those trends are clearly mirrored by the graphs with the absolute bias, which show no clear correlation with plot size and fairly constant dispersion both sides of the zero line, with most values within the plus/minus 0.5 acres range. That seems to suggest that it is the inherent imprecision of GPS devices that causes percentage error to matter much more for very small plots. We therefore turn to investigating more in depth the extent and nature of the errors for observation with an arbitrary set value of plus or minus 10 percent.

Figure 3 - Scatter plots of relative (%) and absolute (acres) bias over plot size (acres)



3. Compass and Rope vs. Self-Reported Estimations

With an understanding of the comparability of GPS and compass and rope objective measurements, we now explore the difference in subjective (self-reported) and objective (CR) measurement. While the mean plot areas as measured by GPS and compass and rope differ by only as much as 3% on average, the mean self-reported and compass and rope measurements differ by as much as 143% on average (Tanzania). The mean difference is smaller in Ethiopia and Nigeria, at 23% and 5% respectively, but still considerably larger than the divergence observed between the objective measurements. Self-reported measures result not only in higher average deviations, but in dramatic systematic error as the size of small plots is overestimated by anywhere from 30% (Nigeria) up to a factor of six (Tanzania), with the over-estimation declining almost monotonically as plot size increases and eventually results in under-estimation in the larger plot size classes in Nigeria and Ethiopia. The scatter plots on the right side of Figure 2 convey the same message in graphic form.

B. Regression analysis of the differences between competing measures

1. Comparison of CR and GPS

The results in Table 2include four specifications(only pooled model shown), the difference among them being the dependent variable, which is: (i) bias (GPS – CR), (ii) absolute value of bias, (iii) relative bias (bias as a percentage of the CR area), and (iv) absolute value of relative bias. Recall from the descriptive statistics that the observed error is generally small, and little evidence of systematic variation with many of the factors that are a priori expected to influence GPS measurement precision was found. It is therefore not surprising that the explanatory power of these regressions (as captured by their R2 values) is low, and that the majority of the estimated coefficients are not statistically significant.

The main variables of interest are the set of terms (levels, quadratic, cubic) related to the plot size itself, as measured by CR. In the first specification, there appears to be a relationship between plot size and measurement error in Ethiopia, where the shape of the relationship is that of an inverted U, with the predicted bias being positive on very small plots, peaking at about 0.7 acres, and becoming negative for plots larger than about 1.7 acres. The coefficients are small, so that the predicted error is in the plus/minus 0.02 acres range.In Tanzania, a linear relationship is exhibited in which larger plot size results in larger bias (in terms of acres). In Nigeria there is no statistically significant relationship between bias and plot size, and in the pooled data there is very little, controlling for other factors.

Of the covariates reflecting physical characteristics that are expected to affect the quality of GPS measures (cloud and canopy cover, plot slope) hardly any are consistently significant across country.

Table 2 - Determinants of Bias (GPS – CR)

OLS Regression
Bias = GPS - CR (acres)

	Pooled			
Dependent Variable:	Bias	|Bias|	{Bias/CR} * 100	{|Bias|/CR} * 100
CR Area (acres)	0.011	0.050***	-1.898***	-3.344***
CR Area^2	-0.001***	-0.002***	0.352**	0.507***
CR Area^3	-	-	-0.012**	-0.017***
Closing Error (%)	0.003*	0.004***	0.762***	0.370***
Number of Corners	0.000	0.000	-0.002	0.055*
Per : Area Ratio (GPS)	-0.006	0.001	-13.442***	11.534***
Number of Satellites	-	-	-	-
Slope (clinometer)	-	-	-	-
Treecover:				
Partial	-0.001	0.001	-0.217	0.692**
Heavy	-0.002	0.004	-0.870	2.170***
Weather:				
Mostly Cloudy - Rainy	-0.004	0.003	0.219	0.772**
Constant	-0.002	-0.008*	3.979***	5.731***
Includes Country Dummies	Yes	Yes	Yes	Yes
N	4158	4158	4158	4158
R2	0.026	0.316	0.095	0.162

*p<.1; ** p<.05; *** p<.01

What appears to matter most are closing error and the perimeter/area ratio. The former reflects inaccuracy in the CR measure, while the latter is a proxy for the complexity of the plot shape which is likely to affect the accuracy of GPS measures, but can in principle also be capturing noise in the CR measure besides what is captured by the closing error. An unsystematic comparison of plot outlines computed from the CR method and collected in the GPS also suggests that it may often be the case that enumerators may tend to simplify the shape of the plot more when collecting CR than GPS data.

2. Comparison of SR and Objective Measurements

The models run above for the comparison of objective measures are ran again in an attempt to explain the difference between self-reported estimates and compass and rope measurements. The claim of plot area affecting the direction and degree of error associated with self-reported area estimates is supported by the regression results. In the first specification (on bias) the coefficient on plot area is negative quadratic and positive in the cubic term in Ethiopia, Nigeria and the pooled data. In the second specification (on absolute value of bias), the coefficients on plot area are positive suggesting that as plot size increases the degree of farmer over-reporting shrinks while at the same time the absolute value of the bias increases. In this second specification, the Tanzania data exhibits a negative quadratic term and positive cubic term. When looking at the relative bias and absolute value of relative bias, the linear term is negative and the quadratic term positive in each country but at very different magnitudes, potentially driven by the difference in average plot size observed across the countries. The distance from the plot to the dwelling holds significant explanatory power in the Ethiopia data, but not in Tanzania. The results from Ethiopia suggest that self-reported estimates of area diverge more from compass and rope measurements on those plots that are further from the household. Consistent with Carletto et al. (2015), the existence of property rights (proxied here by the possession of a title or certificate of ownership or the ability to sell or use the plot as collateral) has a significant, negative relationship with the relative bias in Ethiopia and the pooled data, suggesting that on plots where the household has some form of property rights they are better able to estimate the area. Household characteristics such as the gender, age, and education of the household head play out differently across countries.

4. Conclusions

Several important findings emerge forcefully from this analysis, which translate into clear implications for future survey design and implementation. The first result is that our experimental data confirm what we already knew about the presence of large, systematic measurement error in farmers self-reported estimates of land area, and on its direction, correlates and determinants (which include land area itself, introducing potentially large biases at the data analysis stage). An important finding of the study is that on average GPS measures return very accurate estimates of plot size, even for very small plots, and even for reasonably small samples.We also do not detect any evidence that GPS systematically under-reports land size, as is the case in earlier studies. That should suffice to make GPS an attractive method for land area data collection for most household survey practitioners.

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THEMATIC SET

C19 ASPECTS OF THE IMPLEMENTATION OF THE SYSTEM OF ENVIRONMENTAL-ECONOMIC ACCOUNTING

Session Organizer
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C19

Changes in food diets in West Africa and their implications for domestic producers

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ABSTRACT

Food consumption patterns in West Africa have changed over the past few decades, with a higher proportion in the food basket of animal products, fats, sugars and certain cereals such as rice and wheat. These trends, their causes and implications for food security and households have been widely studied but their meaning for agricultural production and farmers remain a more open field of investigation. Have farmers changed their production patterns in reaction to changing diets of increasingly urbanized consumers? Has agricultural production in West Africa diversified or has it concentrated on a smaller number of highly demanded commodities? What are the implications on the value of the farmers' production and their exposure to risks? The aim of this article is to provide statistical evidence on the economic implications for West African farmers of structural changes in the agricultural sector, such as the impact of the shift towards more diverse, calorie-intensive and often more expensive diets. After a presentation of the data and analytical framework, this article compares long-term food consumption and production trends of West African countries. Then, by combining two international datasets on food balance sheets and agricultural producer prices, the implications of these structural changes on the value of agricultural production and the uncertainties associated with the farmers' activities are assessed.

Keywords: Food balance sheets, structural changes, food trends

PAPER

1. Introduction

The comparison of today's food diets with what they were in the 1960s shows that food consumption patterns in West Africa have changed significantly, with a higher proportion in the food basket of animal products, fats, sugars and certain cereals such as rice and wheat (Vincent C., 2015). A number of megatrends are usually invoked as explanatory factors: rapid increase in urbanization rates, from 7.5% in 1950 to 31% in 2000 (OECD, 2011), a rate that has continued to increase since then; a deepening of globalization, facilitating the import of commodities which, until recently, were not considered as staple food items in West Africa such as rice, wheat or sugar; more recently, rising per capita incomes have also contributed to the evolution in diets, both in terms of calorific intake and composition.

The implications of these trends on food security have been widely studied[2] but their meaning for agricultural production and farmers remain a more open field of investigation. This imbalance in the analysis is first explained by the fact that the change in diets directly affects households and consumers and only indirectly farmers and agricultural production. It can also be explained to some extent by the existence of household surveys or population censuses that allow for a detailed analysis of consumption patterns. Many efforts at national and international level have been and are being made to improve household data, with initiatives such as the LSMS (Living Standards Measurement Study).

The stress that has been put on household statistics is due in part to its importance as a major data source for economic and social statistics: data on household expenses is needed to measure poverty and to construct many of the Millennium Development Goal (MDG, now SDG) indicators, in addition to being the main data source for the weights of the Consumer Price Indices (CPI); household survey data is widely used by national accounting departments to measure and calibrate household consumption, a major component of the supply and use equation in national accounts.

1 At the time this article was written and submitted.
2 Recent references include Vicent (2015), Bricas (2015a and 2015b) and Worku (2015).

Comparatively, fewer resources have been directed towards the measurement of agricultural production and farm-specific data: agricultural censuses and farm structural surveys are infrequent in West Africa, leading to data that lack in timeliness, quality, and level of detail and to the absence of proper sampling frames.

The poor measurement of agricultural production at farm level also has to do with the fact that agricultural statistical services are usually separated from national statistical institutes. Farm-level studies made by non-governmental organizations or the private sector often rely on their own data sources and data collection vehicles instead of using national surveys, which are often lacking or considered of insufficient quality. As a result, many of the analysis of the agricultural sector that can be found in the literature generally lack statistical representativity and is restricted in terms of geographical or commodity coverage. In addition, given the cost of carrying-out statistically representative surveys, these are often one-time exercises, impeding the construction and analysis of time-series. Notwithstanding the limitations attached to data on West African agriculture, international datasets compiling nation-wide data on agriculture do exist, allowing the analysis and comparison of macro-level trends on agricultural production and supply. The Food Balance Sheets (FBS), disseminated and updated on a regular basis by the FAOSTAT platform, is in this respect a unique data source which remains under-exploited.

The purpose of this study is to provide statistical evidence on the long-term trends (1960 - present) affecting the supply and demand of agricultural commodities in West African countries[3], based on aggregated sources of information such as the FBS. Through the construction and analysis of appropriate statistical indicators, this study seeks to identify the major trends of the farming sector in West Africa, in a context of changing food diets, and respond to questions such as: have farmers changed their production patterns in reaction to changing diets of increasingly urbanized consumers? Has agricultural production in West Africa diversified or has it concentrated on a smaller number of highly demanded commodities? What are the implications on the value of the farmers' production and their exposure to risks?

After a presentation of the data and analytical framework, this article compares food demand and production trends in West African countries since the beginning of the 1960s. Then, the implications of these structural changes on the value of agricultural production and the uncertainties associated with the farmers' activities are assessed. These analyses are based on two international datasets on food balance sheets and agricultural producer prices. The last Section concludes and identifies further lines of research.

2. Data and analytical framework

The statistical indicators constructed in this article are mainly based on the Food Balance Sheets (FBS) and agricultural producer prices compiled by FAO's Statistics Division and disseminated through its on-line data dissemination platform, FAOSTAT[4]. The data, its underlying compilation framework, and the main statistical indicators used in this study are presented in the remaining of this section.

2.1 Supply and use equation: the framework for Food Balance Sheets

The supply and use equation states that at any point in time there has to be a balance between the supply of an agricultural commodity and its different uses, for a country or any other geographical grouping, as illustrated by equation (1) (FAOSTAT, 2015):

$$\underbrace{Q_i + M_i}_{\text{Supply}} = \underbrace{C_i + NC_i + F_i + Sd_i + X_i + L_i + \Delta S_i}_{\text{Use}}$$

Where:

Q_i : Quantity produced of commodity i

M_i : Quantity imported

C_i : Quantity available for human consumption

NC_i : Quantity available for industrial or other non-food uses

F_i : Quantity used as feed for livestock

Sd_i : Quantity used as seed

X_i : Quantity exported

L_i : Quantity lost during transportation and storage at farm and wholesale levels

ΔS_i : Change in stocks between two periods

This analytical framework, generally referred to as Food (or Commodity) Balance Sheets (FBS), is analogous to the concept of supply and use equilibrium in national economic accounts.

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[3] According to the United Nations classification, West Africa is composed of the following countries: Benin, Burkina Faso, Cabo Verde, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone and Togo.

[4] http://faostat3.fao.org

It is useful in that it provides a complete picture of the sources of supply and use for a given commodity and a quantification of the associated flows. The common unit used is the raw commodity equivalent, such as kg of wheat, paddy rice, etc., which allows a standardization of the flows associated with different degrees of processing of the commodity. For example, humans or animals generally consume products that are based on some degree of processing of one or more commodities (wheat flour, pasta, bread, feed meals, etc.), whereas exports or imports may include both the commodity in its raw or processed form (cocoa beans and chocolate, for example).

To allow a proper aggregation of flows, processed products are therefore converted back to their raw commodity equivalents using appropriate technical conversion factors (also referred to as extraction factors)[5].

2.2 Statistical indicators

For the purposes of this study, several statistical indicators have been constructed using data from FAOSTAT (FBS, agricultural producer prices) and World Bank's World Development Indicators (agricultural GDP). The indicators are defined below.

2.2.1 Food production and consumption

Production (Q) is one of the variables of the supply-use equation of the FBS. It measures the total amount of the commodity produced for a given time period and country (or any other geographical grouping). C, the amount of the commodity available for human consumption, is given in the FBS framework by the difference between total supply and all the uses other than C. It does not mean that C is the amount actually consumed: losses occur in the transportation, storage and distribution process at the retail level; and a share of food is wasted by households after the actual purchase or production. Nevertheless, this indicator provides a measure of the domestic demand for the commodity in question and can therefore be considered as a proxy for potential consumption[6].

From equation (1), we consider the ratio $r = Q/C$ as the measure of the capacity of domestic production to satisfy domestic food demand. In this article, r is used as an indicator of the extent to which farmers in West Africa have adapted their production mix to the changes in domestic food demand.

2.2.2 Diversity of food production and consumption

Empirical evidence tends to suggest that there is a positive correlation between income per capita and diversity in diets. Doan D. (2014) has estimated that in the case of China income effect on food diversity is significant and positive, but diminishes along the income distribution and overtime. It is interesting to test if these results also hold for a region such as West Africa, which has seen income per capita rise in most of its countries, even if this rise has been relatively recent. In line with the objective of this study, it is also relevant to understand if agricultural production has diversified or not, in other terms if farmers have responded to changing diets by broadening their product mix or by specializing on a smaller number of commodities. To respond to these questions, a measure of diversity is constructed: is the Herfindahl-Hirschman index for C and n the number of commodities. To respond to these questions, a measure of diversity is constructed:

$$div = 1 - \left({[HHI - {}^{1}/_{n}]} \Big/ {1 - \frac{1}{n}} \right)$$

Where:

$$HHI = \sum_{i=1}^{n} \left({}^{C_i} \Big/ {\sum_{i=1}^{n} C_i} \right)^2$$

div is the complement of the normalized Herfindahl-Hirschman index: as the latter measures market concentration, the complement (one minus the normalized *HHI*) measures diversity. The diversity index for food production is computed exactly in the same way, replacing C by Q. As *HHI* varies between1 / n and 1, div varies between 0 (minimum diversity) and 1 (maximum diversity).

2.2.3 Agricultural value of production

Changes in the production mix of farmers impacts the average value of their production. The amount produced valued at farm-gate prices gives the value of production: v = Q.P, where Q is the production of the commodity and P its farm-gate price. A decomposition of changes in can help determine if farmers have benefited from the changing structure of their production, by isolating the share of the change in

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[5] For example, it is estimated that 100g of raw wheat are needed to produce 80g of wheat flour. To convert wheat flour to its raw wheat equivalent, wheat flour quantities are multiplied by 1/80%, the reciprocal of the extraction factor (80%).

[6] In this study, we will refer to indiscriminately as consumption, demand or potential consumption.

v that is due to a structural effect such as, for example, a change in the production mix towards higher-priced commodities. This is done by decomposing the growth rate of the average value of production in a price, quantity and structural (or weighting) effect, as described in Annex 1.

2.2.4 Agricultural prices and margins

The deflator of agricultural production measures changes in the average prices in the agricultural sector: defl = V/Q. It is generally presented in the form of an index: indeed, as it aggregates all kinds of products, its direct interpretation in value per quantity unit has little meaning.

Comparing defl to indicators such as the deflator of the Gross Domestic Product (GDP), an economy-wide measure of inflation, provides a gross indication on the evolution of producer margins. Comparing defl to the food Consumer Price Index (food CPI) provides an indication of the evolution of producer margins with respect to those of other actors of the food chain, such as wholesalers, retailers, transporters or importers. For example, a persistently higher inflation in food consumer prices respective to agricultural producer prices is an indication that average margins of farmers are decreasing relative to wholesalers and retailers margins.

2.2.5 Risks

Farmers operate in an uncertain environment and are exposed to a wide array of risks. The impacts of some of these risks, such as natural catastrophes, are to a large extent independent from the nature of the activities of the farm. Similarly, as farmers are generally price-takers, they face an uncertainty in the prices that they will receive for their product. Farmers can to some extent insure themselves against the impact of some of these risks, through the purchase of hedging instruments such as weather derivatives or futures contracts. However, most of these tools are still out of the reach of farmers in developing countries. Instead, farming practices and commodity specialization can and are used by some as a risk management tool. Indeed, the revenue of a farm in monoculture is more exposed to production risks (a pest, for example) and to price risks (if the price of this commodity plunges, so does the farm revenues) than for a multi-output farm which can spread these risks across different commodities. Therefore, the question of the extent to which structural changes in the production mix affect the exposure of farmers to uncertainties and risks on their revenues is a relevant one. The benefits for farmers of a change in production structure towards higher-priced products may be mitigated by a higher exposure to price and/or production-related risks. This means that, when taking into account the probability distribution of yields and farm-gate prices, the expectancy of earnings may in reality be lower than for a production structure composed of lowerpriced but less risky commodities.

Risk is often approximated through a measure of historical variability. In this study, the coefficient of variation[7] will be used to measure variability in quantities (production risk) and average prices (price risks). We will also provide a measure of the exposure to price risks, based on a decomposition of the variance in average prices. Refer to Annex 2 for details on this decomposition.

The data sources on which these indicators are based and the different operations that had to be done to standardize and fill data gaps are presented in the remainder of this section.

2.2 Food Balance Sheets

A Food Balance Sheet (FBS) presents a comprehensive picture of a country's food supply and utilization during a specified reference period, a calendar year in the case of FAO's FBS data. The FBS shows for each food item (each primary commodity) the availability for human consumption that corresponds to the sources of supply and its utilization (FAOSTAT, 2015). FBS bring together the larger part of the food and agricultural data in each country, as it compiles country information on production, trade and utilization produced at national level. It is therefore a derived statistics and its statistical reliability depends on the accuracy and quality of the underlying data produced by the countries, which is known to be highly variable. In fact, the food available for human consumption (C) is often not measured in the FBS but calculated as a residual. Knowing that there are many gaps particularly in the statistics of utilization for non-food purposes, such as feed, seed and manufacture, as well as in those of farm, commercial and even government stocks, C has to be used with caution. In spite of all these imperfections, FAO's FBS are one of the few database (if not the only one) that compiles annual data for such a large set of countries with more than 50 years of history. Moreover, these imperfections can be partly mitigated by considering the trends and not the absolute values, as done in this study. This is possible thanks to the availability of long time-series (the FBS data in FAOSTAT starts in 1961) and the full coverage of West African countries. Furthermore, this study focuses on the analysis of regional trends, limiting country comparisons that may be hampered by differences in the way the data is compiled.

[7] The coefficient of variation is defined as the standard deviation divided by the mean of the distribution.

2.3 Agricultural producer prices

FAO's agricultural producer price data set is the other source of information used in this study. It provides data on farm-gate prices for more than 130 countries and 200 commodities. Its level of commodity detail, country coverage and data history[8] makes it a unique source of information for the investigation of long-term trends in producer prices. Information on prices is collected annually from the countries, compiled, harmonized and disseminated in July-August of each year. The quality of FAO's producer prices data set depends largely on the quality of the underlying country data.

While a country will generally adequately report data for its major commodities, data availability and quality is lower for minor commodities, or for highly volatile and seasonal items such as fruits and vegetables. Adding noise to the data is the uneven adherence of the reported prices to the farm-gate concept: while some countries report the price of the commodities when they leave the farm, others provide the price at the first point of sale, at wholesale markets or even at retail stores or markets. African countries in particular tend to report wholesale or retail prices, especially for fruits and vegetables.

Focusing on the trends instead of the absolute values cancels out some of these biases, to the extent that these do not vary in time and that the series are exempt from breaks.

2.4 Matching categories of the food balance sheets and agricultural producer price datasets

To compute the value of production, producer prices have to be available for each of the items produced. The commodity classifications used for the FBS and the producer prices differ slightly: the former is a hybrid classification that incorporates most of the raw commodities (for example, wheat and wheat products) but also some processed items (butter, sweeteners, olive oil, etc.). The producer price dataset uses a classification solely based on raw commodities (milk, sugar cane, olives etc.). A procedure to associate the appropriate price to the corresponding item of the FBS data set has therefore been implemented:

- If an item is common to the two datasets, the price of the item is taken and attributed to the corresponding item of the FBS classification without any further modification (except unit transformations);
- If an item of the FBS classification is more highly aggregated than in the price classification, the prices of the corresponding items of the latter are averaged and applied to the FBS item. For example, the price of the item sesame seed and sesame seed oil of the FBS classification is equal to the unweighted average of the price of sesame seed and sesame seed oil, which constitute two different items in the price classification;
- In the opposite case where the item of the price classification corresponds to more than one item of the FBS classification, the price of the former is applied to all the items of the latter. For example, the price of the single item oranges and mandarins from the price list is applied individually to oranges and mandarins, that form two distinct commodities in the FBS list;
- The price of processed products such as butter or vegetable oils is computed based on the price of the raw commodity from which they originate[9], by multiplying the price of the processed item by the reciprocal of the extraction rate. For example, if the price of one litre of cow milk in Mauritania is 0.392 USD (FAOSTAT, 2015) and if the extraction rate of butter to cow milk is 4.2% (4.2g of butter can be produced from 100g of cow milk), the price of one kg of butter will be equal to 0.392*(1/(4.2%))=9.3 USD. This procedure assumes that the price of a processed product is only a function of the price of the raw commodity from which it is produced and implicitly considers that transformation margins are equal to zero. This necessary assumption undermines the plausibility of the absolute prices constructed in this way. However, given the relative stability of transformation margins over time, the analysis of trends may adequately reflect changes in producer prices. This matching procedure and transformation in prices can be summarized in correspondence matrices, an example of which is given in Annex 3.

2.5 Estimation of missing data

The data reported on producer prices is generally incomplete, especially for minor or highly seasonal or volatile items. To ensure that the value of production is computed for all countries over the same set of commodities, missing item prices are estimated. The method is straightforward:

- The missing price for an item is estimated by the average price of the item group to which it belongs. For example, if the price of maize is missing, it is estimated by the average price of cereals;
- If the data is too scarce to compute item group averages, the missing price is imputed by the average regional price for the same item. For example, the missing price for maize is estimated using the average maize price in the West Africa region.

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[8] The data goes back to 1961, although due to a temporary halt in the FAO's data collection activities the data series before and after 1991 have been split into two not necessarily compatible datasets. This article uses only the most recent dataset, from 1991 onwards.

[9] In this classification a processed product originates from only one raw commodity, which simplifies the computations. The computation procedure as described in Annex 3 can in theory accommodate products based on several raw commodities.

This Section has presented the information sources, the main transformations operated to the raw data and defined the different indicators used in this study. We will now analyze and compare the trends in food diets and production in West Africa.

3. Have West African farmers adjusted their production to changing diets?

3.1. Food diets are getting richer

Statistical evidence suggests that West African diets tend to converge towards "western" standards, characterized by a larger share of animal products, fats and sugars in food consumption. Urbanization and economic growth, which contribute to the emergence of a new middle class, are among the main drivers of this structural change (Vincent C., 2015).

The data compiled here for West Africa shows that the share of items such as sugars and vegetable fats in the per capita kilocalories available has risen from an average of 3.7% in 1961-1979 to 5.0% in 2000-2011 for sugars and from 12.8% to 14.6% for vegetable fats and oil crops. In contrast, the share of traditional food staples has declined: for roots and tubers, for example, it has fallen from 17.1% to 14.3%. For other food categories, the changes are less significant: cereals still represent more than half of the calories available, with little change compared to the 1961-1979 average. The weight of meat and animal products has also remained stable over the period of analysis, just under 8.0%. The data also confirms that overall food supply per capita (excluding alcoholic beverages) has increased at a steady pace, from an average of 1957 in 1961-1979 calories per day to 2434 for the period 2000-2011. Changes in food consumption habits become more apparent when looking within the aggregated categories. For instance, the share of wheat and rice relative to traditional cereal crops such as sorghum and millet has increased significantly (Figure 2). The rise in the share of rice is a common and defining characteristic of the evolution in West African food diets. Several studies, such as Me-Nsope and Staatz (2013), have indicated that there is a positive correlation between on the one hand income per capita and urbanization rates, and on the other hand the share of rice in food diets. For meat and animal products, the share of poultry meat has increased markedly (from 2% in 1961-1979 to 6% in 2000-2011). It has also been the case, but to a lesser extent, of eggs, pork meat and pelagic fish. In contrast, bovine and mutton meat have lost ground (from 14% to 10% for beef and from 7% to 6% for mutton). Milk (excluding butter) remains by far the largest item consumed within this category, with a stable share in diets oscillating around 35%. Among the excitants, cocoa has gained significant ground to the expense of coffee and, to a lower extent, tea: its share in the consumption of excitants averaged 68% over the period 2000-2011, against 40% in 1961-1979.

One of the characteristics of the change in food diets is their greater calorific content: the average number of kilocalories by kilogram of food available for consumption has increased from just above 1860 kcal/kg in 1961 to around 2000 kcal/kg in the recent years, after reaching a peak during the mid-80s at 2050 kcal/kg (Figure 3). This is the result of a greater reliance on commodities with a higher calorific content, a change that occurred both within item categories (wheat and rice, for example, have a higher calorific content than millet and sorghum) and between them (higher proportion of fats and sugars in food diets compared to other items, for example). Cereals and oils and oil crops have seen their energetic content rise at a steady and sustained pace: rice and wheat drove the increase for cereals; for oil crops, the rise is due to the higher availability of calorie-rich soybeans and derived products such as soybean oil. Conversely, the average calorie content for meat and animal products has slightly decreased, reflecting the increase in share of less calorie-rich poultry meat and products.

This article will now investigate if the changing composition of food consumption evidenced above has been accompanied by an increase in the diversity of food diets and agricultural production, or if new products have simply replaced old ones.

3.2. More diverse food diets

Recent analysis of consumption behaviors of households or individuals in West Africa have concluded that food diets are becoming more diverse, with significant intra-category substitutions, in a broad context of rising demand for items with higher calorific, fat and sugar content. It has become apparent that lifestyle changes that accompany increases in income are correlated with diversification in food types and with the consumption of products with high added value, animal products and fruits (Bricas et al., 2015). However, most of these studies have concentrated on urban and peri-urban dwellings, leaving out rural households, which, in spite of their declining weight, still represent around three quarters of the population in West Africa[10]. Can the results for urban or peri-urban households be extrapolated to the population as a whole? The analysis of FBS data, which includes by construction all food items produced domestically or imported in the country, can help answer this question.

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[10] Source: Africapolis, dynamiques de l'urbanisation 1950 – 2020 : approche geo-statistique, Afrique de l'ouest

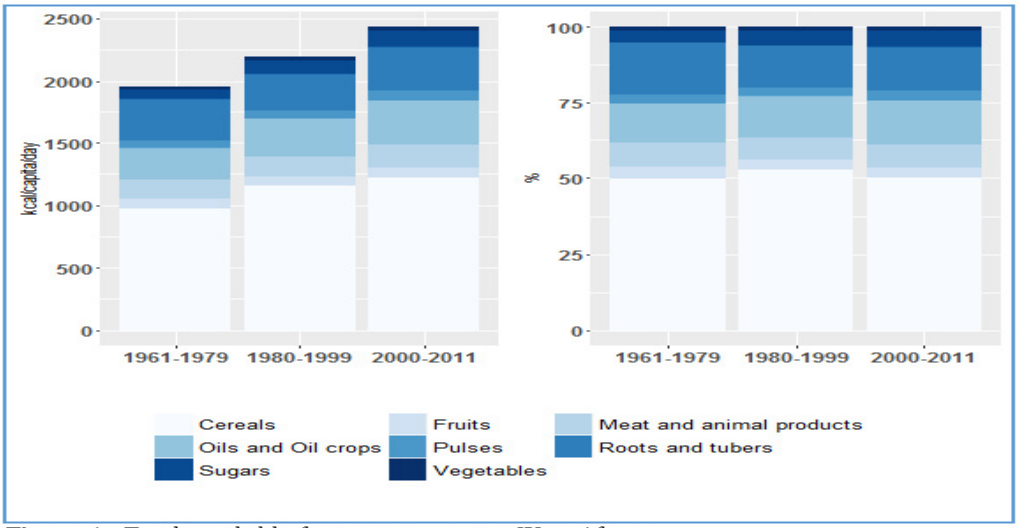

Figure 1: *Food available for consumption in West Africa*
Source: FAOSTAT 2015, author's calculations.
Note: Spices, Excitants and Other are excluded from the legend because of their negligible contributions.

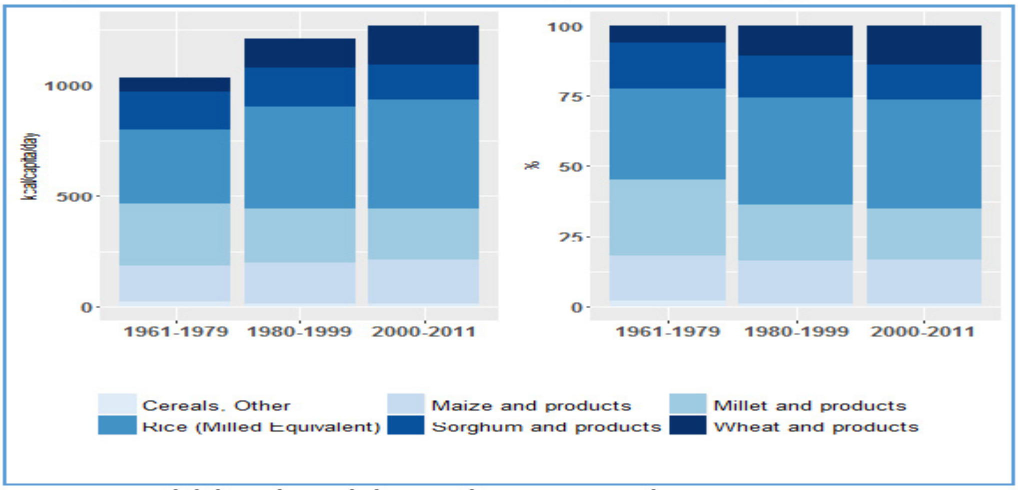

Figure 2: *Availability of cereals by cereal type in West Africa*
Source: FAOSTAT 2015, author's calculations.
Note: Oats, Barley and Rye are excluded from the legend because of their negligible contributions.

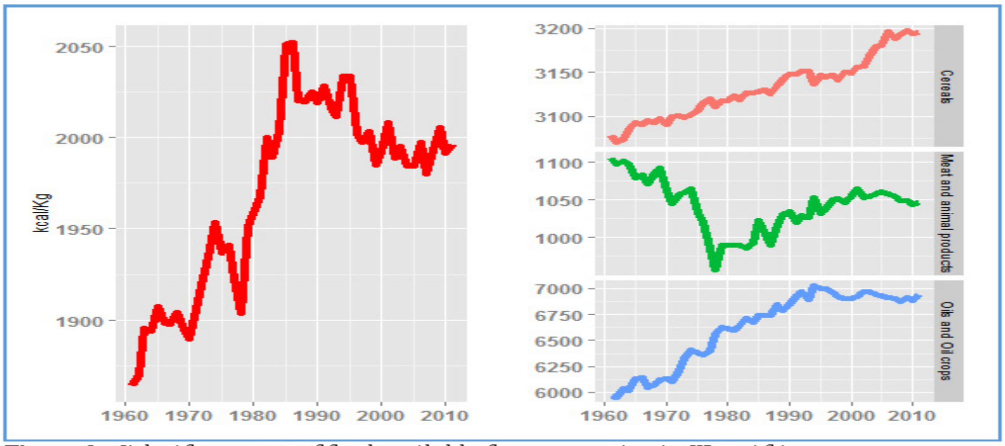

Figure 3: *Calorific content of food available for consumption in West Africa*
Source: FAOSTAT 2015, author's calculations.

The measure of diversity used in this study is the complement of the normalized Herfindahl-Hirschman index, the latter being widely used to measure market concentration (refer to the second section of this article for details). According to this indicator, the diversity in the food available for consumption has increased over the last 50 years for a large majority of Western African countries (Figure 4). This measure also shows that the dispersion among these countries with respect to food diversity has decreased. This indicates the existence of a common trend underpinning the change in food diets in the region, characterized by a re-balancing of the consumption in cereals (with wheat and rice increasing in share) and meat (white meat in complement to red meat). Interestingly, the group of countries that was significantly behind in terms of food diversity (Niger, Liberia, Sierra Leone and Benin) has progressively caught-up with the rest of the countries. This is a sign of improving production conditions and/or an increased capacity of these countries to satisfy food demand through imports.

Contrary to food diets, the diversity of agricultural production has not increased (Figure 4). The diversity indicator also shows that the dispersion among Western African countries with respect to production diversity has widened. This may reflect different food and agricultural strategies, with some countries preferring to widen their production scope while others tend to specialize on a reduced number of crops. The dispersion among countries also highlights their different endowments and capacity to import. The fall in the production diversity of countries such as Nigeria and Sierra Leone, for example, reflects the tendency of commodity-rich countries to neglect domestic agricultural production, a phenomenon that has been exacerbated by the commodity super-cycle of the 2000s[11]. Additionally, the increased demand for cocoa has clearly been one of the drivers of the concentration of agricultural production in the two main cocoa-producing countries of the region, Ivory Coast and Ghana. These findings suggest that farmers in West African countries have responded in different ways to changing and more diversified diets.

To understand if domestic production is now better able to satisfy food demand or, on the contrary, if it has lost ground with respect to foreign providers, food demand has to be compared with production. This is done below.

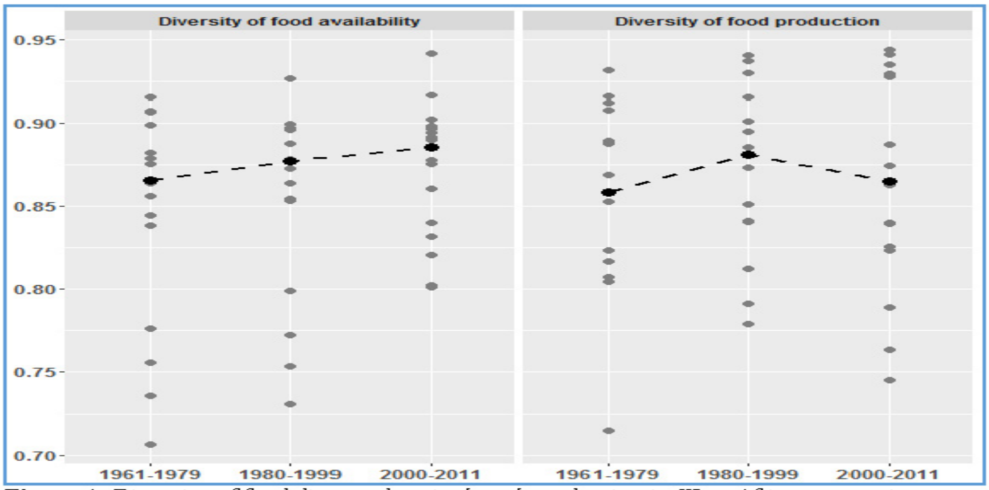

Figure 4: *Diversity of food diets and agricultural production in West African countries*
Source: FAOSTAT 2015, author's calculations.
Note: the dots correspond to individual country data. The median is represented by the connected dots in black.

3.3. Food demand versus. food production

Overall, production-to-demand ratios have not improved nor deteriorated significantly (Figure 5). In a context of increasing food demand and changing food diets, this suggests that producers have scaled-up their production for emerging commodities and/or generated additional surpluses for their major commodities. A stable ratio may be the reflection of an increase in the production of commodities that are largely exported and not meant to be sold on the domestic market (such as cocoa) and not necessarily an indicator of self-sufficiency. A commodity-level analysis is better adapted to draw conclusions that are more meaningful on the capacity of domestic producers to satisfy internal demand. For cereals, the ratio of production to demand has remained stable slightly above one, meaning that West Africa produces enough of the commodity to satisfy internal demand.

Looking at this ratio for the different cereal crops reveals that output of both traditional and emerging crops has increased in volume, but the demand for the latter has outpaced its output. For example, the production of rice has doubled since the beginning of the 1960s to reach 20kg or above per capita in the region but is still insufficient to cover the demand, which has tripled to reach more than 30 kg per capita in 2013. Regarding wheat, because agro-climatic conditions in West Africa are not favorable to the production of this cereal, the increase in demand has directly translated into a higher import dependency. On the contrary, surpluses of maize, a traditional crop, have significantly increased, generating additional export capacity.The statistical evidence provided in this section confirms a structural change in food demand: it has increased in quantity, is more energy-intensive and diverse. In response to these changing preferences, the agricultural sector has partially adjusted its production, by scaling-up its output for emerging food staples such as rice but also by increasing its output for certain traditional commodities, some of them with a good export potential (cacao, maize, sorghum, for example). This has generated revenues that can in turn be used by countries to import the commodities for which they are in greater deficit, such as wheat and, to a lesser extent, rice and certain processed products such as sugar. The next section will delve more deeply into the economic implications for the agricultural sector of the change in the composition of its production mix: has it translated into a higher average remuneration for its products? Is the agricultural sector more exposed now to production and price shocks?

[11] The 2000s commodities boom or the commodities super cycle was the rise in many physical commodity prices (such as those of food stuffs, oil, metals, chemicals, fuels and the like) which occurred during the decade of the 2000s (2000–2009), following the Great Commodities Depression of the 1980s and 1990s. The boom was largely due to the rising demand from emerging markets such as the BRICS countries, as well as the result of concerns over long-term supply availability.

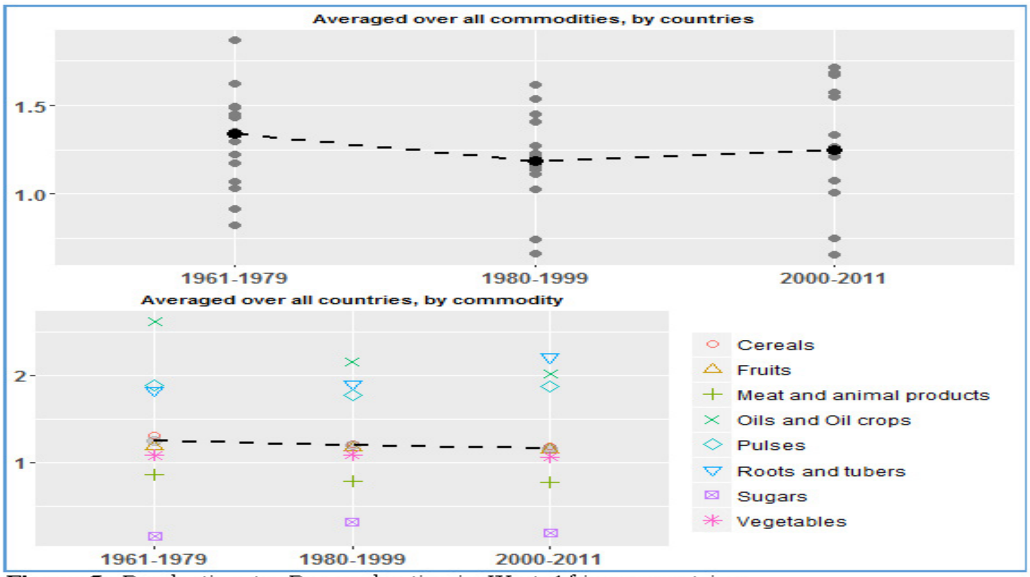

Figure 5: *Production-to-Demand ratios in West African countries*
Source: FAOSTAT 2015, author's calculations.
Note: The median is represented by the greys dots connected with the black line.

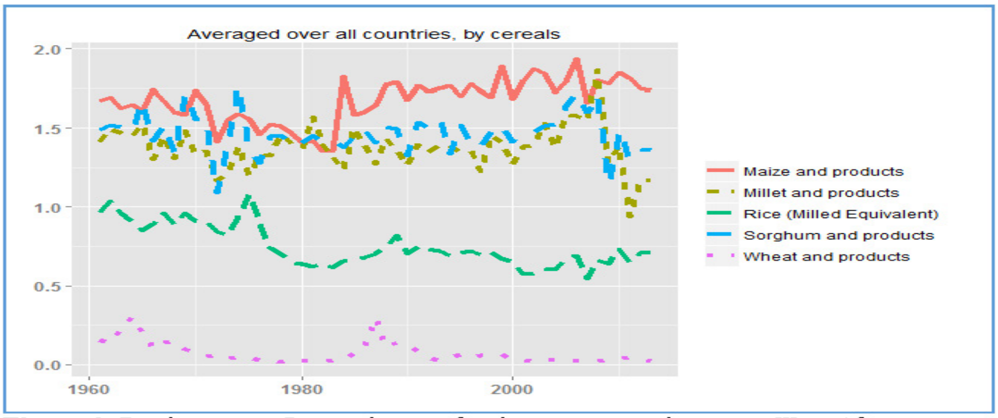

Figure 6: *Production-to-Demand ratios for the major cereal crops in West Africa*
Source: FAOSTAT 2015, author's calculations.

4. Changing food diets and production patterns: economic implications for farmers

4.1. Agricultural value of production: a price-driven increase

The value of agricultural production has risen relatively steadily in West Africa since the beginning of the 1990s, at an average annual rate of 8.5% (Figure 7). This increase has been determined largely by fluctuations in prices (for details on the decomposition procedure, see Annex 1). Fluctuations in quantities have had a smaller influence on value of production, although it has become more significant during the past 10 years. The effect of structural changes (structural or weighting effect due to a change in the production mix) appears minor compared to price and quantity effects. Weighting effects reflect longer-term changes in the specialization of production which, when looked at on an annual basis, are necessarily lower than those resulting from more volatile components such as price and quantities. That said, the average structural effect over the period of analysis, at +0.04%, is negligible compared to the average price and quantity effects (respectively +5.1% and +3.4%). This suggests that the product-specialization of the agricultural sector in West Africa has not been made towards products with a structurally higher remuneration potential. While this is true on average for West Africa, it is not necessarily the case for all individual countries within this region. Indeed, section 3 has revealed different specialization patterns in West Africa, with some countries that diversified their production to satisfy changing consumer preferences while some others tended to specialize into a smaller number of commodities with a higher revenue potential (cacao, etc.).

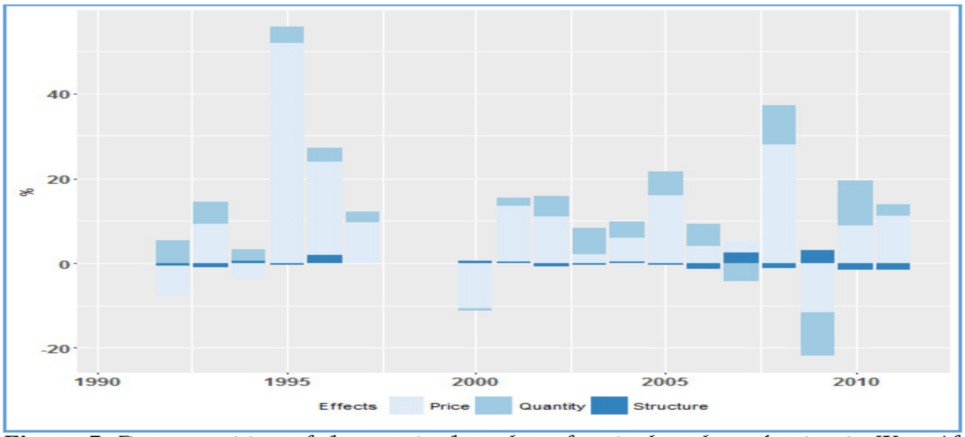

Figure 7: *Decomposition of changes in the value of agricultural production in West Africa.*
Source: FAOSTAT 2015, author's calculations.
Note: 1998 and 1999 have been omitted because of the distortion created by the devaluation of the Naira in 1998.

4.2. Agricultural prices and margins in West Africa have not evolved to the benefit of farmers

Put aside the correction in prices after the end of the 2007-2008 food price crises[12], average agricultural prices in West Africa rose at a steady and sustained pace: the deflator of agricultural production has been multiplied by 2.4 from 2000 to 2012. This does not necessarily mean that producer margins have risen, because the price of agricultural inputs has probably risen in parallel. In fact, taking the GDP deflator as a proxy for the price of inputs, no clear-cut conclusion can be made on the evolution in agricultural margins: the two deflators have evolved at similar rates from 2000 to 2009 (Figure 8). Since then, the GDP deflator has been increasing faster, pointing to deterioration in producer margins. More data points are needed to conclude if this trend is persistent, transitory or if it is due to a statistical artefact. The fact that food consumer prices have increased at a higher pace than agricultural producer prices indicates that farmers have probably seen their margins reduced to the expense of intermediaries (wholesalers and retailers). The widening gap between consumer and producer prices may also reflect structural changes in West African food markets, echoing changes in food diets: food chains are becoming wider and more sophisticated with the emergence of new actors in the agro-industrial complex, lessening the link and widening the gap between prices at both ends of the chain.

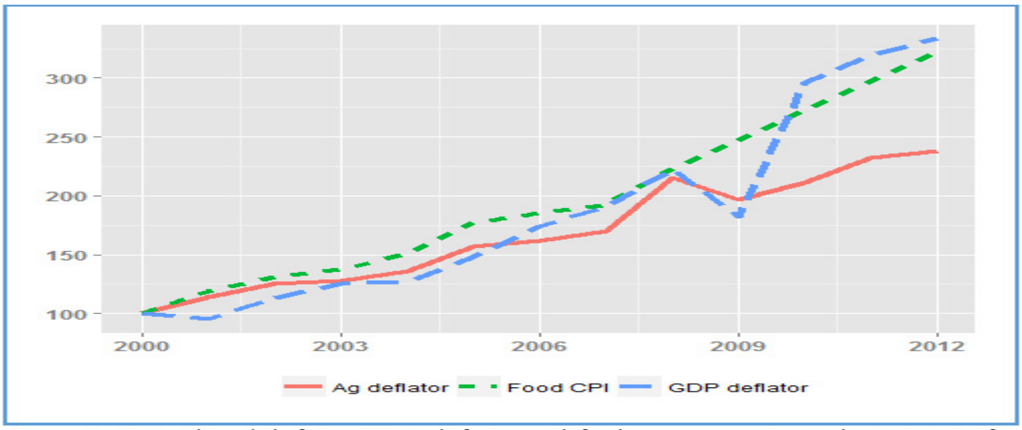

Figure 8: *Agricultural deflator, GDP deflator and food consumer price index in West Afric (100=2000)*
Source: FAOSTAT 2015, World Development Indicators (The World Bank), author's calculations.

The level of uncertainty in the price paid to farmers and, by consequence, in their revenues is a key determinant of production decisions as well as, to some extent, private investment in agriculture. We will know delve into the analysis of the risks to which West African agriculture is exposed, especially price-related risks.

4.3. Decreasing price variability but higher exposure to price-risks

Risks of different nature are faced by farmers: uncertainties affecting yields are mainly exogenous, as most of them are climate-related. Yet, as crops and agricultural activities are diversely exposed to climate-related risks, the composition of the farmer's agricultural production and, by extension, the production specialization of an entire country or region has an impact on the overall exposure to production risks.

[12] World food prices increased dramatically in 2007 and the 1st and 2nd quarter of 2008 creating a global crisis and causing political and economical instability and social unrest in both poor and developed nations. This series of events is usually referred to as the 2007-2008 food price crises.

Farming practices also have a role: for a given crop, specific varieties may be more tolerant or resistant to droughts; cultural practices such as crop rotations may improve water use efficiency[13]; an appropriate use of inputs may also mitigate the impact on yields of adverse climate-related events. An agricultural sector highly specialized in the production of a small number of commodities, with a low level of infrastructure and input use will be highly dependent on weather conditions and therefore over-exposed to adverse climate-related events: yields, production and revenues will, as result, be more volatile and uncertain.

Another class of risks is that affecting the farmer's selling prices. When considering individual crops or agricultural activities, these risks can be considered as largely independent from the farmer's practices: except in exceptional cases, farmers are price-takers and the price received reflects local, national or international market conditions. The price trends, seasonality and volatility are highly dependent on the nature of agricultural products: perishable and non-storable commodities tend to be more volatile than non-perishable and storable ones. The price of some commodities such as rice, wheat or maize is mainly determined on international markets while for others prices mainly reflect local market conditions: the price variability (or uncertainty) of different groups of agricultural commodities tends to some degree to be independent from one another. As a result, the overall price risk faced by a farmer is to some extent dependant on the set of commodities that are produced. His exposure to price risks can be mitigated by choosing commodities with less correlated prices, much similarly to a financial investor who would construct a portfolio of stocks from companies with different activities in order to diversify its risks. By extension, the overall exposure to price risks of a country or region's agricultural sector is dependent on its commodity specialization. The contribution of the product specialization to price risks, defined mathematically in Annex 2, measures the exposure of farmers to these risks.

The results, illustrated by Figure 9, indicate that the variability in price has been declining since the beginning of the 90s: the coefficient of variation has declined from close to 120% at the beginning of the period to just under 80% in 2012. The 2007-2008 food price crises, which was characterized by surging and volatile prices on international agricultural markets, have little impacted agricultural prices in West Africa: the price variability did increase during this period, but by a limited amount (the coefficient of variation rose to 93%, slightly above the pre-crisis levels).

This may be explained by the composition of food production in West Africa: the commodities that saw their price increase the most, wheat and soybeans, are not the region's main crops. Furthermore, as most of the agricultural output in West Africa is either consumed by the farmers themselves or destined to local markets, prices of agricultural commodities respond rather to local market fundamentals than to international market shocks, at least on the short to medium-term. If the impact of the 2007-2008 food crises on agricultural producer price variability has been mild in West Africa, the same is not necessarily true for consumers: their diets, especially of those living in urban centers, relies more heavily on imported commodities and therefore make them more vulnerable to international price shocks. That said, recent econometric evidence suggest that the overall impact on food consumer prices in the region was limited: for example, Cachia (2014) estimates that only 10% of the initial shock in international commodity prices is transmitted to food prices after 4 months, 20% after 8 months.

Figure 9 also indicates that the decrease in variability of average agricultural prices has not been accompanied by a reduction in the exposure to price risks, quite the contrary. The contribution of the commodity production structure to the average price variability, what we named exposure to price risks, has in fact been increasing since the beginning of the 90s (Figure 9, right-hand side graph).

This means that a shock in commodity prices would probably have a higher impact on average prices now compared to the beginning of the 90s: farmers are more exposed to price shocks, either positive or negative. As the final formula of Annex 2 clearly shows, a greater exposure to price shocks can be the result of two effects, which can potentially be combined:

- A structural increase in the correlation between commodity prices. Theoretical and empirical evidence suggests that the integration of commodity markets and the harmonization of farming practices have contributed to increase the correlation between commodity markets. For example, it has been demonstrated that the emergence of bio-fuels has not only increased the integration between energy and agricultural markets but also among crops that are used to produce bio-diesel (soy, oilseeds, etc.) and ethanol (wheat, corn, sugar crops, etc.). This effect may be significant in parts of Europe, Latin and North America, but less in West Africa where the quantities destined to the biofuel market are marginal;
- The second potential effect is an increased specialization in the production of crops with a higher price correlation. In West Africa, the higher share in production of cereals such as rice, maize and wheat and crops such as soybeans has probably contributed to increase the overall exposure to price risks: these commodities are more integrated to international and regional markets than traditional cereals and their prices are known to be highly correlated. For detailed empirical evidence on the co-movements between major agricultural commodities, see for example de Nicola F. et al. (2014).

[13] Crop rotations improve the soil's physical characteristics and structure, reducing or eliminating the necessity to till or plough. The hydrologic supply and the exploration capacity of the plants are therefore improved.

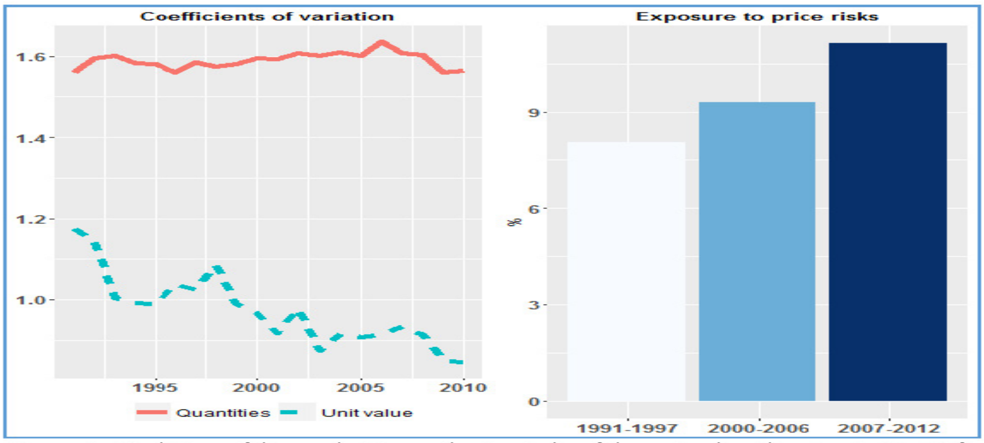

Figure 9: *Evolution of the production and price risks of the agricultural sector in West Africa.*
Source: FAOSTAT 2015, author's calculations.
Note: on the right-hand side figure, data for 1998 and 1999 has been omitted because of the distortion created by the strong devaluation of the Naira, the Nigerian currency, in 1998.

5. Conclusion

This article tried to brush a global picture of the trends in food demand and agricultural production in West Africa. It has first been shown that food diets are getting richer and more diverse, in line with structural socio-economic drivers such as urbanization and increasing income per capita.

At the same time, agricultural production has also evolved: it has responded to changing preferences of West African consumers by scaling-up its output of commodities such as rice, maize and certain animal products such as poultry. This increase in production has failed to match the corresponding rise in demand because yields in West Africa have only started to improve substantially in the past few years. For example, yields for rice (paddy) have been stable around 1.5 tons per hectare during the 1990s and the beginning of the 2000s. They have just recently started to improve to reach levels slightly above of 2.0 tons. In a context of a surging population, a rapid and significant improvement in cereal yields is a pre-requisite to the improvement of food security and a reduction in poverty rates in the region.

Agricultural production has also specialized in commodities that are in greater demand both domestically and abroad, such as cocoa, soybeans or maize. These new specialization patterns have economic repercussions for farmers: they received on average higher prices for their products but prices in the economy rose as well, sometimes faster, such as food prices paid by consumers. This suggests that margins in the agricultural sector have lost ground with respect to other actors of the chain, a structural trend given the higher sophistication and widening of the food chains. New production patterns and higher integration of agricultural commodity markets have also contributed to increase the exposition of West African agriculture to price shocks, a factor that has not yet been a source of concern given the decreasing trend in price variability in West Africa, only mildly affected by events such as the 2007-2008 food crises.

More work and statistics are needed to understand if the specialization of West African farmers has resulted in higher net returns for farmers. High-value or cash crops are also generally grown in input-intensive systems, with high costs. There is a statistical gap that needs to be filled to understand better production costs and returns of agricultural production, especially in West Africa where nation-wide statistically representative data is scarce. Further investigation is also needed to better identify production changes and substitutions within commodity groups, extending the analysis to the agro-food industry in order to see if food production in West Africa is getting higher up in the value chain. Finally, a more formal and comprehensive analysis of the commodity linkages is necessary to better understand the risks to which farmers are exposed, a phenomenon that is often overlooked but which has great implications on the vulnerability of farmers and their households.

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ANNEXES

1. Decomposition of the growth rate of agricultural value of production

The change in the aggregate value of production can be decomposed intro three components: a price effect, a quantity effect and a structural (or weighting) effect. The latter measures the extent to which changes in values are the result of a modification in the commodity mix. This annex describes one possible method to perform this decomposition.

The value of production for a given commodity is equal to its farm-gate price times the quantities produced: $v_{i,t} = p_{i,t}q_{i,t}$, where i denotes the commodity and t the time period. The value of production for a bundle of commodities is therefore: $v_t = \sum_{i=1}^{n} p_{i,t}q_{i,t}$, where n is the fixed number of commodities produced[14].

We start by defining two variables:

- The average farm-gate unit value of the basket of commodities produced : $\bar{p}_t = \frac{\sum p_{i,t}q_{i,t}}{\sum q_{i,t}}$; and
- The average quantities produced: $\bar{q}_t = \frac{1}{n}\sum q_{i,t}$

v_t is therefore also equal to: $v_t = \bar{p}_t n \bar{q}_t$

As v_t is a strictly positive variable, we can take its natural logarithm:

$\ln(v_t) = \ln(\bar{p}_t) + \ln(n) + \ln(\bar{q}_t)$

$\Delta\ln(v_t) = \Delta\ln(\bar{p}_t) + \Delta\ln(\bar{q}_t)$, where $\Delta x_t = x_t - x_{t-1}$ is the first-difference operator.

For "small" enough changes in $\bar{p}_t$ and $\bar{q}_t$: $\dot{v}_t \cong \dot{\bar{p}}_t + \dot{\bar{q}}_t$, where the dotted variables indicate simple growth rates. We will now determine $\dot{\bar{p}}_t$ and $\dot{\bar{q}}_t$, starting with the former:

$$\bar{p}_t = \frac{\sum p_{i,t}q_{i,t}}{\sum q_{i,t}} = \sum \frac{q_{i,t}}{\sum q_{i,t}} p_{i,t} = \sum \theta_{i,t}p_{i,t}$$

$$\Delta\bar{p}_t = \sum (\theta_{i,t}p_{i,t} - \theta_{i,t-1}p_{i,t-1})$$

$$\Delta\bar{p}_t = \sum \Delta\theta_{i,t}p_{i,t} + \sum \theta_{i,t-1}p_{i,t} - \sum \theta_{i,t-1}p_{i,t-1}$$

$$\Delta\bar{p}_t = \sum \Delta\theta_{i,t}p_{i,t} + \sum \theta_{i,t-1}(p_{i,t} - p_{i,t-1})$$

$$\dot{\bar{p}}_t = \frac{\Delta\bar{p}_t}{\bar{p}_{t-1}} = \underbrace{\sum \Delta\theta_{i,t}\frac{p_{i,t}}{\bar{p}_{t-1}}}_{ES} + \underbrace{\sum \theta_{i,t-1}\left(\frac{\Delta p_{i,t}}{\bar{p}_{t-1}}\right)}_{EP}$$

$\dot{\bar{p}}_t$ is composed of two effects:

- ES, which measures the effect on the change in average prices of changes in the commodity shares ($\Delta\theta_{i,t}$). For example, a rise in the production share ($\Delta\theta_{i,t} > 0$) of commodities with higher than average prices ($p_{i,t} > \bar{p}_{t-1}$) will contribute to increase the growth rate in average prices beyond the simple share increase ($\Delta\theta_{i,t}\frac{p_{i,t}}{\bar{p}_{t-1}} > 1$). ES is therefore said to measure a structural or weighting effect; and
- EP, which captures the effect on the change in average prices of commodity-specific price variations (price effect).

Turning to $\dot{\bar{q}}_t$:

$$\bar{q}_t = \frac{1}{n}\sum q_{i,t}$$

$$\dot{\bar{q}}_t = \frac{\frac{1}{n}\Sigma(q_{i,t} - q_{i,t-1})}{\frac{1}{n}\Sigma q_{i,t-1}}$$

[14] A fixed n is assumed here for simplicity, but this decomposition method can also be applied to a situation in which the number of commodities $n(t)$ varies in time.

$$\dot{\bar{q}}_t = \frac{\sum \Delta q_{i,t}}{\sum q_{i,t-1}}$$

$$\dot{\bar{q}}_t = \sum \frac{q_{i,t-1}}{\sum q_{i,t-1}} \frac{\Delta q_{i,t}}{q_{i,t-1}}$$

$$\dot{\bar{q}}_t = \sum \theta_{i,t-1} \dot{q}_{i,t}$$

$\dot{\bar{q}}_t$ is equal to the sum of the commodity-specific quantity changes weighted by their respective quantity shares (quantity effect).

It follows from the above that the growth rate in the value of produced for the set of commodity produced is equal to the sum of a price effect (EP), a quantity effect (EQ) and a weighting or structural effect (ES):

$$\dot{v}_t \cong \underbrace{\sum \Delta\theta_{i,t} \frac{p_{i,t}}{\bar{p}_{t-1}}}_{ES} + \underbrace{\sum \theta_{i,t-1} \left(\frac{\Delta p_{i,t}}{\bar{p}_{t-1}}\right)}_{EP} + \underbrace{\sum \theta_{i,t-1} \dot{q}_{i,t}}_{EQ}$$

2. Decomposition of the variance of average agricultural prices

The variance of $(\bar{p}_t)_{t=1,\dots,T}$, $V(\bar{p}_t)$[15], measures the variability in time of average agricultural prices and can be considered as a proxy for the apparent price risk faced by the agricultural sector.

Using the notations of Annex 1, we can write: $V(\bar{p}_t) = V(\sum \theta_{i,t} p_{i,t})$, where $\theta_{i,t}$ is the share of commodity i in the total quantity produced at period t. By decomposition of the variance: $V(\bar{p}_t) = \sum_i V(\theta_{i,t} p_{i,t}) + \sum_{\substack{i,j \\ i \neq j}} COV(\theta_{i,t} p_{i,t}, \theta_{j,t} p_{j,t})$, where COV is the covariance operator[16].

We now decide to compute the variance over several time intervals $T_1, \dots, T_h, \dots T_H$, such that $\bigcup_{h=1}^{H} T_h = [1, \dots, T]$ and, more importantly, $\theta_{i,t} \cong \theta_{i,T_h}$ $\forall h = 1, \dots, H$. This assumption states that quantity shares are stable within the different time intervals T_h (their variance is 0) and that they can therefore be considered as exogenous and not as random variables.

It follows from this assumption and from the linearity of the variance and covariance that:

$$V_{T_h}(\bar{p}_t) = \underbrace{\sum_i \theta_{i,T_h}^2 V_{T_h}(p_{i,t})}_{EP} + \underbrace{\sum_{\substack{i,j \\ i \neq j}} \theta_{i,T_h} \theta_{j,T_h} COV_{T_h}(p_{i,t}, p_{j,t})}_{ES}$$

ES measures the effect of the composition of agricultural production on the apparent average price risk faced by farmers. In other words, it measures the exposure of the agricultural sector to price risks. EP measures the effect of the price variability of individual commodities on the variability in average prices of the bundle of commodities produced by the agricultural sector.

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[15] The variance of a random variable is a statistical measure of its dispersion from the mean. The unbiased estimator $V(\bar{p}_t)$ is given by $v(\bar{p}_t) = \frac{1}{T-1} \sum_{t=1}^{T} (\bar{p}_t - \bar{\bar{p}})^2$, where $\bar{\bar{p}} = \frac{1}{T} \sum_{t=1}^{T} \bar{p}_t$.

[16] The covariance between two random variables $(X_t)_{t=1,\dots,T}$ and $(Y_t)_{t=1,\dots,T}$ is a statistical measure of the link between these two variables. The unbiased estimator of the covariance is given by: $cov(x_t, y_t) = \frac{1}{T-1} \sum_{t=1}^{T} (x_t - \bar{x}_t)(y_t - \bar{y}_t)$, where $\bar{x}_t$ and $\bar{y}_t$ are the means of the distributions.

3. Correspondence matrices: the example of Cap-Verde

Below is provided an extract of the correspondence matrix of Cap-Verde used to match the products of the producer price classification to the FBS classification and estimate the price of all the items of the latter. It has to be read in the following way:

- Regarding wheat, there is a one-to-one correspondence between the items of the price list ("Wheat") and the item of the FBS list ("Wheat and wheat products"): the price of both items will therefore be equal ;
- Fonio, absent of the FBS list, is added to the item "Cereals, Other": the price of this item will therefore include the price of fonio, as well as other cereals not present in the FBS list;
- Rice is expressed in two different units: in its raw form in the price list ("Rice, paddy") and in milled equivalent in the FBS classification. The coefficient in the corresponding cell is the technical conversion factor: 1.5kg of paddy rice is needed to produce 1Kg of rice in milled equivalent. For a given quantity, the price of the rice in milled equivalent will therefore be equal to the price of the paddy rice times 1.5.
- ... And so on.

As technical conversion factors vary from country to country, the correspondence matrices are country specific.

Table 1 - Correspondence matrix between the Food Balance Sheets classification (FBS) and the producer price classification (PP)

PP \ FBS	Wheat and products	Cereals, Other	Sugar cane	Sugar non-centr.	Sugar (raw)	Groundnuts (shelled)	Butter, ghee	Rice (milled)
Wheat	1	0	0	0	0	0	0	0
Rice, paddy	0	0	0	0	0	0	0	1,5
Fonio	0	1	0	0	0	0	0	0
Sugar cane	0	0	1	12,5	0	0	0	0
Sugar, cane, raw, centrifugal	0	0	0	0	1	0	0	0
Groundnuts, with shell	0	0	0	0	0	1,4	0	0
Milk, whole fresh cow	0	0	0	0	0	0	21,1	0

4. Main data tables

Table 2a - Food available for consumption in West Africa by commodity group

kcal / capita / day (% points)	1961-1979	1980-1999	2000-2011
Cereals	975 (49,8)	1156 (52,7)	1220 (50,1)
Excitants	1 (0)	1 (0,1)	3 (0,1)
Fruits	77 (3,9)	69 (3,2)	76 (3,1)
Meat and animal products	153 (7,8)	164 (7,5)	188 (7,7)
Oils and Oil crops	251 (12,8)	302 (13,8)	354 (14,6)
Other	1 (0)	2 (0,1)	3 (0,1)
Pulses	62 (3,2)	63 (2,9)	79 (3,2)
Roots and tubers	334 (17,1)	297 (13,5)	348 (14,3)
Spices	6 (0,3)	7 (0,3)	8 (0,3)
Sugars	72 (3,7)	101 (4,6)	121 (5)
Vegetables	27 (1,4)	30 (1,4)	34 (1,4)
Total	**1957** (100)	**2193** (100)	**2434** (100)

Table 2b - Food available for consumption in West Africa by cereal type

kcal / capita / day (% points)	1961-1979	1980-1999	2000-2011
Barley and products	0 (0)	1 (0)	1 (0)
Cereals, Other	24 (2,3)	12 (1)	10 (0,8)
Maize and products	161 (15,6)	186 (15,4)	201 (15,9)
Millet and products	281 (27,2)	243 (20,1)	227 (17,9)
Oats	0 (0)	0 (0)	0 (0)
Rice (Milled Equivalent)	331 (32,1)	460 (38)	492 (38,8)
Rye and products	0 (0)	0 (0)	0 (0)
Sorghum and products	172 (16,6)	175 (14,5)	160 (12,6)
Wheat and products	62 (6)	132 (10,9)	177 (14)
Total	**1031** (100)	**1209** (100)	**1269** (100)

Table 3 - Diversity of food availability and production in West Africa, by country

Diversity index	1961-1979		1980-1999		2000-2011	
	Availability	Production	Availability	Production	Availability	Production
Benin	0,88	0,82	0,89	0,81	0,89	0,76
Burkina Faso	0,84	0,86	0,86	0,88	0,88	0,89
Cabo Verde	0,78	0,91	0,88	0,94	0,92	0,94
Côte d'Ivoire	0,90	0,87	0,90	0,89	0,89	0,87
Gambia	0,84	0,81	0,85	0,87	0,90	0,87
Ghana	0,92	0,89	0,90	0,84	0,90	0,79
Guinea	0,91	0,91	0,85	0,93	0,84	0,94
Guinea-Bissau	0,86	0,93	0,80	0,94	0,83	0,94
Liberia	0,74	0,82	0,77	0,85	0,82	0,83
Mali	0,87	0,92	0,87	0,92	0,90	0,93
Mauritania	0,88	0,71	0,88	0,78	0,86	0,82
Niger	0,71	0,80	0,73	0,79	0,80	0,84
Nigeria	0,91	0,89	0,93	0,87	0,94	0,86
Senegal	0,88	0,86	0,88	0,90	0,88	0,93
Sierra Leone	0,76	0,85	0,75	0,90	0,80	0,74
Togo	0,86	0,80	0,90	0,84	0,89	0,84
Median	**0,87**	**0,86**	**0,88**	**0,88**	**0,89**	**0,87**

Note: the diversity index varies between 0 (minimum diversity) and 1 (maximum diversity)

Table 4a - Production-to-Demand ratios in West Africa, by country

	1961-1979	1980-1999	2000-2011
Benin	1,49	1,45	1,71
Burkina Faso	1,35	1,27	1,26
Cabo Verde	0,82	0,67	0,66
Côte d'Ivoire	1,49	1,61	1,55
Gambia	1,87	1,15	1,07
Ghana	1,34	1,41	1,57
Guinea	1,18	1,14	1,27
Guinea-Bissau	1,34	1,23	1,33
Liberia	1,03	1,14	1,08
Mali	1,22	1,15	1,21
Mauritania	0,92	0,74	0,75
Niger	1,43	1,22	1,24
Nigeria	1,62	1,54	1,67
Senegal	1,45	1,11	1,01
Sierra Leone	1,07	1,03	1,69
Togo	1,30	1,23	1,23
Median	**1,34**	**1,19**	**1,25**

Table 4b - Production-to-Demand ratios in West Africa, by commodity group

	1961-1979	1980-1999	2000-2011
Cereals	1,31	1,21	1,18
Fruits	1,18	1,17	1,15
Meat and animal products	0,86	0,79	0,77
Oils and Oil crops	2,61	2,15	2,02
Pulses	1,88	1,77	1,87
Roots and tubers	1,83	1,91	2,21
Sugars	0,15	0,32	0,19
Vegetables	1,08	1,09	1,06
Median	**1,24**	**1,19**	**1,16**

Estimating flows of ancillary biomass resources associated to permanent and temporary crops production and their uses

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ABSTRACT

The growing economic and environmental relevance of biological residues from cultivation (non-edible parts of vegetables, stalks, pruning residues, end-of-life trees…) calls for greater attention to their measurement. Biological residues from cultivation are often gathered and composted, or used as fodder, or for energy production. The remaining quantities are left on the soil or burnt in the open, or landfilled. Different consequences in terms of environmental pressures and economic results arise from different management ways of these residues. It is therefore of great interest for research and policy use, to gain better knowledge on the amounts of biomass involved, as well as of their current distribution between the various possible destinations.
We first introduce the notion of "biological *residues* from cultivation" and clarify its relation to the definitions of "products" and "residuals" in the general SEEA Central Framework physical flow accounts context (SEEA Central Framework 2012, ch. 3), as well as to that of "unused materials" in Economy-wide material flow accounts (Eurostat, 2001; SEEA-CF, 3.6.6). "Residues" covers a broader set of materials than "residuals", which in turn is broader than "unused" (as for biological residues of cultivation).
Not much official statistics is available on biological residues from cultivation. In Italy, estimates were made in the past by using agronomic information. Istat's structural surveys on agricultural holdings, carried out in 2013 (focussing on permanent crops) and 2014, introduced questions for the first time on these flows. In the paper we show the results of these data collection exercises and conclude that, in order to fill this information gap, official statistics needs not embark on regularly surveys but only provide some benchmark as for the supply of residues, while for the management and uses, the phenomenon should be considered in structural surveys and in exploiting administrative sources. SEEA AFF could also play a role in this respect, though maintaining its focus on main crops, by including an account on the connected ancillary biomass flows.

Keywords: SEEA-CF, SEEA AFF, crop residues, biological residuals, unused biomass.

PAPER

1. Introduction

Unused residues stemming from crop, timber, fish and other primary biomass production processes make up for a significant part of the total biomass produced in Agriculture, Forestry and Fisheries activities: 20% of it, i.e. 5.5 billion tons, according to data responding to the Economy-wide material flow accounting (Eurostat 2001) definition of "unused" available on www.materialflows.net. The wise management of these residues, though probably not the key to solving any specific problem, may help reach some sustainable development (SD) goals, many of which rely on an environmentally sound agricultural sector. Indeed, crop residues may be left on the soil; burnt; collected and used - in the same holding or in other establishments – as inputs in the production of other goods (e.g. straw used as fodder; non-edible parts of plants fed into a digester or a composter); collected and put into a landfill. The way they are dealt with has consequences in terms of soils health, greenhouse gas emissions, fertilisers consumption, waste management, energy production, agricultural income. Depending on the way these residues are managed, the nutrients contained in them may be squandered or returned to the soil (directly, or as manure, or after composting). From a policy concepts and programs point of view, this issue is relevant for the *circular economy* (EU, http://ec.europa.eu/environment/circular-economy/index_en.htm), for *sustainable production and consumption* (UNEP - http://www.unep.org/rio20/About/SustainableConsumptionandProduction/tabid/102187/Default.aspx;EU,http://ec.europa.eu/environment/eussd/escp_en.htm) and for the green economy and green growth concepts (OECD, http://www.oecd.org/greengrowth/;ESCAP,http://www.unescap.org/our-work/environment-development/green-growth-green-economy; World Bank, https://issuu.com/world.bank.publications/docs/9780821395516).
In the present paper we first discuss the treatment of residues in SEEA physical flow accounts and then describe calculations and results of two complementary data survey and elaboration exercises carried

out in Italy in the context of a collaborative effort between producers of structural statistics on crops and national accountants in charge of environmental satellite accounts. We conclude by pointing out how, according to our experience, official statistics can deal efficiently with crop residues flows measurement, and highlighting the possible role of the System of Economic and Environmental Accounts for Agriculture, Forestry and Fisheries (SEEA AFF) in promoting knowledge on these important materials.

2. Treatment of crop residues in SEEA-CF physical flow accounts

The SEEA for Agriculture, Forestry and Fisheries (SEEA AFF) is the internationally agreed methodological document in support of the SEEA-Central Framework (SEEA-CF) dealing with the application of the latter in the agricultural field (outcome of the XI meeting of the UN Committee of Experts on Environmental-Economic Accounting – UNCEEA, June 2016). This document focuses on the main products of agricultural activities, and leaves to future developments the "important area of research" of "a more complete and consistent articulation of losses, unused biomass, residues, waste, reuse and recycling in relation to biomass" (§ 2.133, SEEA AFF, draft for consideration by the UNCEEA, June 2016). In trying and contributing to these developments, we therefore will refer directly to the SEEA-CF as for the definitions and treatment of these concepts.
The first and most general concept we use here and in the surveys described in the following chapters, however, is used in SEEA-CF (see in particular §3.99) and AFF (see above), but is not defined in there. It is that of crop residues. The way we use the term here, which we think is consistent with the way it is used in SEEA, it designates all the parts of plants different from their main useful product, such as e.g. non-edible parts of vegetables' plants, stalks or wood resulting from pruning, discarded fruits, crops grown but not harvested for whatever reason. These include not only things that respond to the SEEA definition residuals (§3.73), but also to that of products (§3.64), such as e.g. straw that is gathered and sold (or used on own purpose, which is common for holdings having animals) by the producing units.
In the SEEA-CF, like in the System of National Accounts (SNA), biological resources are distinguished into cultivated and non-cultivated (SEEA-CF §3.54). Non-cultivated biological resources are not covered at all by the present discussion, which only concerns biological residues from cultivation processes, i.e. stemming from cultivated biological resources. In particular, we do not cover here residues from extraction of non-cultivated biological resources (felling residues of natural forests, discarded catch of wild animals) – called natural resource residuals in SEEA-CF (§3.49).

Cultivated biological resources may be considered in two different ways, corresponding to two different system boundaries. Both are described in the SEEA-CF[1]:

▪ In the most general description of physical flows, coherently with the national accounting concept that cultivated plants are assets within the economy, they are considered as "produced within the economy and hence are not flows from the environment" (§3.47). It is important to note however that *natural inputs* comprise the "precursors" (water, inputs from soil, inputs from air) of the *cultivated biological resources*, including of the residues we are interested in (SEEA-CF §3.45, table 3.2). The present discussion is therefore relevant – although only indirectly – for these *natural inputs*. According to this approach, indeed, the physical flow account records, among *natural inputs*, the elements – such as carbon, oxygen, nitrogen, other nutrients and water – entering the cultivated plants, since the nature-economy boundary is set at the trophic level of plants' metabolism (correspondingly, the elements exiting the plant are recorded as residuals flowing to the environment). However, only part of the total plants' biomass, in which the input elements are embodied, constitutes a *product*. The rest is immediately transformed, at the time of harvest or catch, in what the SEEA calls residuals, and precisely into *solid waste*.

▪ In the section dedicated to Economy-wide material flow accounts (Ew-MFA: SEEA-CF, section 3.6.6), instead, the so called "harvest approach" is taken, according to which the treatment is the same as for non-cultivated resources (§3.282). In this approach, the plants and their metabolism are left out of the economic system boundary, so that the flows accounted for as crossing the Ew-MFA environment-economy boundary are directly the quantities of cultivated biomass resulting from the cultivation process. These quantities are then distinguished into *used* and *unused*, according to whether they are subsequently embodied into products or not. Eurostat's 2001 methodological guide (§3.31) gives the following definitions:

o "Used refers to an input for use in any economy, i.e. whether a material acquires the status of a product".

o "Unused flows are materials that are extracted from the environment without the intention of using them, i.e. materials moved at the system boundary of economy-wide MFA on purpose and by means of technology but not for use".

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[1] The two approaches are reconciled within a common framework in the OECD manual on Material Flows and Resource Productivity (OECD, 2008, vol. 2). Within this framework the two different boundaries define a semi-natural system that extends from the trophic level of cultivated plants nutrition (outer boundary of the economy) to the point of harvest (inner boundary of the economy). An accounting scheme could be defined describing inputs and outputs of this semi-natural system. Its inputs would be exactly the ones defined by the first approach (the trophic level of the SEEA-CF); its outputs would comprise the crop residues we are dealing with here.

Unfortunately, these definitions do not seem to be clear enough as to easily accommodate all crop residues to either category, although the two should be jointly exhaustive with respect to crop residues. In fact, some crop residues are inputs for use in economic production processes (which would qualify them as "used") but do not acquire the status of a product (which would qualify them as not "used"). Think for instance of crop residues that are fed into digestors for biogas production, or into composting facilities for making compost, without their owners (who discard them as waste) receiving any payment or allowance in exchange (as is the general case). It is recognised that these residues are generated "without the intention of using them" (which would qualify them as "unused"), that the guidance for implementation provided by Eurostat (2013) – which provides tools for calculation of used residues – does not foresee these flows, and that the common practice of environmental accountants is to ignore them in their estimation of (used) Domestic extraction. All this notwithstanding, we will consider these flows as of materials that are used, because: a) these destinations are becoming more and more common for crop residues and economically important, at least for their users; b) if these residues are not accounted among the "used" materials, material goods would emerge at some point in the economic process (biogas, compost) and at the output side (air emissions, dissipative use of products) without any corresponding input (used domestic extraction or imports) being recorded, which would contradict the logic of Ew-MFA and the mathematical equilibrium of inputs and outputs in its Direct material flow balance account. As a corollary, only the residuals left on the soil or burnt in the open, or landfilled are unused in Ew-MFA sense.

Summarising, we have *unused crop residues* which are a subset of *residuals from crop residues*; these form the total of *crop residues* together with *products from crop residues* – which are of course made of *used materials* in the sense of Ew-MFA. The following scheme shows this, and in the bottom row the connection to the categories used in the presentation of data in chapter 5 of this paper.

<table>
<tr><td colspan="3">CROP RESIDUES</td></tr>
<tr><td>PRODUCTS FROM CROP RESIDUES</td><td colspan="2">RESIDUALS (SOLID WASTE) FROM CROP RESIDUES</td></tr>
<tr><td colspan="2">USED CROP RESIDUES</td><td>UNUSED CROP RESIDUES</td></tr>
<tr><td colspan="2">E.g. Burning for heat, composting use in husbandry, use for biogas production</td><td>E.g. Leaving on soil possibly after shredding, open-air disposal (including burning), disposal as waste outside the holding</td></tr>
</table>

The peculiar nature of *crop residues* is highlighted by considering that many *crop residues* may a-priori be *products* or *used residuals* or *unused residuals*, and what they actually are only depends on circumstances, i.e. on whether there is a market for them or not. E.g. straw is always a crop *residue*, but it is not always a *residual*, as it is often sold or used in the holding producing it: in this case it is a (by-) *product* with a positive economic value of its own. Use of straw as fodder or for animals' bedding is indeed very common and the value of this straw is accounted for in standard National accounts as included in the agricultural industry's output. But not all straw is gathered and marketed or used: if there are no animals, it is usually left on the soil or burnt, which makes it an *unused residual*. In other words, the concept of *crop residues* is a more "stable" one and this seems a good reason for using this more general concept in combination with the concepts of *residuals* and *unused* instead of either of the two alone, because it provides a more sound reference point for analysis, given that the materials contained in crop residues are always relevant from the environmental and/or economic point of view, whatever their fate.

In the general supply-use scheme of the SEEA-CF, the flows of *products from crop residues* are not distinct from those of all the other products, and only if a detailed waste supply and use account is compiled, the fate (being used or left unused) of the *residuals from crop residues* is visible. The Ew-MFA treatment helps in that it identifies the quantities of residues that are left *unused.* These have potential uses as input materials for other production processes or even as *products* of their own, and as such could provide indirect or direct sources of income for crop producers and of raw materials for the potential users.

The latter potential, which appears to be exploited more and more, is not necessarily a blessing for agricultural holdings, as short-term gains in income may from selling the residues could be offset by longer-run effects of taking the residues away from the soils where they were grown. if the crop residues are taken away, indeed, the nutritive substances embodied in them will not return to the soil where they were taken from. In the long run soil quality and eventually fertility may decline, resulting in lower productivity and/or higher costs for other inputs such as synthetic or organic fertilisers.

3. Data gathered through Istat's structural surveys on agricultural holdings

Information on biological resource residues is not gathered in a systematic way. Whilst it is relatively easy to calculate their quantities supplied by agriculture and forestry, on the basis of agronomic knowledge (much less so for fisheries), on the use side no systematic gathering of basic data is available. Some information is provided by waste statistics. This information, however, is neither complete as for its coverage of the phenomenon – residues not entering a waste collection scheme do not feature in them - nor always clearly referable to harvest or felling residues.

For these reasons, in the framework of a collaborative effort of agricultural statistics and environmental accounts, Istat collected data in two different occasions, by introducing some simple questions in two surveys, namely the Survey on Permanent Crops (Permanent Crops Survey – PCS – 2012) and the Survey on the Structure and Production of Agricultural Holdings (Farm Structure Survey – FSS – 2013). These surveys are limited to crop production systems (permanent and temporary respectively). Both are regulated by binding legal acts of the European Union (regulations 1166/2008 and 1337/2011), but the questions on crop and pruning residues were added as ad hoc information sources for enhancing economic accounts and environmental accounts as well as other possible uses such as greenhouse gas emissions estimation., aimed at knowing more especially about the management of biological resources residues by agricultural holdings. These questions concern residues from permanent crops (PCS) and cultivations on arable land (FSS), i.e. from all cultivated biological resources, excluding only felling of cultivated forests, which are out of scope of the two surveys. The questions were kept as simple as possible, reducing to a minimum the information requested, in order to ensure its reliability and to increase the response rate, in view of the secondary importance of the topic with respect to the general aims of the surveys and of the respondents' ability to provide data on non-core activities.

In particular, for permanent crops, two questions were introduced, one concerning the quantity of pruning residues produced, the other concerning the management of all residues produced, deriving from permanent crops. As for the first question, the quantity was requested by species, for the 12 most important species, but notably excluding wine grapes, nut trees and some other minor species. The second question was referred to all residues including – besides the pruning residues covered by the first question – leaves, removed trees, non-saleable fruits etc. With this question we asked for percentages on total residues' weight, by kind of management. For the major possible uses, the residues dealt with inside the holding were distinguished from those given to others in the first place. The former were detailed into: composted; ground and released on soil; used as fuel for heating purposes; disposed of in the open (including – as specified in the instructions – possibly illegal practices such as on-field burning – which is prohibited in Italy); used in husbandry. For the residues given to others, an attempt was made to ascertain from the producer whether to his knowledge they were destined to be composted, used for energy (heat) or landfilled. Finally "other" was included as a possible answer, for special cases such as e.g. the use of the timber as a raw material for artwork, industrial or construction uses, within or outside the holding.

As for cultivations on arable land, we concentrated on the management and only asked for the percentage distribution of the residues of two broad groups of crops – i.e. cereals and crops on other arable land – among four possible management ways: leaving the residues on the soil (whether burying them or not); reusing them within the holding for forage or bedding for animals or for any other use; selling; managing the residuals as waste (including possibly illegally burning them), whether within the holding or outside it. The first and last management ways correspond to the *unused* case, and the other two to the *used* case, with the "selling" surely points at *products* while "reuse inside the holding" includes the case of residues that are *products* – namely for cereals' production residues, which are given a value in Italian economic accounts for Agriculture – and that of *residuals* that are used but are not *products*, having no market value of their own – the case of residues from crops on other arable land.

In the PCS, 27,234 holdings were sampled. In the FSS, 44,550 of which only 28,141 having arable land (excluding land set aside, or with flowers and ornamental plants). The questions were quite successful, with response rates as high as 87% for the production of pruning residues, 86% for the management of residues from permanent crops, 95% as for residues from cereals, 78% as for residues from other arable land. In the PCS, 98.3% of the holdings who provided data on the production of pruning residues also answered to the question on the management of residues from permanent crops.

It is recognised that the overall accuracy of the permanent crop survey's results is negatively affected by the non-participation in this survey of a whole region (Tuscany). This region however is relevant, among the surveyed species, only for olives, and its contribution to pruning residues production was estimated only for this species, by expanding proportionally the results obtained on the respondents (Italy totals for other species may therefore be slightly underestimated). The same was done in order to estimate non-respondents' contributions also for the other questions. We will not dwell further on the process of going from survey data to final, complete estimates, as we followed standard control and correction procedures. An encouraging circumstance, however, is that corrections turned out to be necessary only in a quite low number of cases, e.g. concerning the order of magnitude of the reported pruning residues where it was evident that the respondents had used tons or kilograms instead of hundred kilograms as requested.

4. Estimates of the supply of agricultural residues in Italy

Estimates of agricultural residues have been made for Italy by Istat (2010 and 2011), Ispra (2010), and Paolantoni (2015).

Table 1 provides a summary of our results, showing the source for each of the figures provided. In order to ensure completeness, for those residues from permanent crops that are not covered by the question on residues generation in the PCS – namely residues from pruning of some tree species, from pruning of vineyards and from removal of whole plants – we complemented the estimates with the quantities calculated by Paolantoni (2015). These are in turn based on updating the information contained in Ispra (2010). Our estimates for temporary crops and main permanent crops are substantially in line with the figures provided by the other sources quoted above.

The residues supplied by the cultivation of temporary crops were calculated by applying agronomic coefficients to the produced quantities. These were in turn estimated in the case of dry pulses and other vegetables by the application of agronomic coefficients to the production data supplied by another Istat survey the "crop estimates survey" (CES). In all other cases, where the FSS survey provides accurate area data we calculated the production of residues by each holding by applying the same coefficients to that holding's production estimate, resulting from multiplying the average yield-per-area-unit provided by the CES with the area declared in the FSS by that holding for that specific crop (area data for pulses in the FSS may be overestimated from wrong allocation to it by respondents of fresh peas, beans etc, with a corresponding under estimation of the area devoted to other vegetables).

It is recognised that these supply estimates do not include residues from cultivation of ornamental plants and flowers, as well as from elements of the rural landscape, such as e.g. hedges, which may also be considered as "cultivated" in SNA's sense but do not yield products and are therefore not considered in agricultural statistics. These have so far not been considered in any material flows accounting exercise, not even for the products' part of them.

Table 1 - Supply of residues from the cultivation of crops and source of information, by crop, Italy 2012 or 2013(000 tons)

	Total Supply	Source of the estimate
TOTAL CROPS	**43,573**	
Temporary crops	**35,611**	
Cereals	*29,040*	*Istat's 2014 survey on the structure and production of agricultural holdings, with yields and some area data from crop estimates survey (2013 data)*
Wheat and barley	11,922	
Rye, corn	13,211	
Other	3,907	
Other temporary crops	*6,571*	
Dry pulses	189	
Tubers	1,211	
Industrial crops	1,829	
Other vegetables	3,342	
Permanent crops	**7,961**	
Pruning of main permanent crop species, excluding vineyards	*3,715*	*Istat's 2013 survey on main permanent crops (2012 data)*
Pruning of vineyards, almond, hazelnuts, plum trees	*2,417*	*Paolantoni (2015) (estimates based on agronomic coefficients)*
Removed plants	*1,829*	
main permanent crop species, excluding vineyards	999	
vineyards, almond, hazelnuts, plum trees	830	

5. The "use" side

Tables 2 provides a summary of results from the two surveys, having the same sources as shown in table 1. As for permanent crops other than pruning residues of main species, again we complemented the survey results by using the estimates made by Paolantoni (2015), who exploited information provided by ISPRA in order to separate the used from the unused part of the residues. As said in section 3, *used* corresponds to either "reused within the holding" or to "sold" (in the latter case we have a product for sure), while *unused* corresponds to "left on soil" or "wasted".

Table 2 - Use of residues from crops production, Italy 2012 or 2013, by crop and kind of use (000 tons and %)

	"USED"		"UNUSED"		TOTAL USE (=TOTAL SUPPLY)
	within the holding	outside the holding	Left on soil	Wasted	
TOTAL CROPS	12,233 (28%)		31,340 (72%)		43,573
Temporary crops	***10,116 (28%)***		***25,496 (72%)***		**35,612**
	4,554 (13%)	**5,562 (16%)**	**24,970 (70%)**	**526 (1%)**	
Cereals	*4,356 (15%)*	*5,195 (18%)*	*19,123 (66%)*	*366 (1%)*	*29,041*
Wheat and barley	1,842	3,101	6,704	275	11,922
Rye, corn	1,994	1,675	9,492	51	13,212
Other	520	419	2,927	40	3,907
Other temporary crops	*198 (3%)*	*366 (6%)*	*5,847 (89%)*	*160 (2%)*	*6,571*
Dry pulses	22	21	145	2	189
Potatoes	55	41	1,093	22	1,211
Industrial crops	47	72	1,699	11	1,829
Other fresh vegetables	75	232	2,910	125	3,342
Permanent crops	**2,117 (27%)**		**5,844 (73%)**		**7,961**
Pruning of main permanent species, excl, vineyards	*905*		*2,810*		*3,715*
Pruning of vineyards, almond, hazelnuts, plum trees	*121*		*2,296*		*2,417*
Removed plants	*1091*		*738*		*1,829*
Main permanent species, excl, vineyards	344		655		*999*
Pruning of vineyards, almond, hazelnuts, plum trees	747		83		*830*

Source: our elaborations on FFS, PCS, CES and Paolantoni (2015)

It can be observed that use is dominant for residues from removal of fruit-bearing trees and significant for straws and similar residues from cereals cultivation and for pruning residues of main permanent species (excluding vineyards), whilst residues from all other cultivations are mostly left on the soil.

Table 3 provides some additional detail from the permanent crop survey, showing how the 4.7 million tons of residues from main permanent species (pruning and removal plants) are distributed among the 9 different possible uses proposed in the question.

Table 3 - Management of residues from cultivation of main permanent crops, Italy 2012 (000 tons and %)

	Within the holding					Outside the holding			None of the others – used within the holding	Total
	Unused, left on soil	Unused, wasted	Used			Used		Unused, wasted		
	Shredding and leaving on soil	Open-air disposal, including burning	Burning for heat	Com-posting	Use in husbandry	For energy use	For composti ng	For disposal as waste		
Quantity in thousand tons	2.832	612,4	948,2	77,5	21,9	151,5	6,4	20,4	44	4.714,2
%	60,1%	13,0%	20,1%	1,6%	0,5%	3,2%	0,1%	0,4%	0,9%	100,0%

The allocation to the categories used in table 2 is quite straightforward. *Burning for heat*, *composting* and *use in husbandry* within the holding correspond to the first column in Table 2, *energy* use and *composting* outside the holding to the second, *left on soil* to the third and *open air disposal* within the holding and *disposal as waste* outside the holding to the fourth. The only uncertain category is *none of the others*, which however only weights 0.9% of the total in this residues category, and has been allocated to "used" in Table 2.

6. Conclusions

Gaining sound and detailed knowledge of the amounts of used and unused biomass residuals from agricultural production is of interest for research and policy use, especially for what concern the current distribution of these precious biomass flows between the various possible destinations. However, very little official statistics is available.

In order to overcome this information gap, as far as the supply side is concerned, official statistics need not embark on regularly surveying the quantities involved, since reliable estimates can be constructed by using agronomic information (ratios of ancillary biomass to crops). However, official statistics should provide some benchmark, allowing to validate existing estimates and add detail (geographical, and by kind of plant) to them.

As for the management side, in any implementation exercise it is necessary to come up with a figure for the share of used quantities (in Ew-MFA terms) over total quantities. This share is also something national accountants dealing with the agricultural sector need, in order to estimate the quantity whose value must be accounted for in agricultural production and value added. Potential users are also researchers in charge of estimation of air emission for official national communications, such as those due under the UNFCCC transparency framework and for CLRTAP. Our experience shows that the investigation of the phenomenon greatly benefits from being considered in structural surveys.

As for the way forward, the data collected could be connected to those on the destination of some agricultural residuals, present in administrative sources, e.g. on compost, biogas and biomass-based electrical energy production plants. The analysis could thus be extended to downstream steps in the use of this biomass, and possibly also transformed in terms of nutrient and pollutant elements cycles.

The System of Economic and Environmental Accounts for Agriculture, Forestry and Fisheries (SEEA AFF), promoted by FAO and UNSD, is a powerful tool for organising information on the environmental dimension of AFF activities, covering among others the data domains of crops, forest products, fisheries, energy, greenhouse gas emissions, fertilisers consumption, water use, soil and agricultural income. The supply and/or the use of biological resource residues are related to all of these aspects of the agri-environmental relation. SEEA AFF, however does not explicitly include crop residues in any of its accounts nor deals with it on the methodological level. Only the part of the residues that is used in the sense of Ew-MFA may in principle feature in the physical account for crops (in principle, because it is quite difficult that crop residues be among the main products – almost by definition). But in the future, it could play a role in promoting knowledge about these important material flows, though maintaining its focus on main crops, e.g. by including in future versions, as a possible application or extension, an account for the supply and use of ancillary biomass flows connected to main agricultural products.

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Improving intersectorial water use within the seea accounting framework

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ABSTRACT

This document describes the conceptual basis of two methodological approaches which can be used to fully represent the water use of the fishery sector within the SEEA accounting framework. A broader description of this analysis with reference to several water-related SEEA accounts is available as a FAO Fisheries and Aquaculture Technical Paper (FAO, 2016). The fishery sector uses water resources in two different ways. Fishing, vertical raceways cage and pen aquaculture have an *in-stream* water use as they use water on-site. They do not abstract and do not consume water but they are indissolubly dependent to the availability of surface waters as fish habitats. Pond aquaculture, recirculating aquaculture systems, horizontal raceways have an *off-stream* water use as water is initially abstracted from the natural environment to create a culture environment, which according to the aquaculture method used can require different amounts of water additions during the production cycle. The SEEA accounting framework has been mainly developed for monitoring *off-stream* water uses in terms or water volumes abstracted and consumed. The current limited capacity of the SEEA accounting framework to measure *in-stream* water use raises some concerns in the way to which the water requirements and needs of economic activities that have an in-stream water use can be represented in national water accounting. Several economic activities, including the fishery sector, have an *in-stream* water uses. Due to its nature i*n-stream* water uses tend to overlap to each other as well as to *off-stream* water uses. Therefore, in the SEEA water accounting it is important to further develop methodologies able to better account for *in-stream* water use and to compare *in-stream* and *off-stream* water uses. To advance in this direction two different approaches are suggested below.
A first approach is suggested to measure all kind of *in-stream* water use as water areas. Presently SEEA accounting framework measures in-stream water use as the water area clearly delimited for a specific use such as aquaculture cages and areas for conservation purpose (i.e. single purpose water use) while gathers together all *in-stream* water use that tend to overlap in space and time (i.e. multipurpose water use). A second approach is suggested to measure *in-stream* water use as water volumes. In particular, the amount of water needed by in-stream activities of the fishery sector can be measured as the high (flooding) environmental *water flow* required for the maintenance of aquatic ecosystems and reproduction of resident and migratory fish species. These two approaches are undertaken to be able to subsequently compare *in-stream* and *off-stream* water uses amongst different economic units. The SEEA accounting framework contains a matrix to account for origin and destination of water flows within the economy. The proposal is to expand the scope of this matrix to show interactions amongst *in-stream* and *off-stream* water uses. These interactions are assessed in terms of potential rivalry for water abstractions as well as overlapping use of surface waters in time and space.

Keywords: SEEA, water accounting, water use

PAPER

1. Introduction

Water use is a general, non-specific term that describes any action through which water provides a service (Kohli et al., 2010). Water use can be distinguished into off-stream and in-stream:

. *Off-stream water* use takes the water out of the water source, reducing the amount of available water left on-site;
. *In-stream water use on-site water use* does not remove water from its source or water is immediately returned with little or no alteration.
Some activities such as navigation, hydro-electric power generation[1], recreational activities on water, have an in-stream water use as they occur on-site. Other types of activities such as crop production, municipal water use and sanitation, industrial water use, have an off-site water uses, because they require to abstract water and use it in other locations.

. *Off-stream water use* is usually measured in terms of the water volumes abstracted and consumed and returned to the environment.
. *In stream water use* is usually measured in terms of the water area required for a given purpose. By definition in-stream water use has no water withdrawal, no water consumption and no water return;

The fishery sector is comprised of capture fisheries[2] and aquaculture activities[3] and is characterized by both in-stream and off-stream water use (Table 1)

Table 1 - In-stream and off-stream water use within the fishery sector

Characteristics	Fishery sector		
ACTIVITY	Capture fisheries	Aquaculture	
WATER USE	*in-stream*	*in-stream*	*off-stream*
METHOD	Any types of fishing	Cage (including on-bottom and off-bottom)	Pond
		Pen	Indoor tank
			Recirculating systems
		Vertical raceways	Horizontal raceways

Capture fisheries have an in-stream water use as fishing uses water on-site. Fishing does not abstract and do not consume water but is indissolubly dependent to the availability and access to surface waters as fish habitats. Fishing activities are also highly affected by the seasonal variation of inland waters. The contraction of inland waters is usually detrimental for fishing activities, while their enlargement due to the creation of seasonally flooded areas, caused by overflowing of river and lakes, is highly favorable. Seasonally flooded areas are rich in nutrients and are essential for reproduction of many fish species. For these reasons seasonally flooded areas often are fishing areas characterized by high fish catches. Aquaculture can have both *in-stream* and *off-stream* water use according to the aquaculture methods. Cages, pens are considered to have an *in-stream* water use, while pond and recirculating systems have an *off-stream* water use. For pond culture, water is abstracted to fill the pond, to maintain the water level and compensate evaporation and seepage losses, and to maintain suitable values of temperature and other water parameters. Water is used in the same way for indoor tanks but the amount of water needed to replace evaporation will be lower than for outdoor pond. Recirculating systems use indoor tanks in which water circulates into a closed loop so that water is (partially) reused after undergoing treatment. Thus, an initial water withdrawal is needed as well as limited water addition during the production cycle. In raceways, water is flown through artificial tanks. In horizontal raceways water flows in one end of the device and flow out at the other. In vertical raceways water flows in at the top and out at the bottom. Vertical raceways are usually built as flotation frames and therefore they are considered to have an *in-stream* water use. On the contrary horizontal raceways are considered to have an *off-stream* water use since they are constituted by artificial structures, where water is abstracted and diverted from natural surface waters to create a water flow that artificially mimic the river run-off for aquaculture purposes.

2. SEEA accounting framework and water-related accounts

The SEEA-Central framework (United Nations et al., 2014) has two main categories of water-related accounts related to (i) water areas and (ii) water volumes. The SEEA land cover account describes the landscape composition and specifically measure areas occupied by different water resources. The SEEA land use account describes how the landscape is affected by human intervention and management measuring how water areas are used for different purposes. The SEEA water asset account measures the water volumes of surface water, ground water and soil water yearly available in a country. The SEEA supply and use water account compares the water volume available as yearly national water supply to the water volumes requires to meet water demand by different economic units. The development and degree of implementation of these two categories of water-related accounts vary greatly. SEEA accounting framework has been mainly designed for monitoring water volumes.

This is mainly due to the fact that many policy objectives in water management such as improving water supply and sanitation services, developing a rationale for water allocation permits, managing water supply and demand amongst municipal, irrigation and industrial water users, increasing water treatment and reuse, mitigating the risk of flooding, monitoring climate variability require the accounting of available water volumes rather than water areas.

[1] The hydroelectric plant that uses the river rapids to produce electricity has an in-stream water use. However, if the hydroelectric plant requires a dam for the storage of large quantities of water to create the water drop suitable for power generation, water is retained and consumed through evaporation. In this case the hydroelectric plant has an off-stream water use. In the SEEA framework hydropower generation is generally considered as having an off-stream water uses and therefore quantity of abstracted water is explicitly accounted.

[2] Capture fisheries is defined as the extraction of living aquatic organisms from natural or artificial inland waters, but excluding those from aquaculture facilities (FAO, 2010).

[3] Aquaculture is defined as the farming of aquatic organisms involving intervention in the rearing process to enhance production and the individual or corporate ownership of the stock being cultivated (FAO,2010).

3. SEEA accounting framework and water use

Water accounting is a powerful tool for monitoring and evaluating the use of water resources. It provides a measure of the availability of water resources within a country's territory and also a measure of the pressures on these water resources by different economy activities and overlapping or conflicting uses among different water users. This information can then be used to improve resource management and inform decision making processes by identifying whether a country is using its water resources in an efficient, equitable and sustainable way. Accounting for water use requires to take into consideration both in-stream and off-stream water uses. In the SEEA framework the land use account, which measures water area can be used to describe in-stream water uses, while the supply and use, water which measures water volume can be used to describe off-stream water uses. The current limited capacity of the SEEA accounting framework to measure in-stream water use raises some concerns in the way to which the water requirements and needs of economic activities that have an in-stream water use can be represented in national water accounting. Therefore, there is the necessity to further develop methodologies able to better account for in-stream water use and to compare in-stream and off-stream water uses. To advance in this direction two different approaches are suggested below.

3.1 First approach: measuring in-stream water uses as water areas

A first approach is suggested to measure *in-stream* water uses as water area providing information for both *single-purpose* water use and *multi-purpose* water use. The SEEA classification of water use includes four main water categories: *waters used for aquaculture or holding facilities, waters used for maintenance and restoration of environmental functions, other uses of waters* and *waters not in use*. In principle, these four classes are applicable to inland waters, coastal waters and marine waters. The criterion applied to this classification is that areas of water are be considered 'used' only where they have been clearly zoned or delimited for a specific use. Therefore, the SEEA classification of water use distinguishes specific water use such as aquaculture facilities and areas for conservation purpose (i.e. single water use). In this respect other single water uses could be added as a separated classes such as for example *inland waters exclusively used for irrigation* and *inland waters exclusively used for cooling water to a nearby power plant or industrial facility*.

Despite the addition of other classes the bulk of different *in-stream* water use will remain aggregated into the broad class of other uses of water. All *in-stream* water uses take place in existing surface waters. Since *in-stream* water use do not abstract neither consume water often they often don't occur as single use but tend to overlap in space and time with other water use (i.e. multiple water use).

In order to account for multiple water uses a GIS-based approach is suggested. GIS organizes and analyzes information into overlapping layers and therefore is able to deal with multi-dimensionality of different water uses. In the case of the fishery sector, water areas used as fishing grounds could be represented as well as water areas important as reproductive sites or nursery of important fish target species. In the case of aquaculture water areas could directly identify cage and pen used for aquaculture facilities. In addition, other in-stream water uses such as navigation, tourism and recreation could be made spatially explicit so that an area of use is identified.

Using a GIS-based approach the map of surface water to analyze is divided into a grid. Each water use of a given economic unit constitutes a separate layer of information mapping the grid cells where that use take place.

Each water use records the continuity (e.g. yearly, seasonally, monthly, daily etc.) with which the grid cells are used.

Following such GIS-approach also the spatial and temporal overlap between in-stream and off-stream uses can be captured since water areas used for water withdrawal and water discharge can be also mapped.

Within the same surface water:

. *In stream water* are identified by one continuous area or several disjoint areas

. *Off-stream water use* are identified by points where water is abstracted and (eventually) returned, which often correspond only to one or few grid cells.

On the basis of a criterion of continuous use in time each grid cell can have a primary use of a given economic unit and one or few secondary uses of other economic units.

3.2 Second approach: measuring in-stream as water volumes

A second approach is suggested to measure in-stream water uses as water volumes. This approach is undertaken to be able to directly compare in-stream and off-stream uses.

The fishery sector has an *in-stream* water use, which occur on-site and doesn't consume water, however, this does not mean that the fishery sector don't need water. On the contrary fishing, cage and pen aquaculture are highly dependent on the availability and access to surface waters since they are fish habitats. For this reason the volume of water needed to enable the *in-stream* water uses of the fishery sector is the environmental water flows that support the fish life cycle.

The *environmental water flow* is defined by the quantity, quality and timing of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on them (The Brisbane Declaration, 2007).

There are several methods to estimate the environmental water flow; hydrology-based methods are the most simple to implement as they primarily use time-series of monthly or daily flow records (Thamer, 2003).

Within river hydrology different water flows enable different ecological processes (Postel and Ritcher, 2003).

. *Base environmental water flow* maintains suitable water temperatures, dissolved oxygen and water chemistry and consequently provide adequate habitat for aquatic organisms. A base water regime can enable fish to move to feeding and spawning areas within the surface water. On the contrary when the base flow decreases below the normal level to the drought level this can hamper fish reproduction as well as fish survival;

. *High (flooding) environmental water flow* enables fish not only to reproduce within to surface water but also trigger fish upstream migration of anadromous fish. The increased run-off causes the overflowing of rivers and lakes with consequent creation of seasonally flooded areas. Seasonally flooded areas are rich in nutrient, shallow and often are used by many fish species as spawning areas and nursery areas for fish juveniles.

In order to estimate environmental water flows (base flow and high flow) a GIS-based approach is suggested. The recommended scale of analysis is the watershed defined at an appropriate spatial scale. The 'environmental water flow' or water regime required to support and maintain aquatic ecosystems differs is specific of each watershed. In fact watersheds differ for: climatic condition and seasonality, amount of precipitations, rate of evaporation or evapotranspiration, land cover, land use and management the water inflows received from neighboring countries and consequent water run-offs.

The volume of water needed to enable the *in-stream* water uses of the fishery sector is identified by the high (flooding) environmental water flow. Since the *in-stream* water use by definition has no water consumption, for accounting purposes, a volume of water equal to the high environmental water flow is 'virtually' abstracted by the fishery sector and the same amount is also returned to the environment.

3.3 A matrix of water-based interactions amongst economic units

The two described methodological approaches are undertaken to be able to subsequently compare in-stream and off-stream water uses amongst different economic units.

The SEEA accounting framework contains a matrix to account for origin and destination of water flows within the economy. In this matrix the economic units (industries by ISIC category, household and rest of the world) constitute both rows and columns. The economic units in the rows are considered as '*water suppliers*', those in columns as '*water users*' (United Nations, 2012; para.3.43).

The proposal is to expand the scope of this matrix to show relationships amongst *in-stream* and *off-stream* water uses. The structure of the account is the same of the original matrix in SEEA-Water with the only difference that some economic units can be further disaggregated to be able to account for the different water use of some sub-units. The *environment* is also added as a '*water supplier*' as many activities including pond aquaculture and recirculating aquaculture systems can abstract water directly from the environment without the intermediation of water supplier industry.

The proposal is to compile this matrix of water-based interactions amongst economic units (Table 2) in twin tables with two units of measurement which account respectively for:

2a. Exchange or competition of water flows between units –water volumes

2b. Overlap or competition in space and time between units – water areas

The compilation of the matrix in water volumes gives the possibility to compare *off-stream* uses with those *in-stream* uses which can be expressed in terms of water volumes. Each cell of the matrix records quantity of water originated from the economic unit in the row (origin) and distributed to the one in the column (*destination*). Consequently the matrix highlights the role of each economic unit as water supplier and/or as water user. Aquaculture can be a 'water supplier' since for example as a water supplier as can supply wastewater to sewerage activities but is also a 'water user' often abstracting water directly from the environment. Fishing is a water user of the environmental water flow that support fish life cycle and consequently allow the reproduction of fish stocks.

With the few adjustments made (i) inserting the environment as unit of origin and destination (ii) measuring the in-steam water use of fishing and cage as environmental water flow, this matrix can account both *in-stream* and *off-stream* water use of the fishery sector. It should be noted that the volume of water used by the fishery sector is 'virtual' since it is usually not secured by the fishery sector but in reality remains available for the potential use of all other sectors. Therefore a comparison between the environmental water flow and the major water volumes used by the economic units can reveal a vulnerability of the sector to water conflicts. In particular the matrix can highlight a large share of the existing environmental water flow used for growing non-perennial crops (ISIC 01-1) or the matrix can show a conflicting use in the water volume required for hydroelectric power generation (ISIC 35-1) and the environmental water flow which support upstream fish migration. Less obviously the water volume used by several industrial activity of agriculture (ISIC 01-03), manufacturing (ISIC 10-16) and the volume of water for household consumption can be compared with volumes of water that are collected and treated (ISIC 36 and 39) to gain an indication of the impact of economic activities on water quality.

Table 2 - Matrix of water-based interactions amongst economic units

ISIC description	ISIC category	01	01-111	02	03-1	03-2	10-16	35-1	36	37	39	50-1	50-2	55	56	ENV	HH	WLD
01 Crop and animal production, hunting and related service activities	01																	
01-111 Growing of rice	01-111																	
02 Forestry and logging	02																	
03-1 Fishing	03-1																	
03-2 Aquaculture	03-2																	
10-16 Manufacturing	10-16																	
35-1 Electric power generation, transmission and distributio	35-1																	
36 Water collection, treatment and supply	36																	
37 Sewarage	37																	
39 Remediation activities and other waste management se	39																	
50-1 Sea and coastal water transport	50-1																	
50-2 Inland water transport	50-2																	
55 Accommodation	55																	
56 Food and beverages service activities	56																	
Environment	ENV																	
Households	HH																	
Rest of the world	WLD																	

In few cases the water requirements of water transport (ISIC 50-1 and 50-2) can also be expressed as water volumes required (i) to maintain a depth of surface water suitable for navigation (ii) to operate waterway locks in inland waters for navigation. In these cases the water of volumes used for water transport can be directly compared with those of other economic units. The compilation of the matrix in water areas shows interactions amongst in-stream water uses and qualitatively can pinpoint also situations of overlap between in-stream and off-stream water use.

In the matrix the area of water reserved or delimited for single water uses can be recorded in the diagonal of the matrix, while any each other cell in the matrix records the area of water shared by two economic units. Therefore, the matrix can show the existing balance between the allocation of surface waters allocated to single water use and the area of surface waters freely accessible available for multiple uses. The matrix can be used to report the outcomes of a previous GIS-based analysis aimed at mapping multiple water use and provide a better understanding on the economic units involved their degree of overlap in space and time.

Each cell of the matrix can be used to record the area of surface waters shared by the economic unit in the row (*dominant user*) and another economic unit in the column (*secondary user*) in respect to their different intensity/continuity of their use in time In this way the overlap in space and time amongst different in-stream water users such as for example fishing (ISIC 03-1) and water transport (ISIC (ISIC 50-1 and 50-2), fishing and hydroelectric power generation (ISIC 35-1), fishing and bottom-cage aquaculture can be compared. Although *off-stream* water uses are described by the water abstracted, consumed and returned to the environment, both withdrawal and disposal of used water can occur in surface waters. Therefore a given area can be affected by both off-stream and in-stream water uses. This situation can also be accounted in the GIS analysis and reflected in the suggested matrix.

4. Conclusions

Accounting for interactions amongst *in-stream* and *off-stream* water uses requires water accounting at multiple-scale composed by three main hierarchical levels: the national scale, the watershed and surface waters within the watershed. Correspondingly the *Matrix of water-based interactions amongst economic units* can be compiled at the level of the single surface water, the watershed and the national level. The assessment of *in-stream* water uses is likely to require an analysis at the level of surface waters but an aggregation of the results at the watershed level and at the national level would be equally important. The watershed is a fundamental spatial scale for water accounting. All water resources within a watershed are interlinked in terms of both quantity and quality and the watershed is often the unit where decisions on water management are taken. The national-level is also fundamental since it is the scale targeted by the SEEA accounting framework. Therefore a GIS-based approach becomes a fundamental tool in SEEA for its analytical capacity of integrating information amongst multiple scales, of analyzing interacting biophysical and climatic factors as well as supporting the assessment of different water uses by different economic units.

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The System of Environmental-Economic Accounting for Agriculture, Forestry and Fisheries

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ABSTRACT

Economic activities depend on the environment and its resources and in turn also have an impact on it. The development of a System of Environmental-Economic Accounting Central Framework (SEEA CF) – a UN statistical standard (adopted in 2012 by the UNSC) – aims at organizing relevant statistical information within an integrated framework, coherent with the System of National Accounts (SNA 2008), to facilitate analysis of key processes and their evaluation. FAO and the UN Statistical Division (UNSD) have further developed a satellite application of the SEEA Central Framework (SEEA CF), the SEEA for Agriculture, Forestry and Fisheries (SEEA AFF). This paper aims to supply overview and updates of SEEA AFF.

Keywords: Environment, economy, accounting, agriculture, forestry, fisheries.

PAPER

1. Introduction

1.1 SEEA Agriculture Forestry and Fisheries (SEEA AFF) is a sub-system of the SEEA Central Framework (SEEA CF), the international statistical standard for environmental economic accounting, and is consistent with this framework. SEEA AFF aims to apply the SEEA CF to Agriculture, Forestry and Fisheries activities, pointing out linkages among and between these sectors, the environment and the economy and also highlighting the connections between underlying physical data in these areas and the conceptual framework of the SEEA.

1.2 The development of a System of Environmental Economic Accounting for Agriculture, Forestry and Fisheries was proposed by the FAO in 2010 and endorsed by the UNCEEA in June 2011. In 2013 FAO, in collaboration with UNSD and other relevant international partners, initiated the drafting of the SEEA AFF, including the description of new accounting tables, as an application of the SEEA-CF needed to cover agriculture, forestry and fisheries activities.

1.3 The feasibility of compiling the accounts and the relevance of the information was tested and further refined in four pilot countries: Australia, Canada, Guatemala and Indonesia. Based on the experiences gathered, a SEEA AFF revised draft was elaborated with contributions from FAO technical divisions, UNSD and relevant international partners.

1.4 The SEEA AFF was presented and discussed at a dedicated Expert Group Meeting at FAO (Rome, Oct 7-8 2014), with representatives from SEEA pilot countries, experts from UNSD, Eurostat, OECD, and FAO. The participants highlighted that initial activities in SEEA AFF pilot countries had generated productive cross-agency engagement towards improved national statistical systems.

1.5 The revised SEEA AFF was further presented to the 9th UNCEEA meeting (June 2014) and at the 20th London Group on Environmental Accounting meeting (October 2014).

1.6 Based on comments and suggestions gathered through the above processes, an updated SEEA AFF draft was submitted for the first Global Consultation in December 2014. Constructive feedback was received from more than 30 experts in National Statistical Offices other government agencies and international agencies on the scope, coverage and content of SEEA AFF.

1.7 A plan for further development of the SEEA AFF, including plans for country implementation, were presented at 10th UNCEEA Meeting (June 2015) and at 21st London Group on Environmental Accounting meeting, receiving broad support (November 2015).

1.8 The second and final Global Consultation process was carried out through December 2015 and January 2016. Constructive feedback was again received from more than 30 experts in National Statistical Offices and international agencies, showing broad endorsement of the content of the submitted SEEA AFF draft.

1.9 A revised SEEA AFF draft was then submitted for adoption to the UN Statistical Commission (UNSC) at its 47th session, in March 2016, under agenda item 3(e) Environmental Economic Accounting, accompanied by a technical document detailing specific changes made in response to the feedback from the second Global Consultation. During the discussions, in line with the tenor of the feedback from the Global Consultation, there was a broad welcoming of the SEEA AFF (EU, Samoa), with one country (Sweden) suggesting more testing in countries.

1.10 Since the UNSC meeting, FAO has continued discussion with experts in countries and in other international organizations in order to effectively incorporate all of the comments received through the consultation process. The additional findings have been incorporated in the SEEA AFF draft submitted to the UNCEEA 11th Meeting (June 2016). The UNCEEA agreed on endorsement of SEEA AFF as an "Internationally Agreed Methodological Document in support of the SEEA CF".

2. OVERVIEW AND UPDATE OF THE SEEA AFF

2.1 The SEEA AFF applies the environmental-economic structures and principles described in the SEEA Central Framework to the activities of agriculture, forestry and fisheries. The SEEA Central Framework was adopted in 2012 as an international statistical standard by the UNSC. It was jointly published in 2014 by the United Nations, the European Commission, FAO, the International Monetary Fund (IMF), the Organisation for Economic Co-operation and Development (OECD) and the World Bank (United Nations et al., 2014a).

2.2 The SEEA AFF also applies the conceptual framework of the System of National Accounts (SNA), the most recent edition being the 2008 SNA (EC, et al., 2009). The value-added of SEEA AFF lies not in terms of conceptual advances in accounting, but rather in the integration of information that is considered standard from either an SNA or SEEA perspective.

2.3 The data coverage of the SEEA AFF is broad including data in both monetary and biophysical terms. More in details SEEA AFF has ten data domains:

i. Agricultural products and related environmental assets

ii. Forestry products and related environmental assets

iii. Fisheries products and related environmental assets

iv. Water resources

v. Energy

vi. Air EmissionsFertilizers, nutrient flows and pesticides

vii. Land

viii. Soil resources

ix. Other economic data

Specific accounting tables are then associated to each domain.

2.4 Asset Accounts and Physical Flow Accounts (or Physical Supply and Use table) are the two main types of SEEA AFF base accounts.

2.5 Physical Flow Accounts are structured to record the total supply of products against their total; the required balance between these, i.e. total supply for each product must always equal total use of each product, is the accounting identity.

2.6 Environmental and Economic Asset Accounts instead record information on stocks of assets at the beginning and end of an accounting period, and changes in them during the accounting period.

2.7 Environmental and economic information are integrated into combined presentations that include monetary and physical information. They are not strictly accounts in that the information they contain does not need to be in the same measurement units, and not all entries in a physical flow or asset account need be translated into a combined presentation. The content of combined presentations may change over time to reflect changing analytical and policy priorities, but the structure of the base accounts will be relatively stable. The SEEA AFF describes five combined presentations

i. Activity-specific and product-specific inputs

ii. Food product consumption, losses and waste

iii. Sustainable use of environmental assets

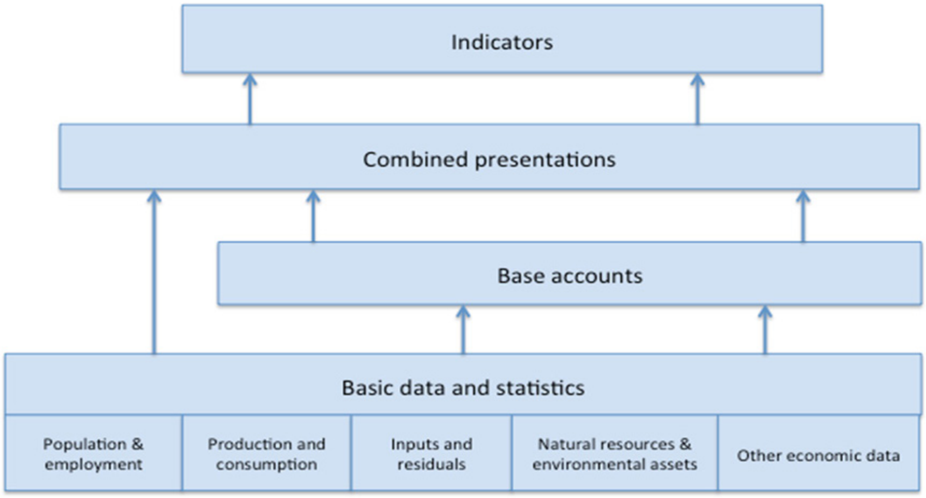
iv. Cross-industry and cross-activity perspectives

v. Reference Combined Presentation

2.8 Combined presentations are valuable mechanisms to focus on a particular theme or to have a synthetic overview of key selected economic and environmental variables (as in the Reference

Combined Presentation). Moreover combined presentations enable the extraction of variables relevant to the derivation of indicators.

Figure 1 - SEEA AFF information pyramid (Source: System of Environmental-Economic Accounting for Agriculture Forestry and Fisheries, White Cover version)



2.9 A critical concept of the SEEA AFF is the phased, tiered approach to implementation. It is recommended that users proceed in three successive phases, starting with the use of national-level default data, including from international organizations (tier 1); it is then foreseen a wider engagement of the country and data gaps estimation (tier 2); and a very complete and full implementation of the SEEA AFF accounts through the use of modelling and GIS information is expected at tier 3.

2.10 SEEA AFF has been already tested in Australia, Canada, Guatemala and Indonesia and additional countries volunteered after the June 2016 UNCEEA meeting (Australia, Canada, and The Netherland). Interaction with the country through a tiered approach is a key element of SEEA AFF methodology and capacity development activities. The capacity development module has been successfully applied during the Uganda Training on Environmental Economic Accounting and Greenhouse Gas Emissions (15 - 17 April 2016, Kampala, Uganda) and further capacity development activities are foreseen on December in Morocco.

2.11 As next step, Technical Notes will supply additional details on SEEA AFF accounting tables' compilation to facilitate SEEA AFF country implementation.

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THEMATIC SET

C20

COMPETITIVENESS INDICATORS OF AGRICULTURE AND OF THE AGRIBUSINESS SECTOR

Session Organizer
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ABSTRACT

This track focuses on competitiveness indicators and measurement at all levels of the agricultural value chain. The session aims at provoking scholarly debate about the basic mechanisms determining the recent trends in the competitiveness of the world agribusiness. A special focus on measurement issue characterizes the scope of the session.

Background

Competitiveness is an elusive concept that has been represented by abstract theoretical definitionsand by a number of diverse and partially inconsistent 'working', applied definitions. Thus, real world measuring of competitiveness in the agribusiness section remains a controversial issue and full consensus has not been achieved yet among scholars, managers and policy makers.

Applied studies in this topic face several challenges as the inherent complexity of the task leads researchers to difficult choices. A field of studies compromised on theoretical foundations in order to develop easy-to-implement indicators. Other approaches grounded on theory at the expenses of more complex methodologies and extensive data requirements. In both cases, there is a substantial demand for new research aiming at improving measurement quality and fostering the use of the indicators in policy and business decisions.

Such state of the art calls for new research in three main areas: i) definitions of competitiveness for the agribusiness sector, ii) innovative and feasible measures and indicators and iii) use of competitiveness measures for policy and business.

Track topic

The track has specific interests in the following themes:

1. Approaches to competitiveness measure of agriculture or agribusiness sectors, incorporating internal and external developments. Contributions in this track may cover topics related to the statistical definition of competitiveness, measuring competitiveness in a multifunctional framework, survey design for competitiveness studies, issues in the organization of competitiveness surveys in the agribusiness sector.

2. Indicators for measuring competitiveness. Examples of topics in this track may include: innovative measures of competitiveness, applications of existing methods to the agricultural and agribusiness sector, analytical framework,

3. Organization of data collection and statistical analysis. Papers in this track may consider: survey design methodologies, data issues, feasibility of statistical systems and other issues related to the organization of statistical systems.

4. The impact of the measured competitiveness. This track covers topics related to the use of competiveness measure for policy and business, dissemination of survey results, data-driven policies for competitiveness.

5. Cross space/time/industry empirical studies on competitiveness, comparing particular products, actors, chains, and/or countries. The contributed papers can address either conceptual or empirical work. Case studies and comparative analyses of best practices from less developed and developed countries are welcome.

LIST OF PAPERS

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Effect of quality assurance deficit on market competitiveness for export commodities and household income in Nigeria

K. Akanni | Department of Agricultural Economics College of Agricultural Sciences Olabisi Onabanjo University,Ago-Iwoye | Ogun State | Nigeria

DOI: 10.1481/icasVII.2016.c20

The "sophistication indices" for the international agri-food trade analysis: the view point of imports

A. Carbone | University of Tuscia | Viterbo | Italy

R. Henke | CREA - Council for Agricultural Research and Economics | Rome | Italy

DOI: 10.1481/icasVII.2016.c20b

Measuring the Competitiveness of EU Wine Business Sector: A Composite Index Approach

M. Greco | Italian National Institute of Statistics (Istat) | Rome | Italy

M. Mazziotta | Italian National Institute of Statistics (Istat) | Rome | Italy

A. Pareto | Italian National Institute of Statistics (Istat) | Rome | Italy

DOI: 10.1481/icasVII.2016.c20c

FAO's new macro-economic statistics: Agricultural Capital Stock and Agro-Industry Measurement

M. Vander Donckt | FAO, ESS Division | Rome | Italy

S. Dubey | FAO, ESS Division | Rome | Italy

DOI: 10.1481/icasVII.2016.c20d

C20

Effect of quality assurance deficit on market competitiveness for export commodities and household income in Nigeria

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DOI: 10.1481/icasVII.2016.c20

ABSTRACT

The Nigerian's agricultural sub-sector contributes about 37 percent of her Gross Domestic Product (GDP) and employs about 65 per cent of the adult labour force. It is thus the major source of food and fibre for the nation. It also provides basic raw materials for the agro-industrial sector and contributes about 88 percent of the nation's foreign exchange. Some of the major agricultural export commodities are cotton, maize, groundnut, hides and skin, beniseed (sesame),cocoa, palm produce, rubber and timber, among others. Nigeria's major trading partners include the United States of America, United Kingdom, India, South Africa, Germany and Spain. However, there are increasing concerns about the quality and level of safety of many of these export commodities. Many of them were recently considered as sub-standard and unsafe for both human and animal consumption, particularly in the European markets due to the level of unauthorized pesticides and were therefore rejected. This is a major challenge to the level of market competitiveness for these commodities in the international markets. It also has an over-bearing effect on household income of the farming households and many Nigerians. This study therefore examined the effect of quality assurance deficit on market competitiveness and household income levels. Trends in Nigeria's agricultural export trade between 1980 and 2014 were examined and emphasis was placed on cowpea,dried maize, melon seeds and palm oil. Both primary and secondary sources of data were used. Primary data were obtained with the aid of structured questionnaire and personal interviews with some randomly selected private exporters of agricultural commodities and officials of relevant government agencies in agricultural sub-sector. Secondary data were again obtained from the records/ publications of the Ministry of Agriculture, Nigeria Export Promotion Council (NEPC), National Bureau of Statistics (NBS),Central Bank of Nigeria (CBN) and others.

Descriptive and qualitative statistical methods were used to analyze the data. Descriptive statistics included the use of mean, median, mode, graphical illustrations and other measures of central tendencies. Quantitative statistics included the use of econometric models such as demand and supply elasticity measures. Results indicated that there was an increase in the general price level of the commodities at the international market over time. The aggregate market demand for each of them dropped sharply in the last one decade even when the market price per unit increased steadily (Price inelastic).This negatively affected the households' average income level as returns on sales of export commodities declined. Huge quantities of the commodities were then forced to be sold at the local markets at cheaper prices. This development negatively affects the consumptions patterns of the exporters as they now have reduced disposable income. Appropriate agencies of government need to be awake to their responsibilities of assessing and certifying the quality of the Nigerian agricultural commodities before exporting them abroad. This will help to further boost the level of consumer confidence in these export commodities especially at the international markets.

Ultimately, the level of aggregate demand for the export products and the household income levels of many Nigerians will increase.

Keywords: Agricultural Export Commodities, Market Competitiveness, Quality Assurance

PAPER

1. Introduction

Nigeria's agricultural sub-sector is the largest contributor (88%) to the non-oil foreign exchange earnings. Development in the sub-sector is therefore capable of bringing about a broad-based economic growth that is characterized by increased per capita income, reduction in poverty and expansion of employment opportunities. Some of the major agricultural export commodities are cotton,maize, groundnut, hides and skin, beniseed,cocoa,palm produce,rubber and timber, among others(Olukosi and Isitor,1990;NBS,2002;NBS,2009). To compliment local supply, Nigeria imports poultry products (such as chicken and turkey) and processed foods mostly from European countries.

Other food imports include canned beef and frozen fish (such as tilapia, mackerel, bonga and stock fish), wheat and fruits and canned juice among others. Huge quantities of these commodities however find their ways into the Nigerian markets through illegal (unofficial) channels. Hence they are often regarded as part of Nigeria's unorthodox trading activities since they do not enter the official transactions of the government. International trading is necessary in order to balance the trade position with Nigeria's trading partners. However, there are increasing concerns on the level of safety of these export and import commodities. For example, just recently, the Nigerian government started enforcing the ban on imported poultry products and frozen fish before they find their ways into the domestic market. This decision was premised on the claims by the Nigeria's Ministry of Agriculture that a large proportion of these imported commodities harbor harmful parasites,bacteria,viruses,chemicals or radioactive substances. In a similar vein, the European Union recently suspended some agricultural food exports from Nigeria. These food items include beans (cowpeas), sesame seeds, melon seeds, dried fish and meat, peanut chips and palm oil. Reasons for the suspension are hinged on the allegations that the items constitute danger to human health because they contain a high level of unauthorized pesticide. For instance, the European Food Safety Authority observed that the beans from Nigeria contain between 0.03mg per kilogramme to 4.6 mg per kilogramme of *dichlorovos* pesticides when the acceptable maximum residue limit is 0.01mg/kg.

Again, in 2013, about 24 of the Nigerian agricultural export commodities were rejected from the United Kingdom and the number increased to 42 food products in 2014.Some of these items were said to have been contaminated by aflatoxins. This makes them unfit for human and animal consumption. The health risk that is associated with the consumption of the imported commodities is further heightened due to the relative market competitiveness and preference they enjoy among Nigerian consumers most of whom care less about the chemical composition and possible health implications (such as cancer, skin irritations, internal organs defect and migraine headaches).These imported food products are ironically cheaper than the locally produced food items; thus putting the latter into some market demand risks and uncertainties. This development has remained a source of worry and concern to the local producers of these food products hence they have often called on the Nigerian government to properly address the situation by reversing the ugly trends.

1.1:Objectives of the study

The broad objective of this study is to examine the level of market competitiveness for selected agricultural commodities and farmers' household income. Specifically, the study;

a) Investigated the level of market competitiveness and consumer preference for selected internationally traded food products in Nigeria.

b) Established the existing relationship between the level of quality assurance deficit of export commodities, market competitiveness and farmers' income.

2.0: Literature Review and Theoretical Framework

Before the discovery of crude oil in commercial quantities in Nigeria, the agricultural subsector was the chief foreign exchange earner constituting between 65 -70 per cent of the Gross Domestic Product (GDP) (Olayemi,1980 and Adeyokunnu,1980;CBN,2006).Some of the major agricultural export commodities include cowpeas, sesame seeds, melon seeds, dried meat and fish, peanut chips,palm produce (kernel and oil),kolanut,cashew nuts and foodgrains (such as millet, maize and sorghum),among others (Olukosi and Isitor,1990;Adekanye,1988;Helleiner,1988;CBN,2006 and NBS,2009).According to Adeyokunnu (1980) and Olatunbosun and Olayide (1980), the marketing of agricultural export crops and the marketing board system dominated the business space in the early period of the nation's post- independence in 1960. The basic intention of the government then was to stabilize producer prices, conduct market research and development and to accumulate the trading surpluses. Between 1955 and 1951,the marketing boards accumulated reserves totalling N43.6 million (Helleiner,1988) and they operated successfully in the Nigeria's agricultural crop marketing space until 1986 when they were proscribed by the Federal government for alleged professional inefficiency and mistrust.

Today, the marketing and distribution of the bulk of agricultural products are in the hands of private individuals and co-operative societies (Adekanye,1988).Again, some acts of corruption bordering on adulteration, distortion of measuring apparatus and poor product qualities now characterize the marketing of agricultural export commodities.Perhaps,the most disturbing implication of this scenario is the recent ban of 42 Nigeria's agricultural food products from the European Union (EU) markets for alleged non-compliance with the minimum quality standards. Some of the affected food products were said to have been contaminated by *aflatoxins*, making them unfit for human and livestock consumption. This development has grossly affected the level of competitiveness of the Nigeria's agricultural export products, particularly at the international markets (NEPC,2015). It has again negatively affected the household income levels of the farming households in the past months (CBN,2015). It therefore becomes imperative for all exporters of agricultural products in Nigeria to adhere to the global standards (international best practices) in food product exports, especially on quality assurance.

3.0: Research Methodology

3.1: Method of Data Collection

Both primary and secondary data were used for this study. Primary data were obtained on the income levels of the exporters of four (4) purposively selected Nigeria's agricultural food exports (cowpeas, dried maize, palm oil and melon seeds).These commodities were sampled for the study because of their strategic importance in the list of Nigeria's agricultural export food items. Samples of export food items were taken with the support and guidance of Nigeria Export Promotion Council (NEPC) and National Agency for Food, Drug Administration and Control (NAFDAC).Secondary data were also used to source data and information from the various publications of the Central Bank of Nigeria, National Bureau of Statistics, Federal Ministry of Agriculture, Nigeria Customs and Excise Department, Federal Ministry of Health, and other relevant bodies. These data consisted of information on the Nigeria's major agricultural export commodities since 1980 to 2014.Emphasis was placed on the export quantities, domestic price of the export commodities and the equivalent foreign price, the destination countries of export and challenges of international trading among other issues. Information was also sought on the types of preservations, preservative chemicals being used for the export agricultural commodities and dosage levels.

3.2: Method of Data Analysis

For objective 1, data were collected on the price regime of four (4) of the Nigeria's major agricultural export products (cowpea, melon seed, dried maize, and palm oil) at the international markets. Then, average market prices were obtained for these food products (in the UK markets) and the equivalent amounts of similar commodities at the local markets in Nigeria and these prices are compared to appreciate the level of parity (or otherwise).The closer these prices, when compared, the more competitive they are. Own-price elasticity was also computed to again observe the degree of responsiveness of the export quantities to declining market prices at the international market in the UK. Thus, according to Frank and Bernanke (2004), own-price elasticity,

$$\mathcal{E}_{op} = \frac{\delta Q/Q}{\delta P/P} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$= P/Q * 1/Slope \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where,

$\mathcal{E}_{op}$ = Own-price elasticity of the export commodities.

Q=Quantity of Nigeria's export at a given time ('000 tonne)

δQ=Change in quantity of Nigeria's export at a given time ('000 tonne)

P=International Market Price (own) of Nigeria's export commodity at a given time (£)

δP=Change in International Market Price (own) of Nigeria's export commodity at a given time (£)

Thus,own-price elasticity was computed for all the four (4) selected agricultural commodities to ascertain the level of reaction of the international market to changing price situations.

For objective 2, a multiple regression model was used to establish the relationship that existed among the level of quality assurance deficit of the export commodities, market competitiveness and farmers' income,among others.

Thus, $Y_N = \alpha_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + e_i$ ……………… (3)

Where, Y_N is the annual farm income of the exporter,

X_1 =Level of quality assurance deficit (mg/kg).Quality assurance deficit was captured by the difference between the estimated quantities of pesticide residues found in samples of selected food items which were prepared for export to international market (in UK) and the acceptable maximum residue limit of 0.01 mg/kg.These samples were collected with the assistance of Nigeria Export Promotion Council (NEPC), Lagos, Nigeria.

X_2 = Level of market competitiveness for selected Nigeria's internationally- traded agricultural export commodities (i.e. cowpea, melon seed, dried maize and palm oil) (in £). Basically, market price competitiveness measures the level of equality/ parity (or otherwise) between international (UK) market prices of the Nigeria's agricultural export food items and the prices of similar items in the Nigerian market.

X_3 = Tax paid on Export commodity (Naira)

X_4 = Annual Output of Export Commodity (tonnes)

X_5 =Government Policy on Export Commodity (Dummy: If favourable to export=1,if otherwise=0)

e_i=Stochastic error term, which is random in behaviour.

N=Number of agricultural commodity exporters which is equal to 200

This model was used to run the analysis separately for each of the four (4) selected agricultural export commodities listed above.

4.0: Results and Discussion

4.1:Market Behaviour and Volatile Prices of Nigeria's Internationally -traded commodities

International market for Nigeria's export commodities continue to vary in reaction to changing market prices and consumer preferences which is often reflected by the direction of consumer demand for the commodities. From Table 1 below, it is indicated that own –price elasticity values drastically declined for all the export commodities between 2004-2014 (compared with the previous years) because the demand for the selected Nigerian agricultural exports dropped at the international (UK) market. This development was largely due to the rejection of many of the nation's agricultural export commodities by the UK market as a result of allegation of noncompliance with the regulations on standards and international best practices on food storage/preservation techniques, especially in the past one decade.

Table 1 - Determination of Own-Price Elasticity for Nigeria's Export Commodities

Export Commodity	Year/Own-Price Elasticity (%)		
	1980-1992	1993-2003	2004-2014
Cowpea	124.6	66.4	34.6
Dried Maize	118.3	58.3	43.1
Melon Seed	106.4	67.6	22.4
Palm Oil	122.6	45.7	18.3

Source:Nigeria Export Promotion Council,(NEPC),Lagos, Nigeria.

4.2: Nigeria's Agricultural Export Trade

Between 1980 and 2014, there was a mere marginal increase in the quantities of agricultural export commodities that were produced domestically in Nigeria (Table 2).The least yearly increase was observed in the case of palm oil while maize recorded the highest. The use of traditional farming technologies, poor storage/preservation techniques, low-yielding production technology and largely aged farming population were responsible for the generally low output levels of the major export commodities in Nigeria. On the whole, only about 35 per cent of the official production output was exported abroad (Table 2).These development had negative implications on the general income level of the farming households.

Table 2 - Profile of selected Nigeria's agricultural export commodities (1980-2014)

Export Commodity	Year /Average Yearly Production level in metric tonne			Year/Average Annual Export Quantity[1] (metric tonne)		
	1980-1992	1993-2003	2004-2014	1980-1992	1993-2003	2004-2014
Cowpea	3669.6	4210.7	4328.3	1284.36	1473.75	1514.91
Dried Maize	8527.9	8685.1	9503.4	2984.77	3039.79	3326.19
Melon Seed	421.1	450.1	479.4	147.39	157.54	167.79
Palm Oil	161.5	172.7	187.0	56.53	60.45	65.45

Source:National Bureau of Statistics,NBS,Lagos,Nigeria,2015.

[1]Only about 35 per cent of the official yearly output was exported.

The level of market acceptability and consumer preference for good is often measured by the price consumers are willing to pay for such commodities, particularly at the international market level here the Nigerian export commodities are in strong market competition with other commodities from other sources. Thus, the average domestic market price (per tonne) was estimated and then compared with the international (UK) prices of the selected export commodities, using the average foreign exchange rate of the Nigerian local currency,(Naira) to the US Dollar (Table 3). Between year 2000 and 2008,it was shown that the domestic prices of the export commodities were highly competitive as their local prices were very close and sometimes higher than international prices.However,the reverse was the case between year 2009 and 2014,as the domestic prices of the Nigerian export commodities declined and the demand for them dropped hence they could not favourably compete with their international market prices (Table 3).A huge quantities of the export commodities were again rejected at the international market largely due to alleged compromised qualities. The US Dollars equivalent values of these commodities were higher than the international prices. This again indicated that there was no parity price2 especially for cowpea, dried maize,and palm oil in the last one decade.Thus,many exporter farmers were discouraged from exporting their commodities and were therefore left with option of patronizing the Nigerian local markets. This led to a decline in the sale of farm produce and a reduction in the general household level of many Nigerian farmers.

Table 3 - Market Price Competitiveness of selected Nigeria's agricultural export commodities

Export Commodity	Year /Average Domestic Market Price per metric tonne (Naira)			Year /Average International Price per metric tonne (Dollars)		
	2000-2003	2004-2008	2009-2014	2000-2003	2004-2008	2009-2014
Cowpea	49,370.0 ($509.81)	56,045.0 ($449.62)	62,717.2 ($403.53)	97.6	101.3	615.85
Dried Maize	28,054.2 ($289.69)	36,782.3 ($295.08)	47,921.0 ($308.33)	42.8	65.9	342.37
Melon Seed	22,134.0 ($228.56)	29,006.0 ($252.69)	34,974.7 ($225.03)	22.3	34.9	118.7
Palm Oil	88,300 ($911.81)	110,151.1 ($883.68)	133,003.6 ($855.77)	121.4	147.5	920.89
Mean Exch.rate of Naira/US$	96.84	124.65	155.42			

Source:National Bureau of Statistics,NBS,Lagos,Nigeria,2015

Note: All values in parentheses were the domestic market prices of the selected Nigeria's agricultural commodities in US Dollars.

[2]Parity price provides the farm products the same purchasing power per unit for goods and services used in both production and family consumption relative to prices that prevailed in the base year. It often reflects the concern of government about the purchasing power of the farmers. It a popular parameter by which many developed economies show concern about the purchasing power of their farmers.

4.3: Farmer's income, market competitiveness and level of quality assurance deficit of Nigeria's export commodities

The level of market competitiveness and quality assurance of the farm output often determine the amount of income farmers realise at the end of the farming season. This is so because the farmers have to present their farm products at the international market where these products compete with other commodities from various sources. Hence, the need to observe and comply with the international best practices on standards and grading of these agricultural commodities, especially with respect to the use of chemical as preservatives. These farmers therefore need to mind the types, quantities and methods of preservatives being used for their farm products so that the quality of these products is assured in the market; since this has a serious implication on market prices. The most common types of chemicals being used for the preservation of farm products include Gamma BHC/lindane,Malathion,Iodafenphos (such as Nuvanol and Elocril),Dichlorvos and synthetic pyrethroid (e.g. permethrin),among others.

For all the four (4) agricultural export commodities, the estimated values of parameter co-efficient estimates (Table 4) indicated that the level of market competitiveness and quality assurance deficit were significant determinants of the annual farm income of the exporters of the agricultural commodities. Specifically,for cowpea, melon seed and palm oil the two parameters were significant at 1 per cent level .In the case of dried maize, quality assurance deficit was found to be a significant parameter at 1 per cent while market competitiveness was significant at 5 per cent level.In addition,tax paid on export commodity, annual output level and government policy on exports were also found to be significant at various levels.However,tax payment and government policy were not significant in the case of dried maize and cowpea respectively. High values of adjusted R2 ,which varied between 0.67 (for melon seed) and 0.92 (for palm oil) indicated the correctness and exactness of the specification of the regression model as stated in equation (3). High values for Log likelihood function, which ranged between 233.04 (for cowpea) and 771.53 (for melon seed) again corroborated the feeling that the regression model had a reasonably acceptable level of reliability.

Table 4 - Multiple Regression Analysis indicating relationship between Farmer's income and determinant variables

	COWPEA		MELON SEED		DRIED MAIZE		PALM OIL	
Variable	Parameter Co-efficient	T-value	Parameter Co-efficient	T-value	Parameter Co-efficient	T-value	Parameter Co-efficient	T-value
Constant term	237.92*** (73.89)	3.22	45.54*** (7.18)	6.34	18.46*** (0.78)	23.73	26.56 (21.25)	1.25
Quality Assurance Deficit (X_1)	15.36*** (1.80)	8.54	22.45*** (8.47)	2.65	82.21*** (30.11)	2.73	34.54*** (2.43)	14.23
Market Competitiveness (X_2)	243.32*** (46.52)	5.23	24.31*** (4.29)	5.67	36.45** (19.81)	1.84	835.31*** (69.44)	12.03
Tax on Export Commodity (X_3)	145.9** (86.83)	1.67	331.95*** (80.57)	4.12	54.2 (49.72)	1.09	134.10*** (43.12)	3.11
Annual Output level (X_4)	43.8*** (11.01)	3.98	121.9*** (49.76)	2.45	51.9*** (17.96)	2.89	212.6*** (40.34)	5.27
Govt. Policy (X_5)	88.3 (70.64)	1.25	332.80*** (69.62)	4.78	72.9*** (10.53)	6.92	227.5*** (78.18)	2.91
Chi square	65.52		71.39		49.32		85.03	
Adjusted R^2	0.74		0.67		0.78		0.92	
Log likelihood function	233.04		771.53		439.20		628.91	

Dependence variable= Annual farm income of the exporter

***=Significant at 1 % level **=Significant at 5 % level

5.0 Conclusion

This study has investigated the effect of quality assurance deficit and market competitiveness on the household income of the Nigerian agricultural commodity exporters. Many of the export commodities now fail the quality assurance test hence they cannot sustain their competition in the international markets which also display many quality products. The immediate implication of this development is that many of the Nigeria's export commodities were restricted from the UK markets. This has caused a huge decline to the annual income level of the Nigerian farm producers who often export their products. But all hopes are not lost, especially if these farmers are able to observe and comply with the global best practices on the use of chemical preservatives for their exported farm products. This will reduce the level of chemical residues which are considered injurious to the health of the consumers of these food items. The local (traditional) methods of product storage and preservation which do not involve the use of chemical substances could be adopted by the farmers as alternative ways of protecting the qualities of farm produce. With this, the Nigerian agricultural export commodities will again be accepted and remain competitive at the international markets. This will bring a higher income to the Nigerian agricultural commodity exporters and ultimately improve the general income levels of the farming households in Nigeria.

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C20

The "sophistication indices" for the international agri-food trade analysis: the view point of imports

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ABSTRACT

In this paper we look at a family of indicators originated around the concept of "sophistication" of traded goods. Usually the sophistication indices focus on export flows and are based on the relationship between the level of per capita GDP and the complexity of exports in terms of technological content, branding and packaging, quality features and so on. We use the same concept to explore import flows of agri-food products, assuming there is a relationship among the level of per-capita GDP of an importing country and the level of sophistication of its agri-food imports. We build and analyse two indices, one looking at the level of sophistication of imported goods (Consy) and one looking at the aggregated level of sophistication of an importing Country (Impy). The indices give a synthetic measure of the sophistication of the final market or, in other words, the kind of demand and competition that the product is going to face in the destination markets. With regards to this, the ranking produced by the two indices are relevant and consistent with the main world trade specialisation and the correlations with GDP confirm the assumption on which the indices are built.

Keywords: trade sophistication, agri-food export specialisation, agri-food import demand

PAPER

1. Introduction

The family of indices that move around the concept of "sophistication" is generally used in the trade literature to analysis the complexity of export flows and is based on the assumption that the higher the GDP of a country the more "complex" is its set of exports. The concept of sophistication includes the technological content, the branding and the packaging of the goods, the quality, and other features that add value to the products. These characteristics of the traded goods have increasingly importance in the international arena, becoming the ground for non-price competition, even in the food sector where, in order to meet a clear trend in the demand, producers and exporters have increasingly focused on product differentiation and quality attributes (Krugman, 1980; Helpmann, 1981; Schott, 2004; Fabrizio et al., 2007).

The sophistication of export flows is measured in the literature by two indices, respectively referred to the set of products exported and the countries exporting them (Lall et al., 2006; Hausmann et al. 2007).

The Prody index refers to a specific good and is given by the per-capita GDP (GDPpc) of all the countries exporting that good weighted by the specialisation of that country in the export of that product.

Similarly, the Expy index is referred to a single country and it is given by the sum of all the Prody indices of the goods exported by the country weighted by the share of the exports of any single good on the total exports of the country. This family of indices has been used for comprehensive studies analysing the entire set of exported items and a wide range of competing countries as well as for trade analysis of specific Countries and/or sectors (Rodrick, 2006: Minondo 2008; Di Maio and Tamagni, 2008). A stream of more recent literature has explored how the measure of export sophistication works when applied to the agri-food sector (Carbone and Henke, 2012; Carbone et al., 2015). In this case, especially for the primary basic goods, factors like climate, resources, conjunct productions, as well as policies, might influence significantly localisation and, hence, the export specialisation patterns. Nonetheless, different papers have shown that quality is a major export driver also in the agri-food sector, especially for processed food (Gehlhar and Pick, 2002; Fischer, 2010). In this paper we move from exports to imports, assuming there is a relationship among the level of per-capita income of an importing country and the level of sophistication of its agri-food imports. This approach is not entirely new, since other works have dealt with the shift from exports to imports[1].

1 See, for example, Marvasi (2013). In his paper, Marvasi builds an Impy index for China which is given by the Sum of the Prody indices of China exports weighted by the share of imports of China for each of the same products.

However, both the construction of specific indices and the analysis have been focused on the comparison of the level of sophistications of the export and import flows of a single country. In our work, we turn the attention to the construction of a new set of indices, defined as Consy and Impy, which are symmetrical to the Prody and the Expy. These indices look at the sophistication of the set of imports of a country, independently from its set of exports.

The Consy is defined as the sophistication index for imported goods: the higher is the role of high income countries in the imports of a good the more sophisticated will be the product. The income level of the destination markets for a product can be considered an indicator of the kind of competition that the product would likely meet.

In the same line of the measure of the export sophistication, the most interesting result is the ranking generated by the index and its time variation. In the same streamline of the Expy index, it is possible to build an Impy index, starting from Consy, that is given by the weighted values of the Consy vector of the whole set of imports of a country, where the weights are the shares of imports performed by the country per each product. We will discuss the following uses of the indices: 1) rank the sophistication of products as measured by the income level of importing Countries; 2) Compare the sophistication measures resulting from the Consy and that one measured by the Prody indices for agri-food items; 3) Show the overall sophistication of trading Countries considered as destination markets for agri-food products 5) compare between them the rankings of Countries obtained with Expy and Impy and among them and to the GDPpc.

The paper is organized as follows. Section 2 first presents and discusses the Consy and Prody indices and, second, shows the Expy and Impy indices. Results are presented in Section 3 while Section 4 concludes.

2. New indices of sophistication

In recent literature the use of the sophistication indices have been focusing especially on the export side, and in particular on the Prody index. More specifically, recent studies have associated this concept of sophistication to the level of prosperity of the exporting Countries, alias their level of GDPpc (Lall et al., 2006; Hausmann et al., 2007). The underlying idea is that, other things being equal, the more a country is specialised in producing and exporting high value products, the higher is the remuneration of inputs and, consequently, the higher the level of its GDP. The Prody index associated to each exported good is a synthetic indication of its level of sophistication and, at the same time, gives an idea of the type of countries exporting that good, so that it gives indirect information about the type of competition that the good in question has to deal with on the international markets (Lall et al., 2006). The core idea is that product sophistication is linked to the country productivity level and that it is important as an export driver. This is in line with Porter's view of the competitive advantages of locations and the strand of empirical literature that stemmed out from his seminal work (Porter, 1985; Ketels, 2006; Sterns and Spreen, 2010).

The sophistication of a given exported item is the result of the sum of the GDPpc of the countries exporting that item, each of them weighted with the trade specialisation of each country in that item. This measure is called Prody and, according to the version proposed by Lall et al. (2006) can be calculated as follows:

$$Prody = \Sigma_j s_{i,j} GDPpc_j$$

where $s_{i,j}$ is the weighting factor of the GDPpc of each country j exporting the i product and it is given by the share of product i on total exports:

$$X_{i,j}/X_i$$

where $X_{i,j}$ is the amount of the agri-food product i exported by the country j and X_i is the world agri-food export of product i.

it is worth noting that this index does not catch all the possible factors influencing the exporting performance of a good. Different localisation factors are at work, especially in the agri-food sector, where natural resources, transport costs and policy interventions, just to mentions some among the most relevant ones, are crucial in explaining the dynamics of export goods (Di Maio and Tamagni, 2008; Carbone et al., 2012). However, previous results showed that, especially for processed food exports, the relationship still stands and works quite well (Carbone and Henke, 2012; Carbone et al., 2015).

The main outcome of the application of the Prody index is a ranking of the products analysed according to their level of sophistication. Moreover, an interesting use of the Prody index and of the family of indices is their variation in time[2]. In this paper we look at the sophistication in a different perspective associating it also to imports rather than only exports.

This is based on the following considerations: i) looking at the destination markets, rather than the markets of origin, reduces significantly the influence of localization factors other than GDPpc; ii) destination markets are the actual competitive arena that products are going to meet, focusing on these seems valuable when the interest of the analysis is more on the competitive conditions relevant to the products rather than the growth effects of exports; iii) focusing on imports allows for narrowing the definition of the relevant markets and thus allows a more accurate analysis.

[2] Its variation in time, in fact, can be due to a change in the GDPpc of the countries exporting the good or as a consequence in the change of the export share, or, also for the change of the set of countries exporting it (new exporters entering in the competition game, or countries phasing out).

This approach can provide a complementary viewpoint to the one based on export analysis, thus bringing new insights and developments to the agri-food trade analysis. Economic literature provides wide theoretical rationale for a positive relationship between GDPpc and demand for diversification and quality (Gabszewicz, and Thisse, 1979; Kearney, 2010). Thus, the assumption the new sophistication indices would rely on (i.e. the sophistication level of demand/imports increase with the average GDPpc of the importing countries) seems based on solid grounds. The first index we consider here is the Consy. This is the sophistication index for imported good i, and it is defined as:

$$Consy_i = \Sigma_j GDPpc_j * c_{ij}$$

where GDPpc $_j$ is the per capita income of importing country j and c_{ij} is the share of total world imports of item i imported by country j:

$$M_{i,j}/M_i$$

where $M_{i,j}$ is the amount of the agri-food product i imported by the country j and M_i is the world agri-food import of product i.

The higher is the role of high income countries in the imports of a good the more sophisticated is the product. In other words, we posit that the income level of the destination markets for a product indicates the kind of competition that the product would likely meet. In the same line of the measure of the export sophistication, also in this case, the most interesting result is the ranking generated by the indices and their time trends.

This index works very well also in order to measure the sophistication level of a subgroup of importing countries. One could, in fact, compute a ConsyiA related to a group (A) of importing countries (lets' say the clients of an exporter under study). By confronting Consyi with ConsyiA it is possible to assess whether Country A (or Countries in group A) forms a more or less sophisticated market for product i with respect to the world markets. It is obviously also possible to do bilateral confrontations between the sophistication levels of destination markets of competing Countries.

In the same streamline of literature, the Prody index is often associated to the Expy index, which is referred to a single country. The Expy index for a country j is given by the sun of the Prody indices associated to the products exported by that country:

$$Expy_j = \Sigma x_i/X_j * Prody_i$$

This index provides a ranking of the countries analysed according to their ability to export "sophisticated" products. As in the case of the Prody index, also for the Expy it is interesting to see the variations in time of the country ranking, which can be due to the different components of the Expy.

As in the case of the Prody and Expy, starting from Consy it is possible to build a symmetric index (Impy) that is given by the weighted values of the Consy vector of the whole set of imports of a Country, where the weights are the shares of imports performed by the country per each product.

$$Impy_j = \Sigma M_{ij}/Mt_j * Consy_i$$

Where M_{ij}/M_{tj}, is the share of the import of the country j of the good i and M is the total import of the country j.

The Impy indices measure the overall level of sophistication of the imports of a given country, thus giving an idea of the kind of market an exporter may find in that country. Obviously, here also it is possible to build sectoral versions of the index that enable to make comparisons.

First empirical results on the rankings associated with indices as well as on the comparison with the results obtained with the export sophistication indices provide scope for discussion on their advantages and further understandings that may stem from the use of such a methodology.

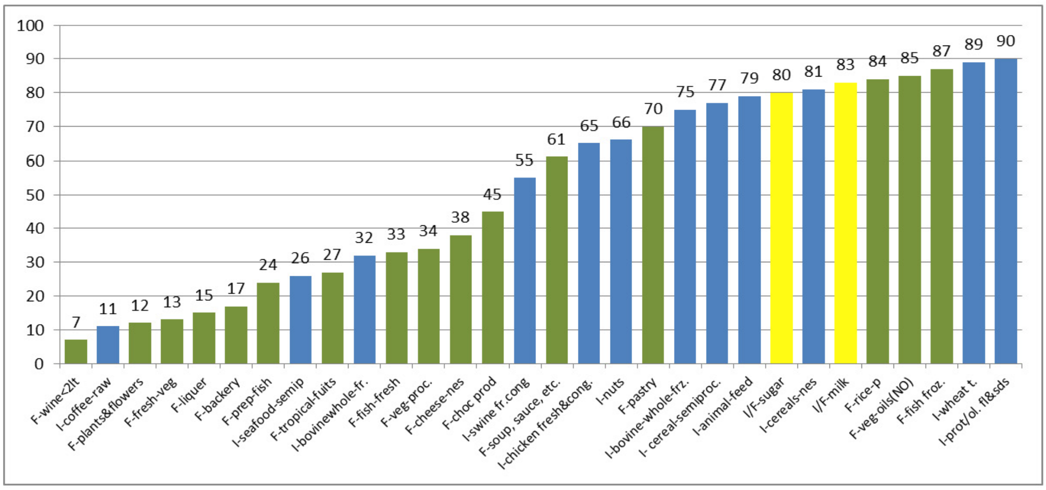
3. Preliminary results of the import sophistication indices

This Section presents and discusses some preliminary results obtained by the application of the indices of import sophistication to agri-food trade data[3]. Throughout the section, for clarity purposes, the comments are restricted to the thirty major items in terms of their shares in world trade, these are labelled in all figures; however, the analysis includes 92 items that represent the whole range of agri-food items. Figure 1 shows the import sophistication ranking of the selected items as measured by the Consy index. The prefix *F* denotes goods that are mainly for final consumption in the destination Country while prefix I stands for goods that are mainly used as inputs; a few items are labelled as *F*-I due to their double nature of intermediate and final goods. This specification is quite useful when comparing the values of the Consy and in particular its ranking. The top positions in the ranking include mainly goods for final consumption. These are complex processed goods, highly differentiated and with a high value added such as prepared fishes, wines (in bottles smaller than 2 litres), spirits and liqueurs, bakery products, processed veggies, cheeses, chocolate products, soups/condiments/sauces/etc. and so forth.

[3] The dataset includes 92 agri-food items aggregated starting from 700 Comtrade HS 1996 at 6-digit level and exchanged among 130 Countries that represent around 90% of all world trade exchanges.

Besides, also some fresh produces are ranked high according to the Consy values; again, these are differentiated and high value perishable products that require complex logistics functions and high transport costs like fresh veggies, tropical fruits, fresh fishes and plant and flowers. At the opposite end, the bottom of the ranking features mainly semi-processed goods, raw materials or commodities for final consumption. These are far more simple goods, non-significantly differentiated and for which competition is mainly performed at the price level. Among these there are wheat and other cereals, flours of cereals, flours/seeds of industrial plants, frozen swine, frozen bovines and frozen poultry, processed rice and vegetable oils (excl. olive oil).

Figure 1 - The sophistication level (ranking) of selected agri-food import items

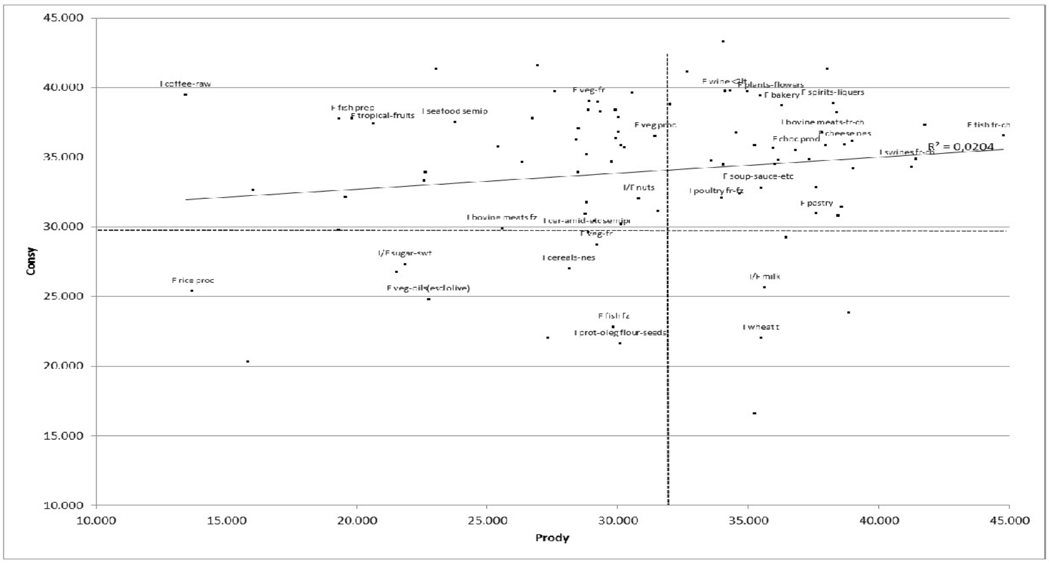


Note: (green bars: products for final consumption; blue bars: intermediate goods; yellow bars: double destination)

The values of the sophistication indices measured on the export and on the import side are compared in figure 2. As expected these two sets of values are not significantly correlated as factors influencing the localization of exports of a good and those affecting the geographical pattern of imports of the same good are different and widely unrelated(R2=0.025).

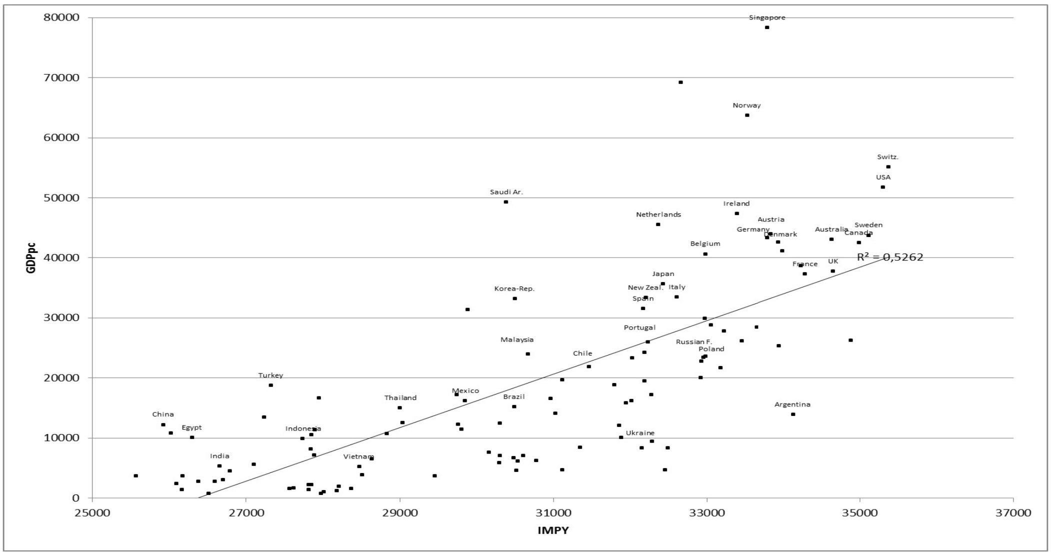
One additional evidence shown in figure 2 is the concentration of products in the up-right end of the graph; this is not surprising as it is the consequence of the major role played by richer Countries in international trade also in the agri-food sector.

Figure 2 - The sophistication of selected agri-food traded items: a comparison between Prody and Consy.



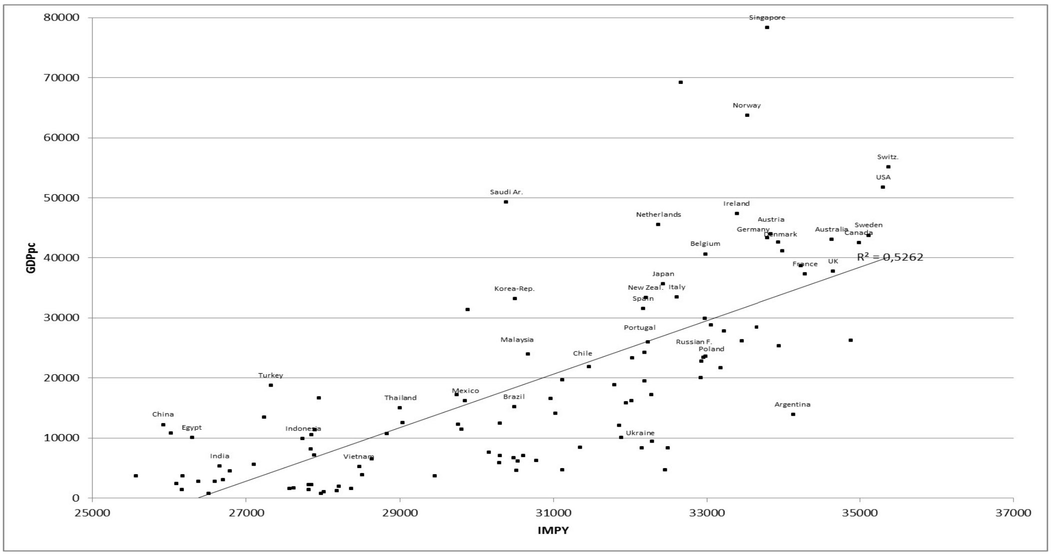
The subdivision of the quadrant of the graph into 4 sub-regions helps to interpret the meaning of the position of the different products in this graph. In the top-right area we find products with a value of both the indices above the average of the group. This is the case for products whose production and consumption is mainly located in rich developed countries and are highly processed and incorporate a higher value added. In the top-left region of the graph we find coffee (raw), tropical fruit, and other products whose main characteristics is to be produced in specific parts of the world, generally, low to mid level of GDP, but heavily exported into developed countries. This justifies the fact that their Consy is significantly higher than their Prody. In the bottom-right sub-quadrant we find fewer products that are also raw materials for the processing industry; however these are mainly exported by rich-developed countries that enjoys comparative advantages due to natural resources endowment (wheat, milk, and so on). In this case, the exporting countries are quite wealthy, while the buying markets are much more heterogeneous. Finally, the bottom-left area of the graph displays commodities or products that could be defined as "quasi-commodities" being semi-processed or semi-prepared which often are inputs for further stages of transformation. They features both Consy and Prody below the average values, but, with the only exception of the processed rice, are basically in the low-mid region of the ranking for both the indicators.

Figure 3 - The correlation between Impy and GDPpc



The Impy index shown in figure 3 is built on agri-food imports data. The graph opposes the import sophistication measure to the GDPpc. The figure displays data for 130 Countries while only the first 37 more important ones in terms of trade shares (either imports or exports of the Country shall be at least 1% of world total trade) are labelled. The first evidence shown by the graph is that there is a significant correlation between the Impy index and GDPpc (R^2=0.526), thus confirming the hypothesis on which the Impy is built and interpreted. At least for the limited case of the agri-food sector, we can affirm that, other things being equal, the more one country is well-off the more its imports basket include goods imported also by other rich countries, or, in other words, its imports are sophisticated. The distribution of the dots in figure 3 also shows, on one hand, that the relationship between GDPpc and Impy is tighter for higher income Countries and in particular for the European ones. On the other hand, relatively poorer Countries are more loosely located around the regression line. Ukraine and Argentine do not seem to follow the general rule as they are both Countries with a medium-low income level but their agri-food imports are relatively more sophisticated.

Figure 4 - A comparison between Impy and Expy for the agri-food trade



Finally, figure 4 explores whether Impy and Expy are associated to some extent. As always in this paper we limit to build Expy and Impy referred to agri-food trade. These are quite clearly correlated (R2=0.499), thus indicating that both indices catch elements that are relevant in influencing the composition and quality of traded products.

Moreover, the degree of association of the two indices leaves room for other relevant issues to play a role in the localisation of production and consumption and, consequently, as determinants of trade directions. The dotted line in figure 4 helps visualising the countries that do not reflect the average correlation. As expected, Countries rich in natural resources enjoy a comparative advantage in producing agricultural raw materials and commodities and, thus, their Expy is higher compared to their Impy. This is the case, for example, of rich Countries such as USA, Canada, Australia, but also of middle-to-low income Countries such as Argentina, Malaysia, Vietnam and others. Differently, the figure shows also the case of countries whose imports are much less sophisticated than their exports. This is the case of Egypt, China, Tukey, among others. These seems to be Countries where both income distribution and economic policies play a role in fostering economic growth via pushing exports while taking under control consumption levels.

4. Concluding remarks

The paper discusses new indices for describing and understanding international trade. These belong to the family of the so-called sophistication indices introduced about ten years ago with respect to exports. The indices here proposed consider imports instead of exports, following the standard hypothesis on consumption that the basket of demanded product is highly driven by income level. Within the limits of our field of observation, we think that the outcomes of the exercise are interesting and encourage further exploration of the theme. The basic results we obtained can be summarized as follows:

i) Goods for final consumption for which quality is much relevant and whose markets tend to be highly segmented are high in the Consy ranking;

ii) together with the previous goods, the higher positions in the ranking are also occupied by goods whose production/transport/conservation/marketing are costly and/or require complex technologies;

iii) on the contrary, at the bottom of the ranking there are basically simpler unprocessed (less processed) products, commodities, agricultural raw materials;

iv) better-off Countries tend to import sophisticated goods, i.e. goods that are also imported by other richer Countries;

v) the hypothesis at the basis of the concept and measure of import sophistication seem compatible and complementary to that one underlying the concept and measure of export sophistication. Both rely on visions of trade determinants that seem to be able to explain at list part of the observed flows.

More insights will come from deepening the analysis, including focusing on specific agri-food products and filieres, observing the time dynamics of the indices, but also analysing more in depth the sophistication level of imports of different sets of Countries that are differently related to competing supplying Countries and so on. The floor is open to further research and to a more articulated and integrated use of this "new family" of rather promising indicators.

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C20

Measuring the Competitiveness of EU Wine Business Sector: A Composite Index Approach

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ABSTRACT

The European Union is the world leading producer of wine. Since the introduction of the common market organization (CMO), the wine market has developed considerably. One of the main goal of the last wine reform was of making EU wine producers even more competitive preserving the best traditions of European wine growing and boosting its social and environmental role in rural areas.

The aim of this paper is to measure a multidimensional phenomenon, the "Competitiveness of EU wine business sector" in the nuts2 regions, through the use of a composite index. The results highlight both areas of the territory for which it is known the strong vocation and less known areas where you need to do further investigation.

Keywords: agribusiness, wine, enological vocation, composite index

PAPER

1. Introduction

The European Union is the world leading producer of wine. Between 2009 and 2014, the average annual production was 167 million hectolitres. It accounts for 45% of world wine-growing areas, 65% of production, 57% of global consumption and 70% of exports in global terms. Inside the European Union the picture is quite different among the Member States and the NUTS2 areas. Beside France, Italy, and Spain that are traditionally the largest EU wine producing countries, representing 81 per cent of total output, other Countries are significant in the sector as Germany, Portugal, Romania, Greece, Hungary, and Austria. And new Countries are emerging as Bulgaria, Croatia, and Slovenia. The aim of the paper is to try to measure the competitiveness of this sector in the EU nuts2 regions and its evolution in the period 2010-2013, through the use of a composite index. The source of data are the EU Farm Structure Surveys.

The competitiveness of EU wine business sector is clearly a multidimensional phenomenon since it is not possible to represent it only with a descriptive indicator; in fact, the phenomenon is composed of different dimensions that need to be considered contextually. In this regard, we have represented the phenomenon by three pillars: Structural, Entrepreneurial, and Qualitative. And each of the three pillars is composed of some individual indicators. In order to obtain a measure of each pillars and a "unique number" that represents the phenomena it is necessary to apply a composite index, combining the individual indicators. In fact, it is common awareness that multidimensional phenomena cannot be measured by a single descriptive indicator and that, instead, they should be represented with multiple dimensions applying methodologies known as composite indices. The paradigm of work for the measurement of these phenomena is developed as: 1) identification of a theoretical framework; 2) selection of the representative dimensions; 3) selection of individual indicators; 4) definition of the synthesis methodology (standardization and aggregation function).

2. The competitiveness of EU wine business sector

In the general context described in the previous section, the study and measurement of the competitiveness of EU wine business sector in the Nuts2 areas seems a necessary step in order to understand such an important sector for the economy and the social development of the rural areas. Among many factors, the structural characteristics of the viticulture, of the vineyard holding' management and of the quality production vocation are relevant and crucial in defining the capability of producing and marketing wine in a certain area. Therefore, three pillars have been chosen in this study, to represent the phenomenon:

Structural, Entrepreneurial, and Qualitative. Variables used are reported in Table 1.

Their relevance in regard to the pillar and the availability in official statistics of the parameters used have been the main criteria for choosing the elementary indicators. In fact, in order to select the individual indicators a formative approach is chosen: the selected individual indicators are causes of an underlying latent variable, rather than its effects. Therefore, causality is from the indicators to the concept and a change in the phenomenon does not necessarily imply variations in all its measures. In this model, the concept is defined by, or is a function of, the observed variables. In this case, indicators are not interchangeable (omitting an indicator is omitting a part of the underlying concept), the correlations between indicators are not explained by the measurement model (Diamantopoulos et al., 2008) and then their level is substantially negligible.

Table 1 - List of indicators of competitiveness of EU Wine business sector

Indicator	Pillar
Area under vines/utilised agricultural area	Structural
Vineyard holdings/agricultural holdings	Structural
Production value at basic price of the wine sector on agricultural output	Structural
Production value at basic price of the wine sector/resident population	Structural
Area of the specialised vineyard holdings/utilised agricultural area	Entrepreneurial
Specialised vineyard holdings/vineyard holdings	Entrepreneurial
Standard Output of the specialised vineyard holdings/Number of Specialised vineyard holdings (euro)	Entrepreneurial
specialist vineyard holdings marketing more than 50%	Entrepreneurial
Vineyard holdings with Standard Output >50.000 euro/vineyards holdings (%)	Entrepreneurial
Vineyard holdings with area under vines > 150 ha/Vineyard holdings	Entrepreneurial
DOC/DOCG area under vines/utilised agricultural area	Qualitative
Organic area under vines/utilised agricultural area	Qualitative
Organic vineyard holdings/agricultural holdings	Qualitative

3. Mazziotta-Pareto Index

The composite indices of competitiveness were constructed by the MPI (Mazziotta-Pareto Index). The MPI is a non-compensatory composite index that can be used to measure multidimensional phenomena, such as development and poverty (De Muro et al. 2011).

The index is designed in order to satisfy the following properties: (i) normalization of the indicators by a specific criterion that deletes both the unit of measurement and the variability effect; (ii) synthesis independent from an „ideal unit (i.e., a hypothetical geographical unit represented by the best values of the individual indicators), since a set of „optimal values is arbitrary, non-univocal and can vary with time; (iii) simplicity of computation; (iv) ease of interpretation.

The steps for computing the MPI are given below.

Let us consider a set of individual indicators positively related with the phenomenon to be measured. Given the matrix $\mathbf{X}=\{x_{ij}\}$ with n rows (geographical areas) and m columns (indicators), we calculate a standardized matrix $\mathbf{Z}=\{z_{ij}\}$ as follows:

$$z_{ij} = 100 + \frac{(x_{ij} - M_{x_j})}{S_{x_j}} 10 \qquad (1)$$

where M_{x_j} and S_{x_j} are the mean and standard deviation of the indicator j respectively.

Denoting with M_{z_i} and S_{z_i} ,respectively, the mean and the standard deviation of the standardized values of the area i, the composite index is given by:

$$MPI_i^- = M_{z_i} - S_{z_i} cv_i \qquad (2)$$

where $cv_i = S_{z_i} / M_{z_i}$ is the coefficient of variation for the area i.

This approach is characterized by the use of the product $S_{z_i} cv_i$ to penalize the areas with unbalanced values of the indicators. The 'penalty' is based on the coefficient of variation and it is zero if all the values are equal. The aim is to reward the units that, with equal mean, have a greater balance among the indicators values. Therefore, the MPI decomposes the score of each unit in two parts: mean level (M_{z_i}) and penalty ($S_{z_i} cv_i$) (Mazziotta and Pareto 2015).

The method provides a 'robust' measure and less 'sensitive' to inclusion or exclusion of individual indicators. In fact, over the past few years, the method has been subjected on several occasions both to influence analysis that to robustness analysis (through the introduction of a stochastic disturbance in the matrix) in order to verify the 'goodness of fit' compared to many other composite indices (Mazziotta C. et al. 2010). The results have always been the 'strength' of the method thanks to its statistical and mathematical properties. Three composite indices of Structural, Entrepreneurial and Qualitative enological vocation were computed by (1) and (2). Then, a global composite index was obtained by applying (2) to the three previous indices.

4. The results

The results of the global composite index, at NUTS2 level in European Union, are showed in Figure 1 and 2. The areas with highest values of the composite index (green in the map) are located in France (Figure 1). Languedoc-Roussillon has reached the highest score followed by Provence-Alpes-Cote d'Azur and Aquitaine.

Medium values of the composite index are recorded in some areas of Spain (La Rioja, Castilla-la Mancha, Region de Murcia), of Italy (Toscana, Abruzzo, Trento, Veneto e Friuli-Venezia Giulia), Austria (Burgenland), Germany (Rheinland-Pfalz) and France again (Alsace, Champagne-Ardenne, Corse and Bourgogne).

These results confirm the importance of some traditional areas under vines and are generally expected. Languedoc-Roussillon, for instance, is the single biggest wine-producing region in the world, being responsible for more than a third of France's total wine production

Figure 1 - Global index of the competitiveness of EU wine business sector. Year 2013

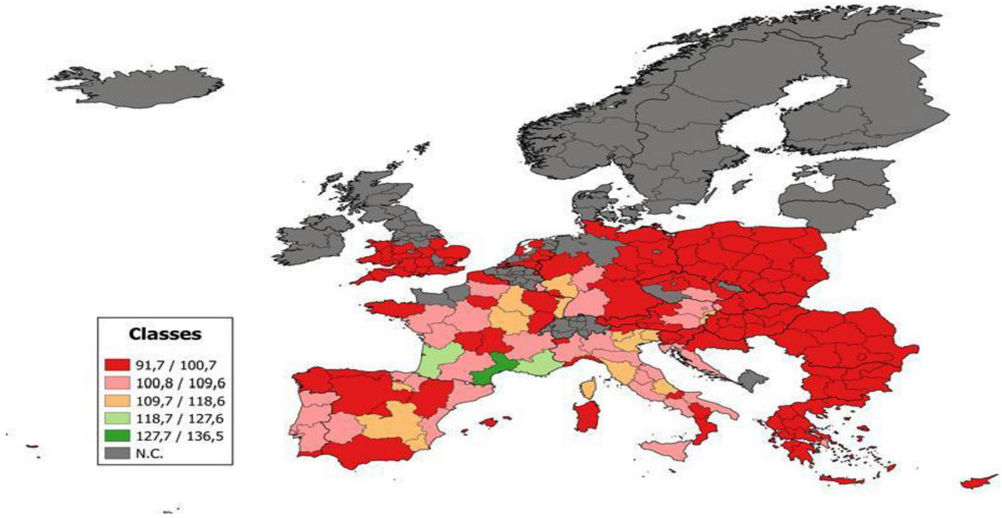
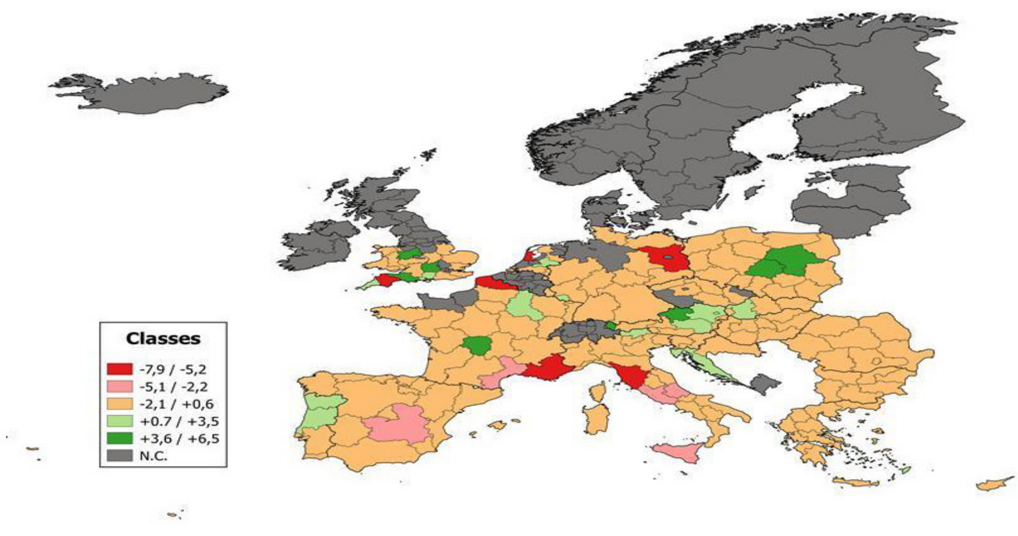


Figure 2 shows the results of the trend of the composite index in the period 2010 -2013.

As can clearly be seen, the score of the areas in this figure is completely different from the first one. The most suitable areas reached generally less points than the emergent but still marginal areas in the business wine sector. This can be explained with the fact that the new areas have more rooms for improvement than the traditional ones. At the opposite, the leader areas have more difficulties to improve or to keep their front-runner position. The areas with the highest values of this composite index are located in some regions of United Kingdom, Austria, Poland and in France. While, among the areas with the lowest scores (red in the map) there are two very important for the sector: Toscana and Provence-Alpes_Cote d'Azur, immediately after Languedoc-Roussillon that was the leader region in the first map.

Figure 2 - Global index of the competitiveness of EU wine business sector. Trend 2010-2013



Let us have a look to the results of the simple indicators associated to the three dimensions. In the following maps the colours are in function with the score (more dark is the colour and more high is the value of the index).

Figure 3 - Simple index of the structural dimension. Year 2013 and trend 2010- 2013

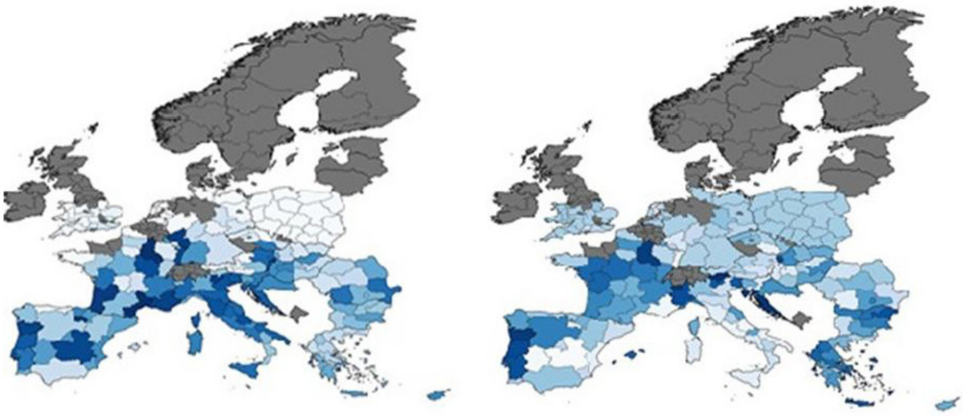


Figure 4 - Simple index of the entrepreneurial dimension. Year 2013 and trend 2010- 2013

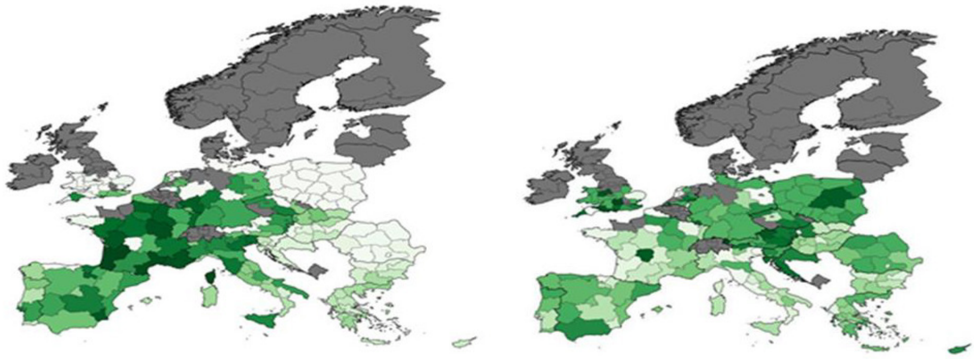
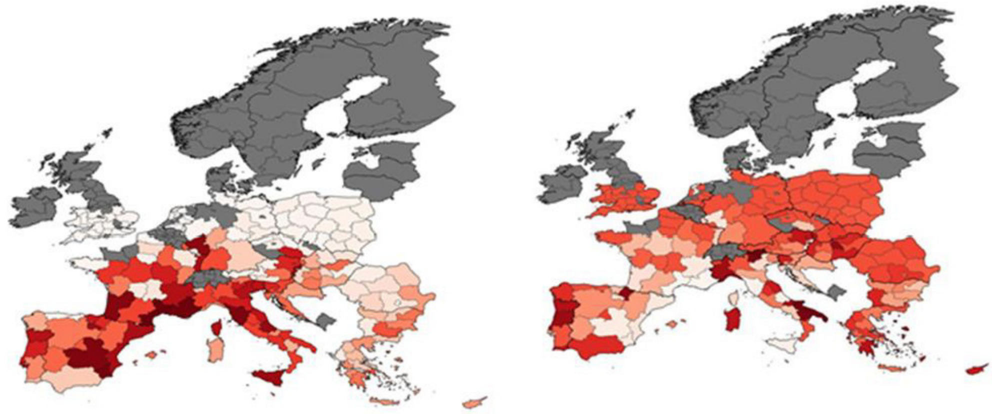


Figure 5 - Simple index of the qualitative dimension. Year 2013 and trend 2010- 2013



For the structural pillar (figure 3) areas with the best performances in 2013 are Languedoc-Roussillon, Champagne-Ardenne and La Rioja while in Bolzano/Bozen, Jadranska Hrvatska and Valle d'Aosta/ Vallee d'Aoste there have been the best trend.

France is the leader Country also in the entrepreneurial pillar (figure 4) placing 7 regions (Aquitaine, Corse, Languedoc-Roussillon, Bourgogne, Provence-Alpes-Cote d'Azur, Poitou-Charentes Champagne-Ardenne) in the first eight positions of the rank. The supremacy of the France in this pillar is broken only by the Region of Murcia (in seventh position). Considering the trend, United Kingdom has placed 3 areas in the first four positions of the rank (Berkshire Buckinghamshire and Oxfordshire, Dorset and Somerset, Shropshire and Staffordshire). Austria fit in the second position with Vorarlberg.

For the qualitative pillar (figure 5), France confirm its leadership placing Languedoc-Roussillon and Provence-Alpes-Cote d'Azur at the first two positions in the rank. They are followed by Region de Murcia, Toscana and Castilla-la Mancha. The trend shows as Italy is investing much in the quality wine. In fact, the first 5 regions in the ranking (Bolzano/Bozen, Puglia, Basilicata, Trento, Liguria come from this Country.

5. Final remarks

The study proposes a composite index to measure the competitiveness of wine business sector inside the European Union combining individual indicators distributed in three pillars: Structural, Entrepreneurial and Qualitative. We start from the assumption that the phenomenon considered is multidimensional and then it is necessary to reduce the dimensions.

The index, derived from the MPI method, classify the nuts2 areas in five classes, from the most devoted to the less devoted in the wine sector. The temporal reference of the analysis is 2013 and 2010-2013 trend.

The results confirm the leadership of the traditional Countries (France over all, followed by Spain and Italy) and rank the European regions according to the three pillars. Less expected are the results of the indexes on the trends that show, even in a very short time of the three years, the improvements of an emerging Country as United Kingdom (in the entrepreneurial dimension) and of a traditional one as Italy (in the structural and qualitative dimension). The UK is become a premium wine-producing region, with around 500 vineyards in England and Wales covering some 4,500 acres and producing sparkling and still wines. English and Welsh wines have also been winning many prestigious awards.

Further developments of the work could be to improve the number of the simple indicators in each pillar and to weight the simple indicators.

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FAO's new macro-economic statistics: Agricultural Capital Stock and Agro-Industry Measurement

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ABSTRACT

This paper reports on recent work in FAO's Statistics Division (ESS) in developing two new global agricultural statistics databases: an analytical database that estimates agricultural capital stock, and a database on agro-industry measurement (AIM). It describes the data sources, methodology and content of these databases, which provide key national accounts type indicators.The overall approach relies on the use of internationally accepted methodologies and the harvesting of data compiled by multilateral agencies, to minimize burden, duplication of efforts and inconsistencies. Priority is placed, where possible, on the use of official country data reported to these agencies. The paper also presents some key results from our cross-country analysis performed based on the databases. It is set to illustrate how the new databases can help improving our understanding of how countries can benefit from the links between agriculture and agro-industrial development and how agriculture and agro-industry can contribute to economic development. The objective of this paper is to solicit feedbackon the data sources, methodologies, indicators, and overall approach in order to enable improvements and establish key next steps.

Keywords: Agro-Industry Measurement, Capital Stock, Gross Fixed Capital Formation.

PAPER

1. Introduction

As economies grow and develop, the productive landscape undergoes structural transformations, sectors become more interrelated, and determining the importance of any specific sector becomes difficult. This is certainly the case for agriculturewhere agricultural production understates the sector's overall contribution tothe economy through its links to numerous industries such as fertilizer production, food processing and manufacturing, transportation, wholesale, and retail distribution.This raises the questions about the relative roles of these sectors as an economy develops, the impact of agriculture on the entire value-chainand the drivers behind time trends and country-level differences.

To answer these questions and to meet the growing need for consistent statistics to measure the agriculture value-chain, FAO s Statistics Division (ESS) began construction of a new FAO "Macro-Statistics domain" that covers two main areas: the "Agro-Industry Measurement" (AIM) and the "Agriculture Capital Stock" (CS) database. The AIM helps determine agriculture and food-processing industry contributions acrosscountries and time. The CS database aims at providing analytical statistics on capital stock and its components in order to inform questions about investment and productivity.

These databases use the System National Accounts (SNA) framework to ensure data comparability over time and across countries. To reduce burden and duplication, they integrate information from existing international databases from the UN Statistics Division (UNSD), the OECD, the World Input Output Database (WIOD) consortium, and UNIDO. These databases have the advantage of covering a large set of countries, and their use minimizes burden, duplication and effort, while maximizing efficiency and coherence.

The AIM and CS are analytical databases providing provisional indicators. While official country data is the backbone of these indicators, the databases require a significant number of imputations, estimations and assumptions. Data sources and assumptions are well documented, in the hopes that official country statisticians and other experts will help validate or improve the databases and the underlying assumptions, and where possible, provide official country data to replace missing data.

To provide some additional insight to the importance of such data, the rest of this section describes some key trends in the GDP contribution of the agricultural sector and the food processing industry. This rest of this paper presents a technical roadmap to the development of the AIM and CS databases. Section 2 proposes an in-depth description of the database content and the overall approach to database construction. Section 3 discusses the main data and methodological challenges and how they are addressed. Section 4 presents analysis and key findings in order to illustrate some of the potentialities of the database. Section 5 concludes.

2.Database Content and Overall Approach

2.1.Data Coverage

The basic set of variables covered in the AIM and CS databases includeValue-added, Gross Output, Gross Fixed Capital Formation (GFCF), and Net and Gross Capital Stock. These variables are provided in both local currency units (LCUs) and US dollars; current and constant prices for capital stock variables. The built-in indicators include productivity-related indicators, such as the AIR (agriculture GFCF to agriculture value-added); value added shares, such as the Food, beverage and tobacco (FBT) value-added share of manufacturing and of GDP; and the Agriculture Orientation Index (AOI) for capital formation, which normalizes agriculture's physical investmentratio by that of the total economy. Capital related variable are currently limited to the agriculture sector in the current version of the database.

The sector's and industries cover the following:

- Agriculture, forestry and fishing (ISIC Rev. 3 divisions 01 to 05);
- Food-processing activities covered by ISIC Rev. 3 divisions 15 and 16, which includes the FBT industry sector.

The current geographical coverage includes over 200 countries and territories, though for the food-processing variables, indicators have been constructed for a reduced sample of 46 countries captured in the OECD and WIOD databases. Subject to resources, the intention is to expand geographic coverage of the food processing sector, subject to data availability, and to expand variable coverage to include among others trade variables. At update, the targeted time span for data coverage is 1970 to year-2.

2.2. Overall Approach to Database Construction

The methodology in compiling both databases followed similar steps. A first step was to identify and bridge data across sources. The second was to estimate missing values for countries that had reported at least some official data, using established statistical estimation and imputation methods. A third step was to calculate final indicators, which included current price versions in both local currency units (LCUs) and US dollars; constant 2005 price indicators in LCUs and USD for capital stock variables; and the above-mentioned set of built-in indicators.

The original data sources used in compiling AIM and CS were as follows:

- United Nations Statistics Division, National Accounts Estimates of main aggregates
- (NAE), and official country tables;
- OECD, STAN and National Accounts databases;
- WIOD, Socioeconomic accounts;
- World KLEMS; and
- UNIDO, INDSTAT database.

Section 3. Data and methodological challenges

3.1. The Agriculture Value Chain and the Input-Output Model

The original motivation for the AIM project was to develop a database tomeasure the farm-to-fork contribution of the agricultural sector. In its widest concept, the agriculture value chain would coverall economic operations involved in the production and distribution of products that originate from or are used in the production of agriculture output. The first challenge was to define a framework for measuring the agriculture value chain. TheInput-Output (IO) model,developed by W. Leontief in the 1930s, was acknowledged as one of the most powerful tools to measure a value-chain as well as a sector's full contribution to an economy through its inter-sectoral linkages. In particular, the IO model shows how output of one sector is used as an input into another sector, showing sectoral interdependenceby identifying buyer of outputs and supplier of inputs. Due to the resource and time intensity of this approach, limited IO data available for developing countries, and lack of timeliness in the IO data that is available, this approach was discarded in favour of the approach used: to integrate and bridge existing national accounts data/indicators across multiple data sources. However, the absence of an IO framework is also creating challenges in measuring the agriculture value-chain, and determining where to start.

3.2. Agro-Industry, Definition Issue

Because the agriculture value chain includes all the suppliers of inputs to agriculture, and all the users of its outputs, direct and indirect, the project needed to first measure a narrow portion of this value-chain. FAO value chain experts recommended the project begin by focusing on the Agro-industry, starting with the food-processing industry. This was recommended both due to constraints on data availability, and due to the absence of international statistical definitions that covered the breadth of the "agro-industry."

An important future step for FAO will be to help define "agro-industry," a request frequently received by both FAO and theUN Statistics Division (UNSD).

3.3. Bridging of Series for AIM and CS Databases

In the actual compilation of data, an important first important database construction stepis to identify and bridge data acrosssources and across varying methodological and classification versions in order toensure time-series continuity and comparability. For both databases, series are rescaled whenever necessary to match the ISIC Rev. 3.1 classification of economic activities and the 1993 version of the System of National Accounts (SNA).Continuity of long time trends is particularly important in constructing indicators such as GFCF, the basis to our capital stock estimations. In bridging data, the first step is to bridge within an input data source, such as between the SNA and ISIC revisionswithin the UNSD National Accounts Official Country Data.The second step is to bridge across data sources.

3.4. Agricultural CS: New Methodology based on the Perpetual Inventory Method

In developing a new agricultural CS database, two approaches were considered. The first is to estimate capital stock using the physical inventory approach, which adds up the sector s components of produced assets. Physical investments in capital, or capital formation, can then be calculated as changes in capital stock between two time periods. In the case of agricultural capital stock, produced assets include land development, machinery and equipment, farm structures, livestock, and orchards. This approach, which had been previously used in a FAOSTAT agriculture capital stock series, was evaluated and abandoned due to several factors:

- Data quality issues in the underlying datasets: This arose in part from low and declining response rates to the FAO questionnaire sent to countries, and low rates of questionnaire completeness. This problems also resulted in limited country coverage.

- Methodological issues in component calculations: A large number of assumptions were required to calculate capital stock components, such as estimating land improvements from land value.

- Exclusive focus on the narrow agriculture sector: the approach excluded forestry and fisheries, making it more difficult to benchmark the capital stock estimates even against those published by some countries in their national accounts, covering the broader "agriculture" sector.

The second approach, adopted by FAO, is to use the internationally accepted perpetual inventory method (PIMs). In this approach, capitalstock in one period is the sum of capital stock in the previous period, plus the current periodflow of capital investments (GFCF) minus the consumption of fixed capital. The central equation to compile net capital stock (K) is

$$K_t = K_{t-1} + GFCF_t - \delta * \left(\frac{GFCF_t}{2}\right) - \delta * K_{t-1} + X_t, \quad (1)$$

where $K_t$is the net capital stock at the end of year t;$GFCF_t$ is gross fixed capital formation in year t; the term $\delta*(GFCF_t/2+K_{t-1})$ measures the consumption of fixed capital in year t, or total depreciation;and X_t is the "other changes in volumes" of the group of assets and it is set equal to zero[1].If series on GFCF are available, this method requires assumptions about the initial stock of capital in $t_0$as well as the depreciation rate.

Depreciation rates, δ.

The first step towards computing the net stock above is to select a rate of consumption of fixed capital, δ, also known as the depreciation rate. In the absence of good information about rates of depreciation, δ can be set in reference to other countries' depreciation rates of similar types of assets or other countries' service lives of similar types of assets.

Following Hulten and Wykoff (1996), we apply the declining balance model that converts an average service life of a group of assets, TA, into a depreciation rate, δ. They propose a two-step procedure based on the 'declining balance' formula:

$$\delta = r/T^A, \quad (2)$$

where parameter$r$ is an estimated declining-balance rate.

In order to fix the depreciation rate and assuming the declining balance model of depreciation in the FAO capital stock database, we need thus to make assumptions on the value of the declining balance parameter, r, and on the average service life of agriculture, T^A.

[1] Other flows are changes in the value of assets and liabilities that do not result from transactions. Examples are losses due to natural disasters and the effect of price changes on the value of assets and liabilities. For more, see SNA2008, paragraph 3.99.

Our review of practices by national statistical offices that apply the declining balance model tend to support a value of r greater than one. In the FAO capital stock database, we assume a unique declining balance parameter common to all countries for which agriculture capital stock has to be estimated that we arbitrarily fix to 1.5.

As for the average service life of assets used in agriculture, it is clear that service lives differ depending on the type of assets considered with structures having the longest average service lives. The average service lives varies also considerably among countries.

We arbitrarily fix T^A to be equal to 25 years. Combined with a declining balance parameter value of 1.5, the derived depreciation rate used in the FAO capital stock database is δ = 1.5/25 = 0.06.

This depreciation rate is consistent with implicit average depreciation rates retrieved using country series on NCS and GFCF for select countries.

<u>Initial capital Stock.</u>

Once a depreciation rate is selected, the next step is to estimate a starting stock of capital. According to Kholi (1982), a simple approximation can be used when geometric age-price profiles apply for thenetstock at the beginning of the benchmark year *t0*:

$$K_{t0} \approx [GFCF_{t0-1} + (1-\delta)\, GFCF_{t0-2} + (1-\delta)^2 GFCF_{t0-3} + \ \dots] \qquad (3)$$

Assuming that the long-run growth in the volume investment is equal to the long-run growth rate of volume agriculture value-added, θ: $GFCF_t = GFCF_{t-1} * (1+\theta)$; and inserting this relation into the equation above, the initial capital stock at the beginning of period *t0* is approximated by :

$$K_{t0}(geometric) \approx \frac{GFCF_{t0}}{(\delta+\theta)} \qquad (4)$$

3.5. Estimating the GFCF Series

Calculating capital stock in periods after t0requiresa relatively long and bridged time series of national accounts variables, particularly on GFCF for agriculture ($GFCF_{AFF}$), but also on auxiliary variables used to estimate missing GFCF variables. Imputation and estimation of missing valuesused a combination of hot deckimputation methods (carrying forward data from previous years for a country within a data series), cold deckimputation(using data from a “nearest neighbour”, in terms of structure and level of economicdevelopment, measured by GDP/capital), and linear interpolation.

The Agriculture Investment Ratio (AIR) was used to construct the $GFCF_{AFF}$ series in the FAO Capital Stock database, where $AIR=GFCF_{AFF}/VA_{AFF}$. The following two-steps procedure was used:

- Estimate the AIR in time *t* for country*i*, through regression analysis;
- Compile the level of investment in agriculture by applying the AIR to value-added:

$$GFCF_{AFFi,t} = AIR^{estimated}_{i,t} * VA_{AFFi,t}. \qquad (5)$$

Two approaches were used to compile AIR series: the first for countries with fully missing AIR data; the second for countries with some but incomplete AIR series.

3.5.1. Estimation of AIR for countries with fully missing series.

The estimation of the AIR for countries with fully missing series is based on panel data analysis, derived from an input datasetcovering 86 countries thathave AIR observations. Data in the input dataset model and estimate the AIR, our dependent variable, based on one or more independent variables. The fitted model infers an AIR series for those countries with missing agriculture investment data.

The approach follows the followingsteps.

1) **Model pre- selection**: Potential predictors considered for inclusion in the model were: log of GDP per capita; log of real GDP (measured in 2005 USD); the trade openness index in agriculture; the total economy investment ratio; the annual GDP growth rate; total population; and VA in agriculture as a

share of GDP. The list of explanatory variables was determined, in part, by data availability. For instance, employment in agriculture and VAAFF over employment in agriculture would have been interesting variables to include and to test for in the regression analysis, however due to lack of consistent data, these variables haven't been included in the analysis so far.

Countries were divided into two sets: low income countries and middle- and high-income countries (separation criterion set at 10,000 USD of GDP per capita, 2011 value).The best models for each set wereselected based on stepwiseregression and on the leaps-and-bounds algorithm (Furnival and Wilson, 1974).

2) **Regression method**: Once the benchmark model was chosen, different regression methods were assessed: pooled OLS, panel fixed-effects (FE); and panel random-effects (RE). The FE method was selected based on the following results:

a. OLS vs. RE: Breush-Pagan Lagrange multiplier. The null hypothesis of no panel effect (no significant difference across units) was rejected, and the RE model selected.

b. FE vs. RE (and OLS): Hausman test. Reject the null hypothesis of a RE. By transitivity, the OLS specification is also rejected (it can be shown that the RE is equivalent to an OLS generalized for panel effects).

3) **Sensitivity analysis and MSE based evaluation**: We next perform an in-sample Mean Square Error (MSE) analysis of the AIR estimated under our alternative model specifications and we select the final benchmark model that will be used for the underlying estimation of GFCFAFF for countries with fully missing series based on MSE and the by-country Symmetric Relative Efficiency measure, following Tratar and Toamn (2014), which is defined as:

$$SREM_{model\,1/model\,2} = \begin{cases} 1 - \frac{MSE_{model\ 1}}{MSE_{model\ 2}} & for\ MSE_{model\,1} < MSE_{model\,2} \\ \frac{MSE_{model\ 2}}{MSE_{model\ 1}} - 1 & for\ MSE_{model\,1} \geq MSE_{model\,2} \end{cases} \quad (6)$$

3.5.2. Imputation of AIR for countries with incomplete series

In this sub-section we discuss alternative techniques to fill incomplete time series on AIR. While, the targeted time coverage for publication in the capital stock database is 1970-2014, most countries present incomplete time series with missing data for the most recent years that have be imputed. The length of "missingness" varies across countries from just a couple of years to over two decades.

Approach 1: Constant ratio

The first approach imputes a missing AIR as an average of the last three to five years of available AIRs. This technique is naïve in the sense that it does not identify and, therefore, fails to project, any trend or cyclical component embedded in the time series.

Approach 2: Exponential Smoothing

Forecasts produced by exponential smoothing models are exponentially weighted moving average of past observations. As such, these models extract information endogenous to the historical time series regarding its four components – level, trend, seasonality, and noise – and use it to produce forecasts.

In the second approach, the ETS package in R (Hyndman et al., 2008) was used to forecast missing values. The ETS statistical framework allows selection of the best exponential smoothing model based on the AIC information criteria. In total, 30 model combinations are possible in the ETS framework depending on the type of trend and seasonal components considered (e.g. additive/multiplicative/damped additive/damped multiplicative trend, etc.) as well as on the underlying statistical model (additive vs. multiplicative errors).

This approach is better able to capture trend and/or cyclical components contained in the historical profile of the series. However, the information in the series is insufficient to address the structural break in countries' agricultural investment profiles that originated from the financial crisis.

In the next two sections we present the results obtained from applying time series regression techniques that allow for the inclusion of exogenous variables: the ARIMAX and, its generalization, the autoregressive distributed lag model (ARDL). These methods are preferred as they make use of both the information embedded in the historical series of the indicator under consideration and the knowledge of relationships between the indicator and external factors so that special events as the crisis can be account for.

Approach 3: ARIMAX

In the third approach, we fit ARIMA class models with exogenous variables before using the best model for forecasting purposes. The autoregressive integrated moving average model including exogenous covariates, ARIMAX(p,d,q), extends the

ARIMA(p,d,q) model by including the linear effect that exogenous series have on the stationary response series y_t. The general form of the ARIMAX(p,d,q) model is

$$\phi(L)y_t = c^* + x_t'\beta + \theta^*(L)\varepsilon_t \qquad (7)$$

where $c^* = c/(1-L)^d$ and $\theta(L)^* = \theta(L)/(1-L)^d$. Vector x_t'holds the values of the r exogenous, time-varying predictors at time t, with coefficients denoted β. We use this model to check if a selection of exogenous variables has an effect on a linear time series.

It should be noted that ARIMAX models have the same stationarity requirements as ARIMA models. If the response series y_t is not stable, we need to difference it to form a stationary ARIMA model with d degrees of integration. In addition, it is also required to assess in the pre-estimation phase whether the predictor series x_t are stationary and to difference them if necessary. If $x_t$is nonstationary, then a test for the significance of β can produce a false negative. As usual, the practical interpretation of β changes if you take a transformation (difference) the predictor series.

For each country, we perform a best model fitting exercise looping through a maximum of 144 models (8 combinations of explanatory variables times 18 possible combinations of ARIMA(p,d,q) specifications). The preferred model is selected based on the BIC minimization criterion, we then backcast/forecast the country series using preferred model.

Approach 4: Auto-regressive distributed lag model (ARDL)

The fourth approach tested relies on the autoregressive-distributed lag (ARDL) model, which takes the following general form:

$$y_t = \alpha + x_{i.t-q}^{'}\beta_i + y_{t-p}^{'}\gamma + \varepsilon_t, \qquad (8)$$

whereE_t is a random disturbance term that is assumed to be serially independent. The model is autoregressive in the sense that it contains one or more lagged values of the dependent variable, yt..The model also has a distributed lag component, in the form of successive lags of the explanatory variables, xt. A model containing p lags of y and q lags of x is denoted ARDL(p,q).

Due to too short a time series and because of multicollinearity in the data, the ARDL approach fails in most cases. We therefore prefer the ARIMAX based approach.

3.5. Food-processing industry.

The AIM database uses national accounts (NA) variables for the FBT when available, as for many OECD countries, and the INDSTAT2 database from UNIDO, otherwise. Since INDSTAT2 data are based on national industry surveys, which do not correspond to NA data for coverage and conceptual reasons, the INDSTAT2 series is re-scaled and estimated to national accounts levels. Re-scaling is performed using composition ratios, such and manufacturing to total economy value-added.

Since indicators relating to the food-processing industry are jointly compiled with UNIDO, and UNIDO provides a complete series, see Boudt et. al. for the methods used to impute missing data.

4. Analysis and findings

In this section, we present and comment a few results extracted from the new FAO macro-statistics database. We first look at the relative contribution of agriculture and food processing.Looking at select countries, Figure 5 shows that agriculture as a share of GDP tended to decline between 1970 and 2013, while food processing remained relatively stable.

Figure 6 presents the value-added share of food and beverages processing in total manufacturing against the contribution of manufacturing to total GDP, and shows the resilience of the FBT sector even during crises such as the 2009 Financial Crisis. This can be interpreted simply by the fact that the population still needs to eat, that is there is a low income elasticity of demand for food and beverage products.

Figure 1 - Contribution of Agriculture and Food-processing to GDP.

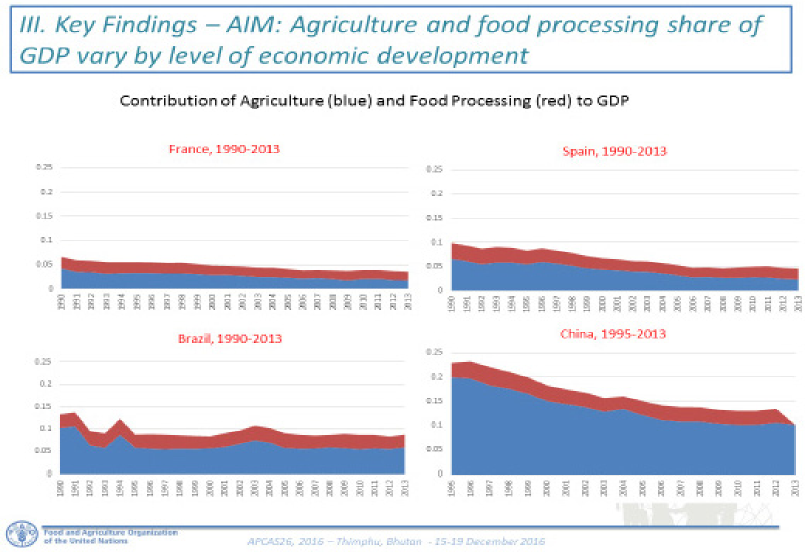
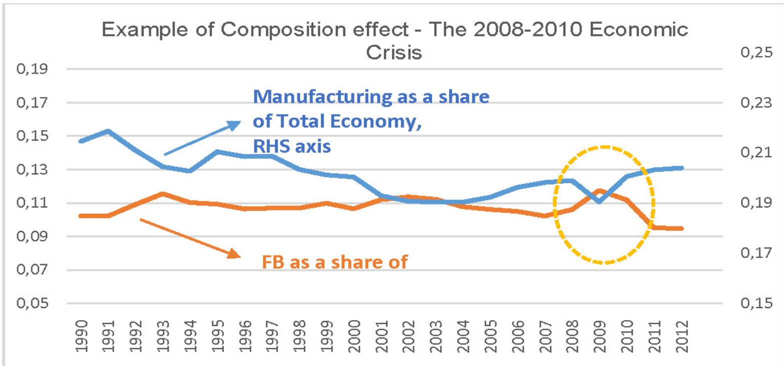


Figure 2 - Resilience of the Food-Processing sector

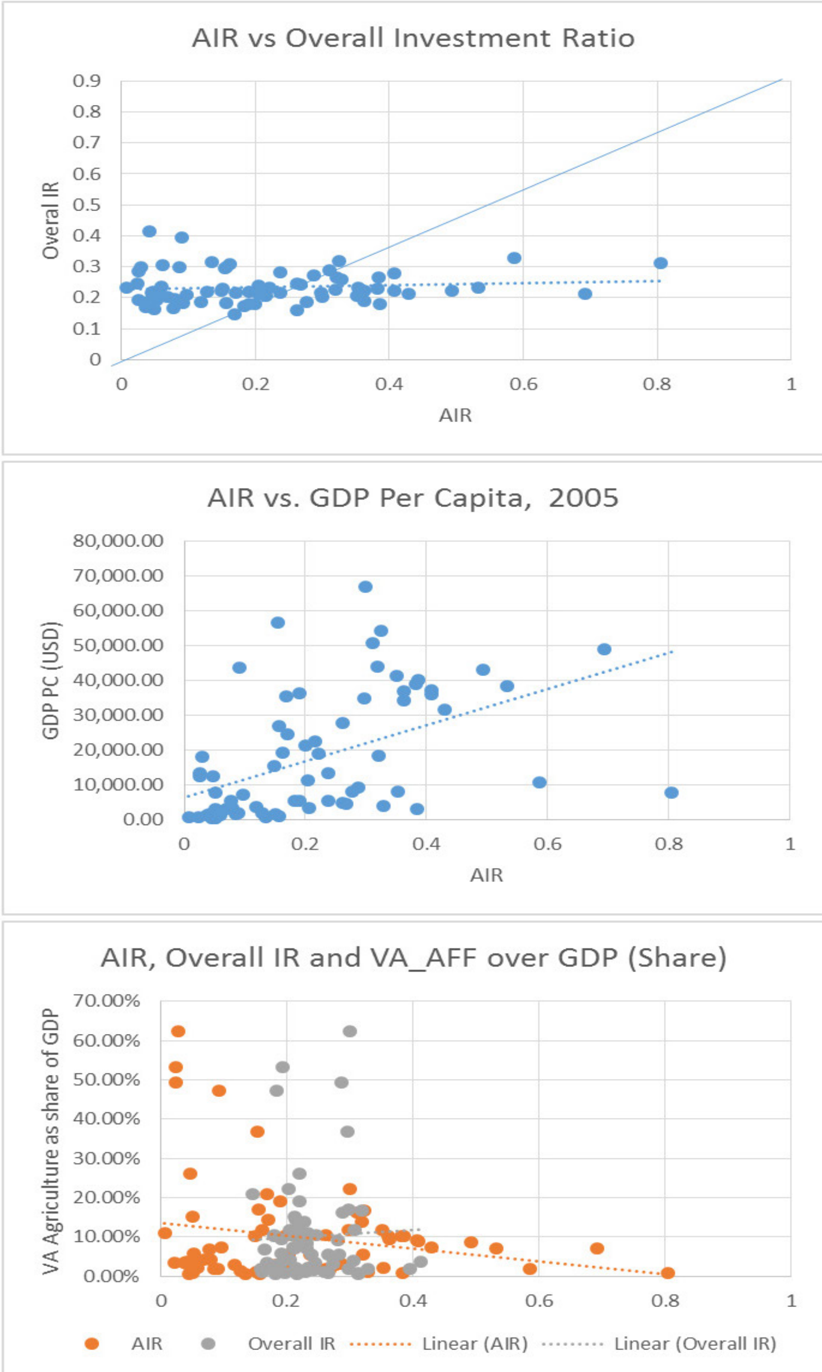


Another possible line of analysis bears on capital stock related variables in the agriculture sector.[2] The following set of graphs present the AIR as defined in Section 3 against a set of economic variables.

The upper part of Figure 8 indicates that there is no clear positive relationship between the overall investment ratio (calculated for the total economy) and the AIR. It also shows a larger variability of the AIR relative to the overall economy investment ratio. When presenting the AIR against GDP per capita, we instead find a clear positive relationship; and when presenting against the agriculture share of GDP, we find a negative relationship (i.e. countries with a high agriculture share of GDP tend to have a low AIR).

[2] The insertion of capital stock variable for the food processing sector will constitute an extension of the current AIM database.

Figure 3 - AIR against overall investment ratio, agriculture VA and GDP (2005 data)



An interesting pattern (Table 1) emerges between the AIR and the overall investment ratio when we divide the countries into two groups, low-income countries versus middle- and high-income countries. While countries in both groups present a similar average overall investment ratio, the average AIR is much lower in low-income countries, indicating that in those countries – where agriculture often remains an important contributor to GDP – the primary sector is behind in terms of investment in physical capital with respect to the other sectors of the economy. On the other hand, industrialized countries tend to have much more mechanized agriculture sector.

Table 1 - Average AIR: Total economy vs. Agriculture

(all years)	All countries	Low income countries	Middle- and high-income countries
Avg. AIR	0.214	0.109	0.255
Avg. Overall IR	0.231	0.222	0.235

5. Conclusion

The aim of this paper is to present a new macro-statistics database developed by the statistics division FAO, in order to meet the growing need for consistent statistics measuring agricultural capital stock and the agriculture value-chain.

While largely based on secondary data, the database construction implies a large number of data challenges to be overcome, from integrating series based on different SNA versions and classification systems, to imputing missing values, to making assumptions about depreciation rates. This leaves wide scope for further improvements, as country experts provide better information and replace FAO estimates with their own, as well as extensions of the database in terms of geographical, variable and subsector coverage.

It is hoped that presenting the work and making available the databases in 2016 will facilitate the type of feedback that will lead to an even more useful evidence-base for agriculture and food policies.

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THEMATIC SET

C21

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ABSTRACT

In the era of climate change uncertainty, water scarcity, soil fertility degradation and disease-pest dynamics, it is hard for the farmers to obtain the optimized yield and sustain their agri-business. This has led to increased incidents of farmer suicides and has a direct impact on the India's food security. To make agriculture sustainable, an integrated analytically enabled Digital Farming Platform - ***InteGra*** (derived from **Inte**lligent **Gra**m (Village)) – has been proposed. InteGraprovides holistic services, including efficient crop planning, operations scheduling and management by minimizing climate and market risks.The resulting "climate smart" and "market smart" entities called ***SmartPRIDEs*** (Smart Progressive Rural Integrated Digital Enterprises) can transform the lives of millions of farmers across the globe and lead to self-sustaining and economically viable farming. The business model around ***InteGra*** is inclusively designed to bring together agricultural input and output companies, financial and insurance institutions, and policy makers with the appropriate clusters of farmers on the same platform enabling the formation of a mutuallybeneficial and self-sustaining, vibrant ecosystem.

Keywords: Sustainable Food Security, Modelling, Digital Technologies

PAPER

1. Introduction

Agriculture plays a vital role in India's economy. The GDP of Indian agriculture reached US $259.23 billion in FY15 while providing livelihood to nearly 58% of the population and is one of the largest contributor to the Indian GDP [1]. However, all is not well in this sector. India is home to 25 percent of the world's hungry population [2]. India ranks 55 among 63 countries on the Global Hunger Index (2015) and 135 among 187 countries on the UNDP Human Development Index (2014), [3]. Food production has seen only a marginal increase over the past 20 years while there has been an exponential jump in the population. Productivity is extremely low due to unscientific farming practices, fragmented land holdings, lack of agro-climatic focus for crops selection and access to the right farming advice at the right time. Thus food security is a rising question to feed the growing population.

Food security is a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life [4]. Climate change is a fundamental threat to global food security, sustainable development and poverty eradication [5]. Anticipating appropriately the impact of climate change on agriculture requires data, tools and models at the spatial scale of actual production areas [6]. There is an urgent need to organize farming groups which will enable affordability to use modern technologies for sustainable agricultural development.

In order to make Agri business sustainable within the farmers groups, the PRIDE™ (**P**rogressive **R**ural **I**ntegrated **D**igital **E**nterprise) model has been proposed for farmer cooperatives and similar setups [7]. PRIDE™s leverage the power of farmer social networks and ensure that the farmers are able to reassert their place in the agriculture value-chain. To empower PRIDE™s and all associated stakeholders with precision agriculture capabilities obtained from various sensors and other data sources, we propose an integrated digital farming platform –***InteGra***empowered by advanced analytics systems.

PRIDE is digitally enabled a collective group like a cooperative or a farmer producer company is the central channel through which various business and agricultural activities are carried out. This collective group is generally an entity that operates in the field to connect various organizations like agri-input industries, food-processing industries, government organizations, financial institutions, agricultural machinery industries and the stakeholders, i.e. the farmers. In addition, they also trade in large quantities collectively associating with all the farmers.

Through a process of cyclic data optimization involving continuous data collection from the field, data analytics on the backend and directing on-field operations on the basis of intelligence derived from the data, the PRIDE™s are converted into ***SmartPRIDEs. InteGra*** augments the PRIDE™ with precision farming capabilities facilitated through intelligent decision support. **InteGra** is supported by a proprietary, patented scouting application, Intelligent Rural Integrated Sensing (IRIS)which facilitates data collection from the PRIDE™ group of farmers. The regional level agricultural knowledge and data is being stored in an Agriculture Knowledge Base, (AgriKnoBTM), which enables experts to provide recommendations.

As a first step towards transition to ***SmartPRIDEs, InteGra*** offers a variety of services such as crop and variety selection, disease and insect pests' incidence forecasting for selected crops, weather, fertilizer recommendation, irrigation scheduling, market price predictions, and valuation of crops based on consumer pay-off. It is believed that the advanced services for the famer groups in **SmartPRIDE**s will not only lead to a self-sustainable livelihood but also ensure the food security in a collective manner through the formation of an increasing number of intelligent farmer groups.

2. The Analytical Framework of InteGra

The key capabilities of **InteGra** can be captured by the 4As: Acquire, Analyse, Advise, and Actuate. **InteGra**has various components such as *KwikSense, aNutva, ChurnBot, DataPlus, mPush* and CROPS that play a key role in enabling these capabilities.KwikSense can acquire data from personalized sensors installed in farms and can also actuate farm-equipment. aNutva (analytical tool) and *ChurnBot* provide a mechanism to plug in rule-based and statistical algorithms that give useful results from a variety of data sources. Integrated data management is carried out with *DataPlus*. Data is the key driver for the **InteGra** analytical engine to provide intelligence for the farming business. Farming activities depend on multiple phases with inputs from a variety of sources. Hence, data from the corresponding sources is required for better decision making. The cultivation of a crop can be divided into the following four phases.

Table 1 - Cropping phases and Activities

Phases	Present or Upcoming Activities
Phase 1 – Crop Planning	Crop Selection based on Resource estimates, Farmer Constraints, Historical Climatic Conditions and Localized Weather Forecasts, Market demand
Phase 2 – Aggregation and Ordering	Aggregating the Input Requirements across the PRIDE™ and ordering for timely delivery
Phase 3 – Crop Cycle Management	Crop Advisory, Farm Management, Plant Protection, Fertilizer recommendation,Certification, Yield Monitoring & Irrigation scheduling
Phase 4 – Harvest Planning	Crop Valuation and Market Linkages

The core component of InteGra, Crop Rotation, Optimization and Planning System (CROPS™), provides recommendations on the appropriate crops taking into account macro parameters like the historical climatic conditions, market dynamics and micro parameters like the farmer constraints, localized weather conditions, soil fertility and projected market demand. For the selected crops, the revolutionary **InteCrol** (Integrated Crop Protocol) is created by the system. **InteCrol** is the DNA of the platform and has embedded within it a wealth of information which is used by all the downstream phases as well as by various stakeholders in the agricultural value-chain. We discuss in the following sections a variety of analytical techniques that help in critical decisions for the different crop phases:

Crop and Variety Selection: The crop selection is the first and vital step of the entire cropping cycle, which falls under Phase 1- Crop Planning. The selection process is based on two criteria.

Crop Selection: The crops are selected based on the maximum return on investment, considering the resource availability (can be based on quantity orcosts), Agro climate, Soil conditions and market price availability. The Linear – Programming model is used to select the best possible crop and area of cultivation. Following is the Linear Programming model in Matrix form.

$$\text{Maximize } [S_1 \quad S_2 \quad \dots \quad S_n] \begin{bmatrix} x_1 \\ x_2 \\ \dots \\ x_n \end{bmatrix} \qquad (1)$$

$$\text{Subject to } \begin{bmatrix} 1 & 1 & \dots & 1 \\ I_{11} & I_{12} & \dots & I_{1n} \\ I_{21} & I_{22} & \dots & I_{2n} \\ \dots & \dots & \dots & \dots \\ I_{m1} & I_{m2} & \dots & I_{mn} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ \dots \\ x_n \end{bmatrix} \leq \begin{bmatrix} L \\ I_1 \\ I_2 \\ \dots \\ I_m \end{bmatrix}, \begin{bmatrix} x_1 \\ x_2 \\ \dots \\ x_n \end{bmatrix} > 0 \qquad (2)$$

where,

$S_i = Selling\ price;\ I_{ji} =$
$Inputs\ allocation$ (Fertilizer, Pesticides, Labour etc.) $with\ respect\ to\ crops;\ I_j =$

$Maximum\ Inputs\ available$, (Fertilizer, Pesticides, Labour etc.), $j = 1,2, \dots, m$; $x_i = Crops, i = 1,2, \dots, n$; $L = Land\ Availability$

Crop-Variety Selection: The crop variety is selected based on the productivity in the available conditions. The crop variety responses are recorded based on prior yield estimates and historical weather information and inputs assisted in yields. The variety selection has been done in following two steps –

1. Stepwise Regression determining the relation between yield and other independent variables – Stepwise regression equations have been fitted with yield response of the respective crop varieties with respect to weather and input variables (depending upon the available data):

$$Y_{cv} = W_{tf} + I_{uf} \tag{3}$$

where, $Y_{cv} = Yield\ of\ respective\ crop - variety$; $W_{tf} = Weather\ effect$; $t = Weather\ type\ (Temperature, Relative\ Humidity\ etc.)$; $I_{uf} = Inputs\ for\ yield$; $u = Input\ types\ (Fertilizer, Pesticide, etc.)$; $f = Frequency\ (cumulative\ seasonal\ weather, average\ monthly\ weather, etc.)$

2. Forecasting for the upcoming season

The estimated yield responses for the crop-varieties are obtained based on the fitted regression equation (3) with the forecasted weather variables and available input resources for the upcoming season(s). The forecast for the Weather variables are obtained based on time series forecasting, Auto Regressive Integrated Moving Average (ARIMA) model.

A case study has been conducted to select the best Soybean variety with farm level data of Michigan area of United States. The selection is based on the number of trials, average yield and yield differences and their relational responses with respect to weather, irrigation and soil characteristics for 182 Soybean varieties. Five varieties have been selected, which are suitable for recommendation to provide a better yield for the coming season, based on the above mentioned technique.

Plant Protection: Plant Protection is one of the major aspects to increase crop productivity by saving the crop harvests. It is part of Phase 3- Crop Cycle Management. Presently, it has been envisioned for two aspects – a) plant disease-pest forecasting framework and b) plant insect-pest forecasting framework.

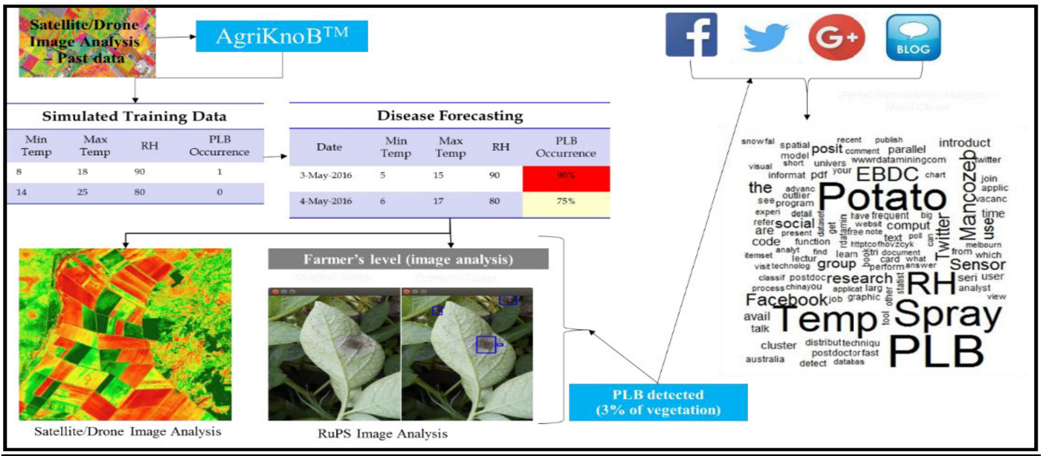
a) *Plant Disease-pest Forecasting Framework*- The framework is designed to accommodate various crops and their diseases. The approach can be initiated having prior knowledge of the disease incidences with the vital causal variables, mostly weather. Having the data of disease occurrences helps to build specific crop-disease models for forecasting and broadcast the alerts. But in the situation where we lack data, disease occurrences data has been simulated based on the weather variability and distributions. The literature thresholds of disease occurrences are mapped with the simulated weather data of the crop growing season with respect to the crop varieties. The historical remote-sensing data (satellite images) can also help in enriching the simulation data. Thus the training data can be used for disease forecasting through Machine Learning algorithms (Logistic Regression, Artificial Neural Network, etc.).

The disease occurrences are broadcast to the farmers at least 7-15 days prior to manage their logistics to protect the crops. The data acquired through the various data sources below the soil, on the soil and above the soil is augmented with geo-tagged, localized field level data obtained from a proprietaryIntelligent Rural Integrated Sensing (IRIS) application. The geo-tagged data is further processed through Image Analysis (Image Enhancement, Region of Interest Segmentation, Feature Extraction and Machine Learning algorithms). Thus we can get the scale of disease severity of different geo-spatial regions, which is posted to the farmers for their region of interests.

The above validation process can also be facilitated through high resolution images either captured by drones or satellites. Thus,remote sensing data analysis for various crop reflectance with respect to the disease helps to generate the disease severity map of the region of interests.

The disease severities evaluated in the validation phase is prompted to the users to post in Social Networking groups. The power of social networking helps to evaluate various factors related to the crop diseases and associated diseases. Additional knowledge is gathered through Social Networking Analysis. This knowledge in turn enhances the knowledge base (AgriKnoBTM) and thus the training data, which is advantageous for disease forecasting during the next season.

Figure 1 - Disease forecasting framework demonstrated for Potato Late Blight (PLB) disease, Hapur region, Uttar Pradesh, India



Besides the simulated data approach for forecasting disease incidences, proven statistical models have been explored for Rice Blast disease, with some modifications. The EPIBLA model was developed to forecast disease incidences for South India region based on the spore counts of *Pyricularia oryzae*,using Burkard volumetric spore trap [10]. The spores per cubic meter have been estimated with respect to daily temperature and relative humidity, through multiple linear regression. The proportion of disease incidence is modelled through step-wise regression model with respect to minimum, maximum and dew point temperatures and relative humidity.

In our context we have modified the EPIBLA model based on observation of disease occurrences.We took samples from five zones of a rice field (average 1 acre) with an average of 40 tillers inspected under a ring. The count of affected tillers is recorded among the inspected tillers in Chennai Horticulture Produce Producer Company Limited (CHPCL) PRIDETM, Villupuram district of Tamil Nadu. The observations are recorded for every week of rice growing season for twelve farmers with average rice growing area of 1 acre. The disease incidence is calculated with the ratio of infected and observed tillers for each of the observation. The calculated disease incidences are fitted with weather variables following step-wise regression model, as followed in EPIBLA model.

The management practice to control EPIBLA was followed by four farmers during the season.

Following is the developed model –

$$DI = 0.150 - 0.005 \times W_1 + 0.003 \times W_2 + 0.005 \times W_3 + 0.002 \times W_4 \qquad (4)$$

where, DI = Disease Incidence (%); W_1 = Dew Point temperature;

$W_2 = Minimum\ Temperature; W_3 = Maximum\ Temperature; W_4 = Relative\ Humidity$

b) Plant Insect-pest Forecasting Framework- The insect-pest framework is another sub-module of ***InteGra*** under Plant protection. The framework is supported by mathematical models, derived from Lotka Volterra, Predator-prey model, with statistical estimates supporting the initial values for the model.

$$\frac{dx}{dt} = ax - \alpha xy + (w_{1x} + w_{2x} - w_{3x})x \qquad (5)$$

$$\frac{dy}{dt} = -cy + \alpha\gamma xy + (w_{1y} + w_{2y} - w_{3y})y \qquad (6)$$

where, $x(t) = pest\ population$; $y(t) = predator\ population$;
$a = natural\ growth\ rate\ of\ pest$; $\alpha = predation\ rate$;
$w_{ix} = growth\ of\ pest\ due\ to\ weather\ variables, i = (1 - Max\ Temp; 2 - Min\ Temp, 3 - Rainfall)$; $c = reduction\ rate\ of\ predator\ due\ to\ natural\ death$; $w_{iy} = growth\ of\ predator\ due\ to\ weather\ variables$; $\gamma = increase\ of\ predator\ population\ due\ to\ predation$

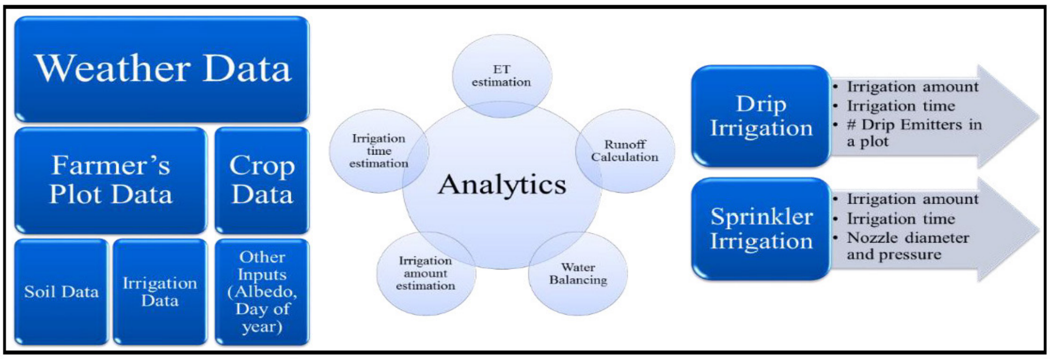
The cultural and biological control measures and its effects on prey and predator are adjusted in the above equations, based on the statistical estimates of population and growth rate. The numerical simultaneous solution of the differential equations 5 and 6 suggest the effective control measures of the pest. The growth rates are estimated based on variety of interactions, preypredator (compound annual growth rate), prey-weather-predator (regression), prey-chemicalpredator (regression) and prey-cultural/biological-predator (regression). The yield component being added in the model will complete the production system, considering growth components of yield.

The insect-pest model is being tested and explored for controlling the devastating Tea looper (*Hyposidra talaca*) of north-east region of India.

Fertilizer recommendation: The fertilizer recommendation module for other crops has been explored through Monte Carlo Markov Chain (MCMC) model. The MCMC process considers a set of states. After initiation from one state it flows to the successive states following the transition probabilities. The probability does not depend upon which states the chain was in before the current state. The depletion rate of fertilizers due to natural erosions and plant uptakes have been considered to determine the available nutrients in soil on periodic basis. Initial soil sample tests have been done to determine the nutrient status. The fertilizers are recommended when the nutrient status get depleted as per plant requirements. The fertilizer recommendation has also been explored through a software (named as Nutrient Expert) developed by International Plant Nutrition Institute (IPNI) for rice.The Nutrient Expert is presently available for Rice, Wheat and Maize. The fertilizer recommendation and irrigation scheduling are important modules under Crop Cycle Management of Phase 3.

Irrigation scheduling: The water requirement is one of the major inputs for the plants to grow. In the era of climate change, precision in irrigation is needed to have "per drop more crop". A novel framework has been designed comprising the modern methods of estimations for irrigation scheduling (Figure 2). The irrigation scheduling is believed to be more efficient having sensors installed in the field, through which precise information on temperature and moisture levels is obtained.

Figure 2 - Irrigation framework



The Evapotranspiration (ET) has been estimated through Penman Monteith Model.

Crop Valuation: The market price forecasting for the crop and variety is one of the most advantageous attributes of the **InteGra**, under Phase 4 – Harvest Planning. It has been noted that the seasonal variation of the crop prices is pretty much predictable, except for some unpredictable occurrences caused by Nature and/or policy makers (which are reported more often). In this scenario, the price prediction models (through ARIMA) fail. There is a need to develop a methodology to evaluate value of crops based on the amount paidby end consumers. The crop valuation has been mathematically structured by solving three partial differential equations considering demand of crop products due to population growth, urban growth and cost of production and products and productivity, respectively.Let c(t), p(t) and u(t) be three dependent variables representing crop valuation, population and urbanization, all depending on time t. The crop valuation includes the crop productivity, costs related to crop production and processing and valuation of crop products in market.

Thus, $\frac{dc}{dt} = \frac{\gamma}{n}c + \delta c - \rho c + \frac{\varphi}{q_1}cu + \frac{\theta}{q_2}cp$ (7)

where, γ = % of growth of c per unit of μ per unit time; n = crop units processed to produce a product; δ = % of growth of c per unit of μ per unit time; ρ = % of loss of c per unit of μ per unit time; φ = % of growth of c per unit of u per unit time; q_1 = unit of products of crop available in urban space; θ = % of growth of c per unit of p per unit time; q_2 = unit of products of crop available; μ =the units of products processedin unit time

$$\frac{dc}{dt} = \{(\frac{\gamma}{n} + \delta - \rho) + \eta p\}c \quad (8)$$

where, $\eta = (\frac{\varphi}{q_1}\lambda + \frac{\theta}{q_2})$, $u = \lambda p, \lambda = growth\ of\ Population$ (9)

$$\frac{c}{c_0} = e^{F(t)},\ F(t) = \left(\frac{\gamma}{n} + \delta - \rho\right)t + \frac{K\eta}{\alpha} ln\left\{\frac{1+\beta e^{\alpha t}}{1+\beta}\right\} + b.\eta(1 - e^{-mt}) \quad (10)$$

The numerical analysis of the model through statistical estimates for various crops, crop-products for different geographies need to be evaluated.

Population theory

Verhulst [8] suggested the famous logistic growth model for population,

$$\frac{dp}{dt} = \propto p\left(1 - \frac{p}{K}\right) where, K = \frac{\propto}{a}, \text{ at } t = 0,\ p = p_0 \quad (11)$$

Solving equation (11) we get

$$p(t) = \frac{Me^{\propto t}}{1+\frac{M}{K}e^{\propto t}} \quad \text{where, } M = \frac{p_0}{1-\frac{p_0}{K}},\ \lim_{t\to\infty} p(t) = K \quad (12)$$

The law of entropy in Informatics suggests that as the population grows a census of a nation will miss some number of people which is likely to be caused mostly by the dynamics of the very system of recording the census. So let us assume,

$$p(t) = P(t) + \varepsilon(t) \quad (13)$$

where, $P(t)$ is recorded by the census and $\varepsilon(t)$ is the error in the record.

Thus, $\frac{dp}{dt} = \frac{dP}{dt} + \frac{d\varepsilon}{dt} = \frac{K\beta e^{\alpha t}}{1+\beta e^{\alpha t}} + \varepsilon_0 e^{-mt}$, where,if $\beta = \frac{M}{K}$, then $\beta = \frac{\frac{p_0}{K}}{1-\frac{p_0}{K}}$ (14)

This gives,

$$\frac{P_0}{K} = \frac{\beta}{1+\beta} \; and \; \frac{d\varepsilon}{dt} = \varepsilon_0 e^{-mt} \; , m > 0 \tag{15}$$

$$\text{Urbanization, } \frac{du}{dt} = \lambda \frac{dp}{dt}, \text{ att} = 0, u = u_0 = \lambda p_0 \tag{16}$$

The developed mathematical model is developed considering the cost involved in producing the crop based products, productivity of the crop and the demand of the crop products due to urban tastes and population growth. The model framework is expected to provide the farmers the valuation of the crops before cultivation, which will enable the farmer to choose themost profitable crop. It also provides the farmers betterbargaining power and encourages building food processing enterprises to reach the consumers through the least possible channels. This helps famers to createsuccessful business groups and organize profitable farming business units.

3. Conclusion

The Digital Farming Initiatives of Tata Consultancy Services [7] is empowering the farmers, especially the small and marginal agrarians to combat against all the uncertainties such as weather risk, water and soil degradation, pest and disease attacks and market price fluctuations. The farmers are facilitated through a collaborative network called **SmartPRIDEs** supported with an advanced analytical platform **InteGra**. A Smart Ecosystem is enabled for farmers to collaborate and produce optimized yield with appropriate inputs overcoming major risks associated with climate & pest/disease and to market their produce to obtain maximum profit. In addition, the real time data driven framework ensures operational efficiency and resource optimization at every stage of crop cycle, thus making Agribusiness systems more productive, profitable and competitive to ensure food security across the globe.

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C21

Computer usage and Internet access on agricultural and horticultural farms in Finland

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ABSTRACT

Computer and Internet access have become essential tools in modern society. The use of computers and the Internet on Finnish farms has been surveyedseveral times since the year 2000.

90% of farms used computer in 2013 whereas in 2000 only 50 % of the farms did so. By 2013 the use of the Internet had increased to the same level as the use of computer.

The use of mobile broadband connection has increased rapidly and by 2013 it was at the same level as the use of fixed broadband. The proportion of the farms using mobile broadband is higher and that of farms using fixed broadband is lower in sparsely populated areas, probably due to lower availability and speed of fixed broadband in those areas.

Almost half of the Internet-using farms access the Net with mobile phone and about 20% of the farms use tablet. Access to the Internet also in sparsely populated areas will be crucial for farms in the future, as an increasing proportion of farm management activities are carried out overthe Net.

Keywords: computer, Internet, broadband, mobile, farm

PAPER

1. Introduction

In Finland the development of the access to the Internet in the rural areas has been monitored in the national rural policy. As the development of the digitalisation of both public and private services has accelerated in the last decade, it has become an issue of general and governmental interest to support the development of Internet networks across the country. Equal access to the Internet has become an issue related to an open and democratic development of the Finnish society. In relation to its population Finland is scarcely populated country. In addition to the concentration of population to urban areas, the rural areas are both very scarcely populated and remote. This reflects also to the technical functionality of Internet services. In remote areas, costs of fixed broadband networks per customer may be very high which favours mobile connections. However, if the number of customers is low, operators are not motivated to develop the coverage and speed of the mobile networks.

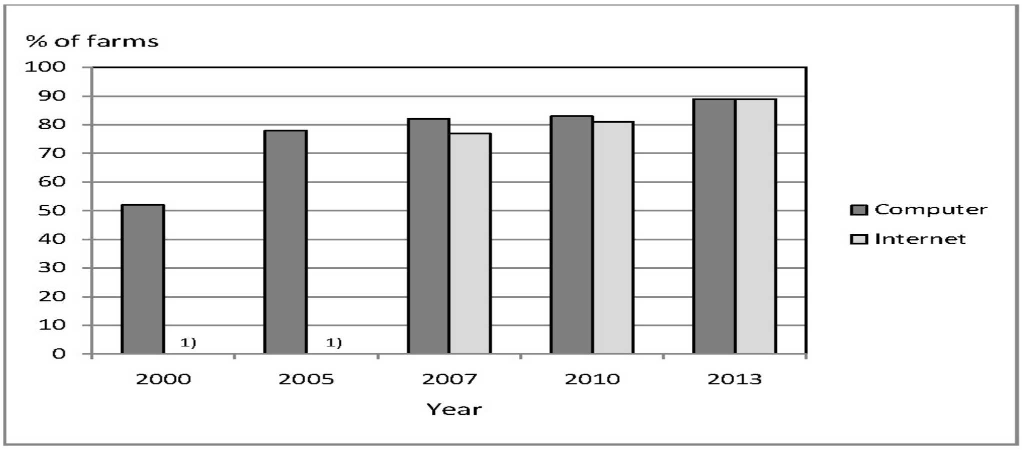
The Finnish agricultural Farm Structure Survey (FSS) has collected information on the use of computers and of theInterneton farms since the year 2000. The FSS covers 30 % of the farms; and in 2010 the survey was conducted as a full census. The composition of the questions will be revised for the forthcoming FSS 2016.

2. Use of computers and the Internet on farms

The use of computers has increased rapidly since 2000, and now almost all farms use computer and the Internet in the running of the farm (Figure 1).

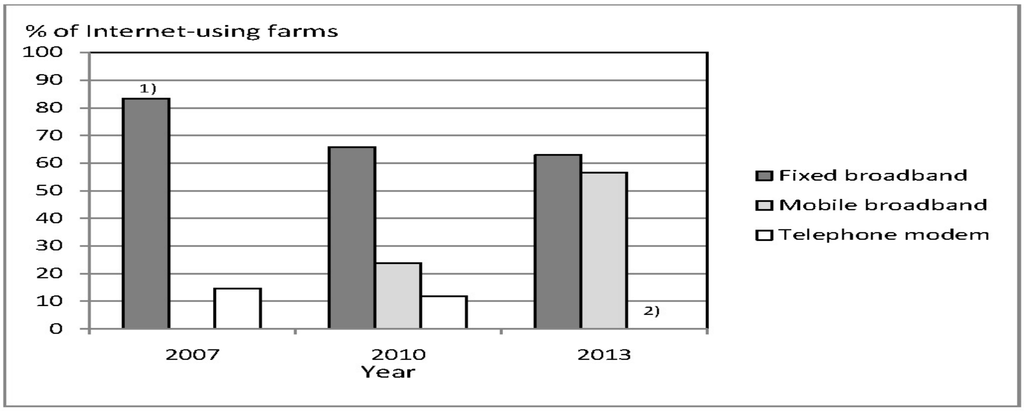
Fixed broadband is still the most common type of Internet connection but the use of mobile broadband has increased to an equal level (Figure 2). Some of the farms use both of the two techniqes. The use of mobile broadband on the farms was lessthan in Finnish enterprises in general. In comparison 68% (2010) and 92% (2013) of all enterprises had a mobile broadband connection to theInternet(Statistics Finland 2010 and 2013).

Figure 1 - Share of Finnish farms that use computer and theInternet.



1) The use of the Internet was not surveyed in 2000andin 2005.
Source: Farm Structure Survey

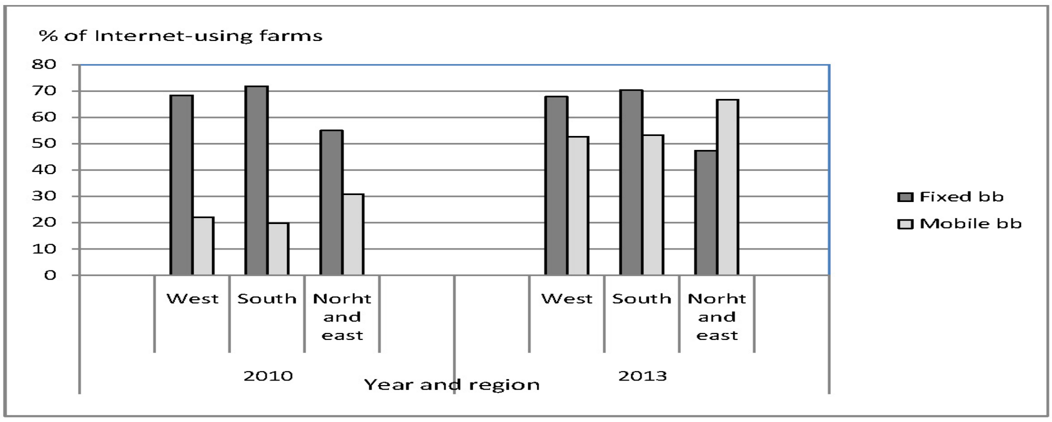
Figure 2 - Use of various Internet access techniques on FinnishInternet-using farms.Multiple techniques may have been used on a single farm.



1) Includes all types of broadband connections used in 2007.
2) The use of telephone modem was not surveyed in 2013.

Source: Farm Structure Survey

Figure 3 - Use of fixed broadband and mobile broadband onInternet-using farms in the regions of Finland (NUTS2) in the years 2010 and 2013.The region "South" includes the NUTS2 region "Helsinki-Uusimaa".



Source: Farm Structure Survey

3. Differences between regions

There are no large differences between regions in the share of the farms that use computer and the Internet.However, the frequency of the use of fixed broadband is lower and that of mobile broadband higher in north and east than in other regions (Figure 3). This may be a reflection of a lower availability of fixed broadband in the more sparsely populated north and east. For some farms mobile broadband is the only alternative, even though in many cases it has been slower and less reliable than fixed broadband.

In the FSS of 2013, the farms that did not use fixed broadband were asked, whether they could subscribe to fixed broadband if they wanted to. In north and east, fixed broadband was unavailable for 57% of these farms, where as in other regions about 40% of the farms not using fixed broadband could not get it. The region north and east differs also for the availability of high-speed fixed broadband for households in 2014: in north and east fast fixed broadband was available for 60 % of households, whereas in south and west these percentages were 72% and 62%.(Finnish Communications Regulatory Authority 2015).

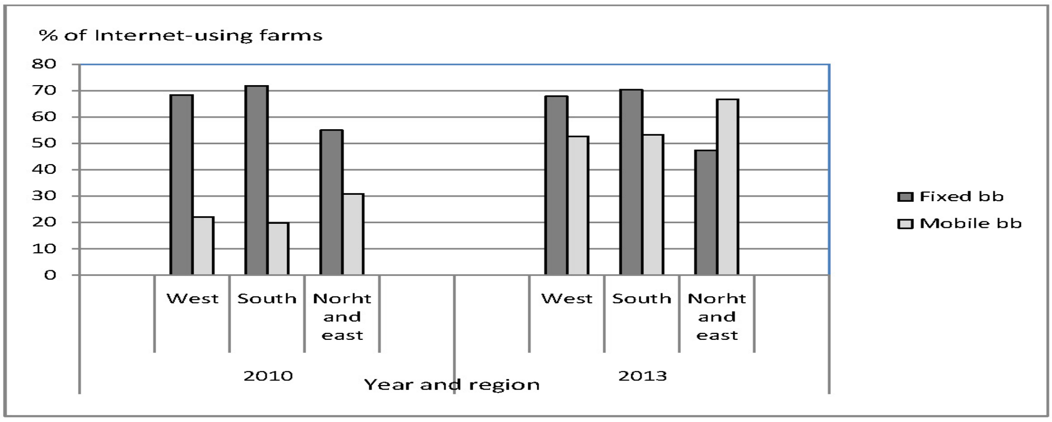
The use of mobile broadband has increased clearly from 2010 to 2013 in all regions (Figure 3). This reflects the increased use of mobile Internet applications as a supplement to fixed broadband.

In north and east, the use of fixed broadband has reduced slightly from 2010 to 2013 (Figure 3). This may relate to the dismantling of fixed telephone network in some areas due to a rapid reduction in the number of fixed telephone connections.

4. Differences between production sectors

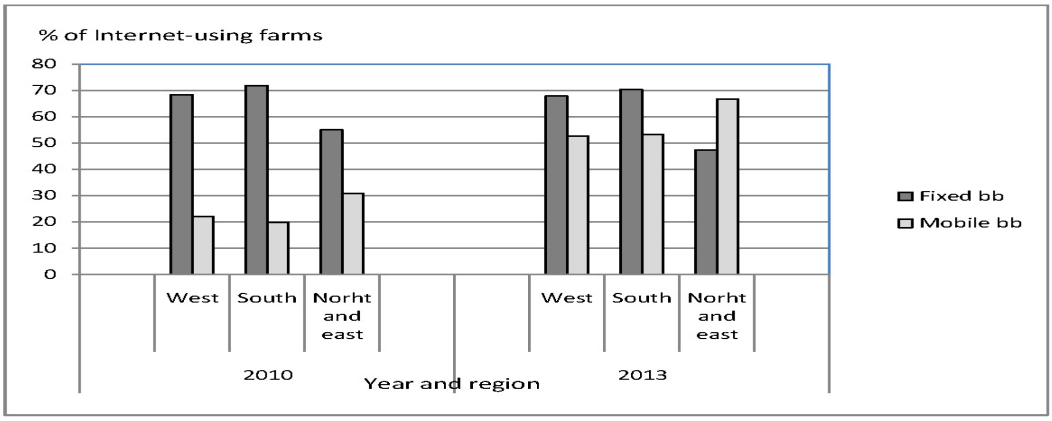
In the comparison of the production sectors, pig and poultry farms seem somewhat more advanced in the use of new technology. In 2010, they had a slightly higher rate in using fixed broadband and, respectively, a lower rate in using mobile broadband. By 2013 the rate of fixed broadband use was still higher on pig and poultry farms and the use of mobile broadband had increased on these farms relatively more than on other farms. Pig and poultry farms may have been somewhat more active in adopting new mobile Internet applications, which is also indicated by a higher rate in the use of mobile phones and tablets (Table 5).

Figure 4 - Use offixed and mobile broadband on Finnish Internet-using farms in the years 2010 and 2013 by selected production sectors.



Souce: Farm Structure Survey

Figure 5 - Devices used to access Internet on Finnish Internet-using farms in 2013 by selected production sectors.



Souce: Farm Structure Survey

Horticultural sector has a little higher rate in the use of mobile phones and tablets compared with cereal and dairy farms (Figure 5). Especially greenhouse enterprises use the newer devices more than average.When looking at all production sectors, it seems that farmers who are younger than the average and more business oriented are more active in using new technology.

5. Use of the Internet in farm surveys and in the application of subsidies

According to the Agricultural Census of 2010, about 80% of the Finnish farms used computer and the Internet in farm management. However, only 57% of the farms that responded to the survey used the web service of the Census while 43% used telephone interview. In the FSS of 2013, less than half of the respondents used web survey.

A study was carried out to investigate the factors affecting the use of theInternet service of the 2010 Agricultural Census in Finland (Unkari 2011). The web service was more likely used by younger and more educated farmers. 31% of the responses were from farms that used computer but did, however, not use the web service of the Census. Reasons for not using the web survey included slow and unreliable Internet connection, insufficient instructions, difficulties in the use of the web survey and a negative general attitude towards surveys.

In the Agricultural Census of 2010, 4% of the respondents declared in the survey that they did not use computer but, nevertheless, submitted their answers in the web service. In these cases, the web service may have been used by a person other than the farmer, such as an advisor, an accountant or a relative. Some farmers may have used a public Internet access, for example in a library.

In the application of farm subsidies, the use of web service has increased rapidly in Finland (Mavi 2016). In 2010, 21% of the applications were made in theInternet, while the percentage was 66% in 2013 and 90% in 2016.

6. Conclusions

The Internet has become an essential tool in farm management as in any other activity where ITC is used. Therefore, the availability, speed and quality of Internet connections will be of the utmost importance. Farms in sparsely populated areas may face a problem here, because supplying the best available connections is not always profitable for the operators in these areas. This is a concern for all activities and has already caught public attention and measures to ensure sufficient Internet connections in all regions.

7. Links to the statistics on the use of computer and the Internet on Finnish farms

Farm Structure Survey 2013

http://stat.luke.fi/en/machines-and-appliances-agricultural-and-horticultural-enterprises-2013_en

Agricultural Census 2010

http://stat.luke.fi/en/agricultural-census-2010-agricultural-census-2010-labour-force_en

E-publication "Agricultural Census 2010 - Agricultural and horticultural labour force" (includes the use of computer and theInternet):

http://stat.luke.fi/e-agricultural-census-labour-force/

Farm Structure Survey 2007:

http://stat.luke.fi/en/farm-structure-survey-2007_en-0

Farm Structure Survey 2005:

http://stat.luke.fi/en/farm-labour-force-decreased-25500_en

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C21

How to analyse the farm structure, how to support innovation by data

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ABSTRACT

Thanks to the natural characteristics of the country, Hungarian agriculture has played an important role in our country's economy over the past centuries and this is still the case nowadays. In 2015 the share of Agriculture in GDP was 3.7 percent. The total gross output of agriculture was more than 2 000 billion HUF, out of which crop production represented 58 percent, animals and animal production 35 percent, agricultural services and secondary activities 7 percent. From the 9.3 million hectares surface area of Hungary 5.3 million hectares are agricultural land area (in the European Union it is only in Denmark that this proportion is higher).

According to the Agricultural Census 2010, in the period of the census 8.6 thousand enterprises (legal units engaged in agricultural activities) and 567 thousand private holdings performed agricultural activity. 54 percent of the enterprises were exclusively engaged in crop production, 6 percent in animal husbandry only, while the proportion of enterprises with mixed activity amounted to 40 percent. The proportion of the different types of activities performed by private holdings differed to some extent. Nearly half (49 percent) of private holdings dealt with crop production, 22 percent with animal husbandry, and 29 percent with both activities. In Hungary the census has been observing for more than 10 years the purpose of the production of private holdings as well. According to the 2010 census data 60 percent of private holdings produced exclusively for own consumption. There has been a change in the proportion of private holdings producing specifically for the market (it increased from 8 percent to 20 percent over the past decade). The rest of the private holdings sold the surplus remaining after own consumption.

The distribution according to the legal forms of farming of agricultural product output provides also important information on the structure and efficiency of Hungarian agriculture. This is especially the case when the proportion of the output is presented for different legal forms of farming, size categories or in the case of private holdings according to the purpose of the farming as well. There are significant differences in farming methods, the use of internet, adopting precision agriculture or incorporating new or improved machinery, etc. by legal forms of farming and size categories.

If a country intends to have a competitive, modern agriculture and make a better use of its natural resources, it is indispensable to form well-trained qualified experts and - as the age of Hungarian farmers is quite high – to promote a change of generation as well. With a view to implementing this change, the Hungarian Association of Young Farmers (AGRYA) in cooperation with Hungarian agricultural statisticians launched 5 years ago a special research. Using the statistical data available (supplemented by special surveys) statisticians analysed the situation, characteristics, innovation of farms managed by farmers under the age of 40. We used for this purpose the databases of agricultural and population censuses, regular statistical surveys (including surveys on social issues too). Two separate publications have been published up to now, the purpose of the presentation is to present the results of the research as well. The collaboration between statisticians and the AGRYA can be an example of how to support decision makers with statistical data, information.

Keywords: structure of agriculture, efficiency, education, collaboration with users

PAPER

1. Introduction

Thanks to the natural characteristics of the country, Hungarian agriculture has played an important role in our country's economy over the past centuries and that is still the case nowadays. In 2015 the share of Agriculture in GDP was 3.7 percent. The total gross output of agriculture was more then 2 000 billion HUF, out of which crop production represented 58 percent, animals and animal production 35 percent, agricultural services and secondary activities 7 percent. From the 9.3 million hectares surface area of Hungary 5.3 million hectares are agricultural land area (in the European Union it is only in Denmark that this proportion is higher).

The distribution according to the legal forms of farming of agricultural product output provides important information on the structure and efficiency of Hungarian agriculture. This is especially the case when the proportion of the output is presented for different legal forms of farming, size categories or in the case of private holdings according to the purpose of the farming. There are also significant differences in farming methods, the use of internet, adopting precision agriculture or incorporating new or improved machinery, etc. by legal forms of farming and size categories.

2. Structure of Hungarian Agriculture

When we analyse the current farm structure in Hungary – for the sake of a better understanding – we have to go back to the period of the change of the political and economic system of 1990. The structural transformation of Hungarian agriculture at the end of the 19th century took place gradually and in various stages. The restitution of the land to the original owners and new applicants was not a smooth process, the transformation of the cooperatives of production and state farms caused considerable loss of assets.

In the 1990-ies different forms of holdings were created, a great number of small private farms with a less viable size emerged. Great part of the state farms and cooperatives were liquidated and replaced by different forms of farming. The change of property did not always entail the change of the type of farming, in many cases the property and use of the land diverged. Different forms of renting or use changed the situation prevailing during previous years, which would not have been a problem if it had contributed to a more rational and rentable form of farming.

The change of ownership of the means of production was in the centre of the changes in agriculture, but it occurred extremely slowly and not always in the most suitable way. The establishment of productive types of farming, the optimal distribution of subsidies were not coupled with sufficient foresight and firmness. The means of production of the previous great farms and the lands were not distributed according to local needs. Many of the newly created holdings – lacking of the necessary means of production – had only a low-level production and quite a great number of farms did not even cultivate the land recovered.

While before 1990 agricultural enterprises for large-scale production were producing on nearly 90 percent of the land, at the turn of the millennium this proportion decreased by half. From 2005 land use of enterprises and companies has been increasing at the expense of private holdings, and other legal forms began to use land. Another characteristic of the processes was that land use of cooperatives (despite the creation of new forms of cooperatives) became negligible.

Land-use according to the legal forms 1990–2015

Year	Enterprises and Companies	Cooperatives	Private holdings	Other	Enterprises and companies	Cooperatives	Private holdings	Other
	hectare				proportion of land area, percent			
1990	2 867	5 147	1 289	..	31	55	14	..
1995	2 593	2 208	4 035	467	28	24	43	5
2000	2 711	1 160	3 902	1 529	29	13	42	17
2005	3 384	462	2 984	1 317	36	5	32	14
2010	3 488	290	3 016	1 144	38	3	32	12
2015	3 404	150	3 263	1 032	36	2	35	11

It was only in 1988 that land use of **private holdings** exceeded that of agricultural enterprises, it was the only year when it reached 50 percent of the territory of Hungary. After the turn of the millennium this proportion began to decline and ten years later the proportion has stabilised at the same level (enterprises and companies 36 percent – private holdings 35 percent). In 2013 – year of the last Farm Structure Survey – the average size of agricultural enterprises was 310 hectares, the land used by private holdings was 5.5 hectares.

3. Structure of Agriculture by type of activity

Although the Statistical System of the European Union classifies holdings according to a defined Typology, in Hungary we use to analyse agricultural holdings three types of farming – more suitable for our domestic conditions – livestock farming, crop farming and mixed production.

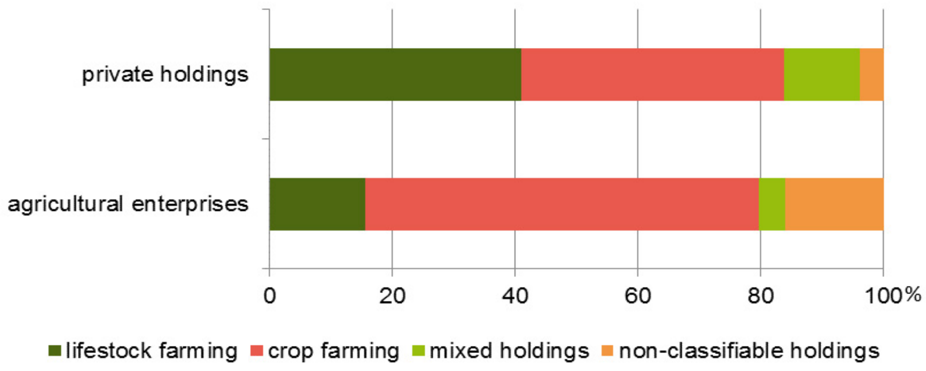
– **Livestock farming** are holdings where only the livestock has reached or exceeded the threshold applied for the census in 2000.

– **Crop farming holdings** are holdings where only land use has reached or exceeded the threshold applied for the census in 2000.

– **Holdings with mixed production** are holdings where both land use and livestock have reached or exceeded the threshold applied for the 2000 census.

In the year 2000, from the existing 5007 **enterprises** performing agricultural activity more than half (52 percent) were engaged in crop production, more than a quarter (28 percent) in mixed production and 20 percent dealt only with livestock production. The distribution of **private holdings** by type of production shows a different structure; while the share of livestock farming is higher, that of crop farming is lower.

Distribution of the holdings by type of production, 2013 (%)



4. Structure of Agriculture by purpose of production

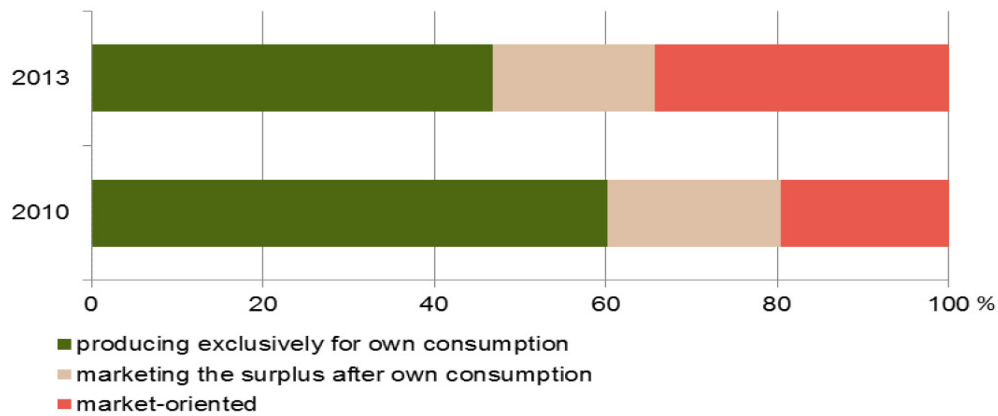
Great number of statistical tools are at our disposal to analyse holdings. **The size of the holdings can also be measured in innumerable ways.** The size of agricultural holdings can be characterized by the size of the area used, the size of livestock, the combination of different indices, labour input, the size of the output, the value of the products or services marketed or the gross value added produced. The – specific – Hungarian agricultural structure requires nevertheless the examination of other aspects as well.

Goods production is tangible, traceable and measurable. But what do we mean in Hungary by goods production? Can we call for example goods production if somebody sells regularly some eggs or some kilos of fruit (which still happens frequently in Hungary)? The answer is probably "yes" from the point of view of the producer/seller for whom it counts, it is a source of revenue, but from an economic point of view such a unit of production cannot be considered as a market oriented holding. It was the reason why we have defined a category such as producers **producing exclusively for own consumption** (these agricultural units are not holdings in the economic sense). In addition to the previous one we have established two additional categories; **holdings selling the surplus remaining after own consumption and the market oriented holdings.**

In the case of **agricultural enterprises** (legal units of production) the purpose of the production is undoubtedly market production, income, even if in certain cases they perform agricultural activity only as a complementary, ancillary activity, but the situation is different for **private holdings**.

For the above mentioned reasons, Hungarian censuses, surveys have been observing for more than ten years the purpose of production of private holdings as well. According to census and survey data, in 2010, 60 percent of private holdings produced exclusively for own consumption (despite the considerable decline of the number of private holdings, this proportion is the same than the one measured during the census of 2000). There has been a change in the number of private holdings producing specifically for the market, in 2010 they represented 20 percent of private holdings, the rest of the private holdings sold the surplus remaining after own consumption.

Distribution of private holdings by purpose of production, 2010-2013 (%)

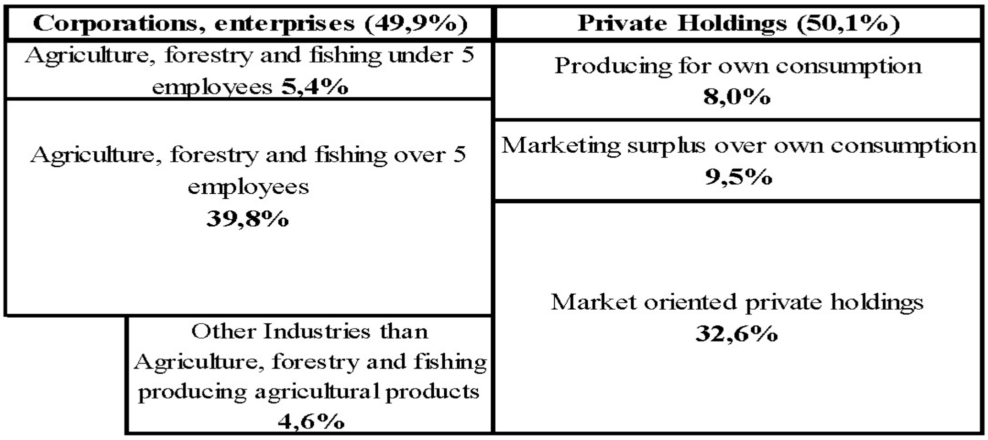


5. Output of Agriculture, efficiency

From the point of view of the analysis of efficiency and productivity the distribution of agricultural gross output by legal forms and use provides valuable information. This is especially the case if we take into consideration the size categories of agricultural enterprises, the output of agricultural activity performed as main or ancillary activity, and in the case of private holdings the output of the holdings producing for own consumption, for the market and selling the surplus.

Since the turn of the millennium the gross output of the two main types of agricultural enterprises (agricultural enterprises, private holdings) has been more or less on the same level. It is not surprising, that in the case of **agricultural enterprises** two third of the output is produced by medium-sized and big enterprises performing agricultural activity as main activity. The picture is more varied if we examine the output of **private holdings** according to the purpose of production. It is not surprising that major part of the output is produced by the market-oriented private holdings.

Share of Agricultural Gross Output by type of organisations, 2013

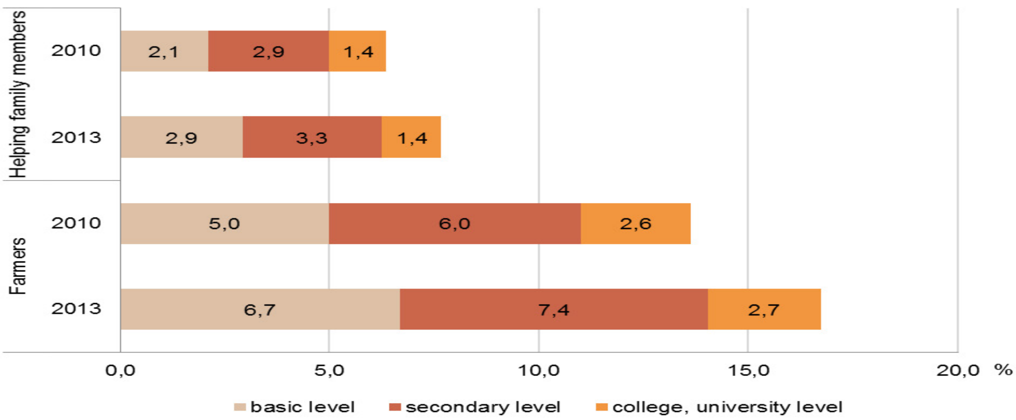


On the basis of the data it is legitimate to ask in the case of which agricultural enterprises efficiency and productivity could be analysed? In my opinion **the analysis of efficiency, productivity makes sense mainly in the case of agricultural enterprises and market-oriented private holdings**. This does not mean of course that we don't have to analyse the output of private holdings producing for own consumption, or selling the surplus, but in their case the focus should be more on the place and role they have in society with special emphasis on social questions.

6. Ageing, education

In Hungary the **age structure and qualifications** of Hungarian farmers reach the critical level. Despite all the efforts, the age composition of persons engaged in agricultural activity has not improved in the past years. In 2013, 31 percent of the farmers performing agricultural activity were above the age of 65, the proportion of farmers under the age of 35 was hardly superior to 6 percent. Similar efforts are needed to improve **the qualifications of farmers** as well. In 2013 only 3 percent of the farmers had college or university degree, the proportion of farmers with secondary school degree was also low (7 percent), the majority of the farmers performed agricultural activity relying on their practical experiences. The specialized (agricultural) qualifications of the persons employed in agriculture is also below the expectations and it has not been changing significantly.

Proportion of persons with agricultural qualification in private holdings



7. Technology of agricultural production

In the case of EU member countries Farm Structure Surveys (FSS) constitute the backbone of statistical data related to agriculture. The FSS system is composed of full-scope censuses carried out every ten years and sample surveys conducted every three years. Among the data surveyed, there are data which are surveyed in each case, but there are also data that are surveyed less frequently, there are additional modules in some cases. The latest case refers for example to the observation of technology of production. Due to our natural conditions I would highlight one important issue which is the irrigation.

In the case of irrigation only enterprises belonging to the bigger size categories possess irrigable areas. Irrigation equipment of higher capacity is mainly available in agricultural enterprises. Orchards have the highest proportion of irrigable area, but even this remains still below the ideal level.

8. How to support innovation by statistical data

Data on the Hungarian agriculture prove undoubtedly that further analyses, further proposals are necessary in relation to farm structure, the efficiency of farms, the age structure and qualifications of farmers, the technical background of production. The analysis of FSS data revealed in Hungary that young farmers, AGRYA could be the "flagship" of innovations and development. In Hungary 13 percent of private farms are managed by farmers under the age of 40. In their case the average size of the farm, qualification, the technical conditions of agricultural production, the efficiency of the production are more favourable than the average. The analysis of this situation led to establish a fruitful cooperation between statisticians and the AGRYA.

The AGRYA in cooperation with Hungarian agricultural statisticians launched 5 years ago a special research program. Using the statistical data available (supplemented by special surveys) statisticians have been analysing the situation, characteristics, innovation of farms managed by farmers under the age of 40. The statisticians and the AGRYA used for this purpose the databases of agricultural and population censuses, regular statistical surveys (including surveys on social issues as well). Two separate publications have been published up to now on the structure of Hungarian agriculture, social and market aspects of production focusing on the most intensive branches of agriculture like horticultural production. The collaboration between statisticians and the AGRYA can be an example of how to support decision makers with statistical data, information.

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C21

Farm Structure: Towards an Integrated Classification Framework and Typology

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ABSTRACT

Numerous experiences show the value of developing classifications of farms based on structural characteristics to better design and evaluate policy. Specifically, farm typologies provide policy makers a better understanding of the evolving diversity of agricultural holdings to more efficiently target policies. Such tools are widely used in the European Union and the United States but are less common in developing countries. In addition, cross-country comparisons are key to informing dialogue at regional and international levels but require enhanced harmonization of existing information. Session IDCB 5 in the ICAS VI provided an introductory look at how various countries quantify structural change in agriculture. The Global Strategy to Improve Agricultural and Rural Statistics (GSARS) has started to systematically identify the core data that should be available. Beyond this, there is no common theoretical and empirical framework to monitor and analyze the diversity of agricultural holdings and their transformations. Yet, such a framework could provide national policy makers a comparative or relative vision of various local and national contexts, while serving as an evidence-based resource to inform policy dialogue at an international scale. To respond to such issues, the GSARS, together with the World Agricultures Watch (WAW) and international experts, is developing an international framework for characterizing agricultural structure to support countries as they develop comparable typologies to inform policy dialogues and improve monitoring at national and international levels. This paper summarizes the progress to date in working towards an international harmonized typology framework.

Keywords: Farm classifications, Typology, Agricultural Structural Change, Policy

PAPER

1. Motivation and Efforts to Create a Policy-Relevant Farm Typology

Rapid changes are occurring in agricultural supply chains worldwide and are directly connected to transformations in agricultural structures. Changes are impacting the structure of agriculture at all levels of capacity, but oftentimes, structural changes impact the most vulnerable who control fewer assets and have difficulties in managing risks. Rapid structural changes and attention to contemporary issues—such as sustainability, food safety and nutrition, and equity—amplifies the need for policy makers to carefully consider the diversity of holdings and transformations they may experience in the context in which they operate.

Numerous experiences show the added value of developing farm typologies to analyze, summarize and better understand the evolving diversity of agricultural holdings to better design and evaluate policy.[1] Such tools are widely used in the European Union and the United States but are less common in developing countries. In addition, cross-country comparisons are key to informing dialogue at regional and international levels but require enhanced harmonization of existing information. Session IDCB 5 in the ICAS VI provided an introductory look at how various countries quantify structural change in agriculture. The Global Strategy to Improve Agricultural and Rural Statistics (GSARS) has started to identify systematically the core data that should be available (FAO, 2010). Beyond this, there is no common theoretical and empirical framework to monitor and analyze the diversity of agricultural holdings and their transformations. Yet, such a framework that provides national policy makers a comparative or relative vision of various local and national contexts, while serving as evidence-based resources to inform policy dialogue at an international scale is largely missing.

[1] In addition, typologies have been developed for a variety of purposes outside of agriculture. (See Saravia-Matus, et al., 2015, for an extensive review of typology development and methods.)

In order to fill such a gap, the GSARS, together with the World Agricultures Watch and international experts, is developing an international framework for characterizing agricultural structure based on key domains of structure to inform policy dialogues and improved monitoring at national and international levels. The guidelines will also provide reference points for countries, to facilitate progressive harmonization of concepts, classification and reporting systems.

As a first step, an extensive literature review was completed and highlighted a series of domains common to most existing international, national and regional typologies (Saravia-Matus, et al., 2015). In October 2015, an international expert group was formed with recognized experts bringing various technical and geographical expertise to consider key dimensions to be taken into account in the typology guidelines. In January 2016, a first concept paper (Ahearn, et al., 2016) was reviewed by the international Scientific Advisory Committee of the GSARS. Following the meeting, a parallel process has been undertaken to combine the production of an international typology informed by the recent release of the Sustainable Development Goals (SDG), and a country-driven process to develop nationally relevant typologies from a set of relevant policy domains.

In this paper, we outline the progress to date in the development of a harmonized classification system. First we review the major policy issues facing decision makers that are relevant to a classification system. Next we consider the classes of characteristics—or as referred to here, domains—that can best capture the most important policy considerations. Upon these domains, a harmonized system will be developed, including consideration of the critical underlying questions that must be addressed in light of the ongoing and future transformations of farm structure. We then consider the potential for an integrated international and national typology drawing on these domains and showing the challenges and options for such a framework. We also consider a country-driven process, based on a flexible framework targeted to support nationally relevant typologies. Finally, we conclude with the next steps in the development of a harmonized farm classification system.

2. Need for a Typology and Domains of Structure

2.1 Common Critical Policy Issues

The policy challenges are recognized to be multi-faceted, including challenges exogenous to agriculture. In addition, there is a diversity of farms with different challenges, contexts, and contributions, which contribute to their different responses to policies and market signals. Policy objectives and priorities may vary over time and place as a result of this diversity. Due to the multiple and inter-related objectives of policies, there is a corresponding need for a farm typology framework that goes beyond a single dimension—such as farm size measured in hectares of land—for informing those policy maker decisions. The recognition of the integrated nature of multiple objectives has increased the interest—and frankly the need—for policy makers to have the benefit of statistical frameworks that simultaneously consider a variety of measures of farm structure in the development of a typology. In a globalized economy, it is useful to both international and national decision makers to have a common framework in which to consider the diversity of farms. The most recent example of the value of an international perspective is evident in the wide interest in the Sustainability Development Goals (SDG).

2.2 Policy Relevant Domains

The preferred approach to typology development at the international level, and perhaps national, is through a deductive process, rather than a multivariate statistical approach.[2] The deductive approach consists in defining types on the basis of pre-selected domains of characteristics and specified levels, identified by expert knowledge, literature reviews, and/or a specific policy objective/focus. Ahearn, et al. (2016) identified an expansive list of domain characteristics of agricultural holdings and households that could be considered as core concepts in the conceptual framework include the following:

- Legal Status/Management (household or corporate/cooperative/other),
- Dependence of the holding on family labor
- Off-farm Work/Pluriactivity of household member(s)
- Extent of marketing (compared to self-consumption)
- Commodity specialization (could be defined in various ways, e.g., food or cash crop, or based on specific commodity),
- Farm Size (measured in either area or value of production),
- Gender
- Access, and the form of access, to assets or capital
- Origin of the capital and its intergenerational transfer

[2] It may be preferred by some stakeholders that a typology be developed using multivariate statistical analysis, rather than a deductive process. Saravia-Matus, et al. (2015) review alternative approaches.

According to FAO (1999) devising an appropriate typology begins with a declared operational interest: trying to simplify the heterogeneity of the farms through the identification of groups or types defined under a core set of traits and presenting similar potential and experiencing similar problems. Such key traits have been identified above as core concepts but require further organization into domains of interest. For this purpose, we identify thematic domains that may guide farm typology building: Legal Status, Economic Size, Product Mix and Input Use, and Human Capital and Household Characteristics. These domains connect to a series of distinguishing criteria and their policy relevance (Table 1).

Table 1 - Typology Thematic Domains

Thematic Domain	Main Distinguishing Criteria	Policy Relevance
Legal Status/Management Starting point for the international typology. National typologies may also use this domain as starting point, depending on typology objectives.	Legal status is designated and varies across countries	Only a small share of farms are designated as corporate farms even in developed countries, however, they account for a disproportionately large share of output and they have been a growing share over time. Furthermore, this designation is used in the System of National Accounts, and so an indicator is likely to be available at least at a macro level.
Farm Economic Size Recommended as the starting point for national typologies, but may vary according to national policy interests.	Economic value of agricultural output (e.g., including self-consumption and sales)	By considering an economic size indicator which captures total agricultural income generating capacity (including self-consumption and sales), it is possible to compare farms involved in widely diverse agricultural activities. While it is useful to know the extent of self-consumption relative to sales, rather than refining the typology classes, this information may be provided as part of the reporting of statistics by typology group. Farm size distribution measures are generally available for most countries; hence this availability will facilitate monitoring trends.
Production Mix and Input Use Since commodity mix varies significantly by country, aggregations will vary significantly in national typologies, and will be major categories in international types.	Commodity mix, specialization, input use and production practices, and access to land and capital	Production level information is a basic indicator for policy since many farm policies and marketing options are commodity-specific. It also incorporates information on physical capital, technology and agronomic practices. Thus this domain allows for the evaluation of production efficiency and access to factors of production (other than labor, treated in last domain). Input use and production practices are relevant to agri-environmental indicators.
Human Capital and Holder(s) Household Characteristics For national typologies focus on gender and the family farming sector may be of specific relevance.	Farm Labor Usage (Working time on Holding for family & employees) Working time and income from family working off-farm. Total family income from farm and off-farm sources. Market Orientation Gender	This domain is important for policies focused on both farm production and farm family well-being. It brings more visibility to emerging international policy agendas, such as the SDG, and national agendas that focus on specific categories such as: small scale family farms, female-headed households, young farmers and selected ethnic groups. Data to measure specific labor information are at times missing (particularly off-farm working time and income), but due to their policy importance they are now included in core data goals and their availability is expected to increase.

3. Organization of Domains into International and National Typologies

It is important that a typology have a balance between a framework that offers a harmonized classification system and that offers value in differing contexts and under a variety of policy goals. The organization of the domains into typologies for international and national purposes is expected to differ. The international typology will be guided by common agricultural, economic, social, and environmental issues, such as those captured in the SDGs. The national typologies will be guided by unique national priorities, especially those focused on improving the well-being of the population and the farm and household structure.[3] Consequently, the organization of the policy domains will differ, but the goal is to provide a typology organization that can link the many national typologies to the international typology, or perhaps a family of international typologies. A useful transition between national and international typologies would be the regional typology, like for example the typology built in the European Union, allowing for regional comparisons and common analyses.

3.1 International Typology Development

Different challenges in developing a useful typology for agriculture are amplified when the scope of analysis extends to the international context. Although there is significant diversity in agricultural structure across and within countries, basic agronomic relationships and an increasingly globalized marketplace bring some commonality to the challenge. Similarly, there are some socioeconomic characteristics that are common to countries regardless of stage of development. In particular, first, it is worth noting that agriculture in all countries is dominated by family control and management and, secondly, nonfarm employment is important in sustaining family farms across the globe. Finally, the wide acceptance of the SDGs brings agreement to the multiple policy goals that will drive an international typology.

One logical difference between an international typology and a national typology may very well be the starting point, or highest level of classification. In particular, an international typology may logically begin with a distinction based on legal status, that is, non-corporate family holdings and corporate holdings, whereas a national typology may not. This is because, first, large multinational firms increasingly entering the supply chain tend to have a corporate organization. Such a distinction may be less critical for a national typology because of the absence of much market presence by multinational firms. But, understanding the variation and growth of corporate activity spatially across the globe may be of significant interest in an international typology. It is these large holdings that further complicates classification and data collection because they often have a complex organizational structure, for example, to manage risks and reduce taxes. Furthermore, many distinguishing characteristics related to the family of the holding may be irrelevant in a corporate holding. For example, the off-farm income of corporate holdings or the gender of the corporate board would be irrelevant. Hence, in an international typology, it is necessary to recognize that different domains will be employed below the legal status distinction.

Finally, in the interest of consistency with statistical guidelines, the legal status is a useful entry point in an international typology because it is compatible with the U.N. System of National Accounts and is, therefore, commonly available.

3.2 National Typology Development

Since national typologies will be guided by national goals, inclusive multi-stakeholder interaction about the design of a country-specific typology is critical.. However, a likely key entry point in national typologies is an economic size criterion or a total family income criterion. Depending on the overriding policy focus of a nation, the entry level of a national typology could focus on either (1) the farm economic size indicator (based on total agricultural income including sales and self-consumption or similar) or (2) the total family income indicator provided agriculture is considered the main income source. Under either scenario, units will be classified as below or above the selected threshold. Regardless, additional distinguishing criteria are to be integrated in order to identify relevant national types. It is instructive to examine an empirical case for a national typology. In the case of El Salvador (Guanziroli, 2016) In this particular instance, there was a policy interest to distinguish family from non-family farming sectors as a first step, so the universe of farms was first disaggregated in such terms using both legal status and family labor information. In addition, country-relevant thresholds were chosen for selected key indicators of distinguishing criteria within the class of family farms, such as:

- total agricultural income, with four levels – high, medium, low and very low;
- market integration, with 3 levels – Commercial (more than 2/3 of the production is commercialized); transitional (less than 2/3 but more than 1/3 of the production is commercialized) and subsistence.

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[3] The development of typologies for farm households in developing countries should recognize that different "types" may be relevant for different development trajectories (e.g., see Fan, et al. 2013).

- Specialization, with three levels according to the presence of a main product in total output – specialized (+70%), semi-diversified (30-70%), diversified (less than 30%);

- And technological , with three levels based on the relative usage and proportion of variable inputs: intensive (over 50%), semi-intensive (30 to 50%) and low intensive (less than 30%). This is the first step to engage in crossings of distinguishing criteria that can lead to highly policy specific farm types.

That is, it is possible to identify specialized family farms with high income and technological level on one hand, and the poorest and less marketed integrated family farms with diversified portfolios and reduced used of inputs on the other hand. The advantage is that all farm types in the middle of such a continuum may also be well targeted.

4. Conclusions

International and national typologies are expected to provide new insights into agricultural transformations. For example, it will be possible to assess phenomena related to challenges within the agricultural sector, including agricultural feminization, so-called land grabbing, rural economic diversification, etc. Farm typology development rests on established general statistical frameworks and specialized frameworks focused on agriculture and rural areas.

However, the proposed development faces a variety of challenges, including data availability, complex organizational forms, and capacity building. Furthermore, addition of an agri-environmental dimension faces significant hurdles since natural resources and policy priorities are often specific to local areas, but a typology will benefit from the significant efforts that are being invested for other purposes. More in-depth analysis is needed on the variation in the definition of a farm, land tenure systems, and off-farm work income. It is essential that typology development engage with multiple stakeholders, including those closely associated with policy development, in order to ensure that typologies live up to their potential to become a valuable tool in policy making.

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THEMATIC SET

MEASURING THE EVOLUTION OF FARMING PRACTICES

C22

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ABSTRACT

Farming practices play a fundamental role for the promotion of food security and safety and overall agriculture development. Changes in farming practices involve several actors in the food chain, from input producers, farmers, agribusiness and food enterprises to research, extension and rural development services. There is a wide range of technology options available which are often difficult to classify. There is the need to select appropriate measure indicators and identify data requirements and gaps in available statistics. The session will discuss criteria and quantitative indicators related to the development, adoption and implications of changes in farming practices. Specifically, the session will focus on the following areas: 1. Drivers to change agriculture practices: environment and climatic conditions, resource availability, policies and institutional factors, markets and food chain dynamics, access to input and technological knowledge, effects on factor productivity, technological innovation, research results 2. Actors in the development and adoption of new farming practices: research and extension services, NGOs, firms in the agri--food chain, farmers (adopters and involved in participatory research) 3. Implications of farming practices adoption: resources use, climate change adaptation/ mitigation and risk management, substitution effects among inputs, environmental protection (e.g. reduced pollution), farmers income and welfare, food security and safety, rural development. The session will welcome thematic papers focusing on these three areas. Methodological studies concerning constraints and difficulties for farming practices measurement and classifications such as data gaps/needs (data typologies, data collection) and implications for Institutions involved in agriculture statistics will be welcome as well.

LIST OF PAPERS

Intensity of adoption of agricultural innovations in risky environment: the case of corn producers in West-Cameroon

P. Koncy Fosso | University of Douala, Faculty of Economic Sciences and Applied Management | Douala | Cameroon

DOI: 10.1481/icasVII.2016.c22

How has farming practices affected the cereal production in Morocco?

A. Mansouri | High Commission for Planning | Rabat | Morocco

DOI: 10.1481/icasVII.2016.c22b

Evolution of farming practices in the French vineyard The use of pesticides 2006-2013

J. Pujol | Ministry of agriculture, food and forestry Office for Statistics and Prospective Complexe agricole d'Auzeville | Castanet-Tolosan | France

DOI: 10.1481/icasVII.2016.c22c

Climate-smart agriculture practices in Zambia: an economic analysis at farm level

G. Branca | Dipartimento di Economia e Impresa, Tuscia University | Viterbo | Italy
A. Paolantonio | International Fund for Agricultural Development, IFAD | Rome | Italy
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M. Kokwe | FAO Representation in Zambia | Lusaka | Zambia
L. Lipper | CGIAR Independent Science & Partnership Council (ISPC) | Rome | Italy
DOI: 10.1481/icasVII.2016.c22d

The set of indicators for assessing progress achieved under the National Action Plan for the sustainable use of plant protection products, in Italy

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S. Lucci | ISPRA - Italian National Institute for Environmental Protection and Research | Rome | Italy
L. Segazzi | ISPRA - Italian National Institute for Environmental Protection and Research | Rome | Italy
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DOI: 10.1481/icasVII.2016.c22e

C22

Intensity of adoption of agricultural innovations in risky environment: the case of corn producers in West-Cameroon

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ABSTRACT

This study identifies factors that affect the intensity of use of improved maize seed and chemical fertilizer, the main modern inputs used to produce maize in West-Cameroon, by producers in West-Cameroon. The multivariate tobit model is used to take account of correlation between the disturbances. Results mainly indicate that the perception of risks is an impediment to a simultaneous adoption of agricultural innovations such as improved maize seeds and chemical fertilisers by corn producers in West-Cameroon and that, as a consequence, the price of corn has no effect on the intensity of use of modern inputs. We conclude that policies aiming at setting up sustainable risks management could greatly promote the adoption of agricultural innovations by farmers of the western region of Cameroon in general and probably by their peers in other regions of this country.

Keywords: Intensity of use of agricultural innovations; Multivariate Tobit model; Risks; West-Cameroon.

PAPER

1. Introduction

Despite the fact that agriculture is a very risky activity, it continues to be a fundamental instrument for sustainable development, poverty reduction and enhanced food security in developing countries. It is a vital developmental tool for achieving the Millennium Development Goals. However, Africa faces huge food supply challenges due to increasing human population, limited opportunities to increase arable land, and declining yields associated with continually declining soil fertility. Currently, agricultural productivity growth in sub-Sahara Africa lags behind that of other regions in the world, and is well below that required to achieve food security and poverty goals (Morris, 2007). Increasing agricultural productivity in Africa is an urgent necessity and one of the fundamental ways of improving agricultural productivity is through the introduction and use of improved agricultural technologies.

In Cameroon as in most countries of sub-Saharan Africa, although agriculture is a predominant sector, there is a low adoption of agricultural innovations, particularly among producers of food crops (INS/ECAM 3). In this regard, this paper analyses the determinants of intensity of adoption of improved maize seeds and chemical fertilizers by farmers (especially corn[1] producers) in western Cameroon. This is aimed at providing an empirical basis that would guide effective programs to promote agricultural innovations use[2] in Western Cameroon. A study on the intensity of adoption of agricultural innovations being more complete than that which is only limited to the examination of the adoption decision, then, while introducing the risks, this paper analyses the factors influencing the intensity of use of modern inputs by corn producers in West-Cameroon.

Although there is a well-developed literature on the impact of a host of explanatory variables on technology intensity adoption (Eba and Bashargo, 2014; Arslan et al, 2014; Turinawe et al., 2014), there is a dearth of the analysis which provides new evidence on policy relevant variables such as prices (particularly the price of output) and risks. In fact, facing some economic incentives such as the rising price of output, some atypical behaviours of producer (i.e. negative or absence of production/input demand response to output price incentives) in developing countries can be better explained only if risks are introduced in the analysis.

[1] This interest for corn stems from the fact that it is among the main food crops that is most consumed in Cameroon. Indeed, almost 67% of Cameroonians consume corn, about 12 million people; corn is also used in animal feed and in industry (ACDIC, 2008). In addition, maize is consumed in all regions of Cameroon. It should also be noted that today, this product is also used to make energy (corn is a bio fuel).

[2] A survey of 564 corn producers in West-Cameroon indicates that the intensity of the use of agricultural innovations is very low in this region.

Even if Asfaw et al. (2011) and Beshir (2013) take into account risks, they don't take into account the interdependence of adoption of agricultural innovations.

The contributions of this paper are twofold: First, in this study, farmers' perceptions of different types of risk are introduced in the list of factors influencing the intensity of adoption of agricultural technologies. We also introduce prices, particularly the price of output (here, the price of corn) as a driver of adoption. Second, we provide a rigorous analysis of the interdependent adoption of agricultural innovations by using a simultaneous equation Tobit model for estimating the intensity of technologies adoption.

The remainder of the paper is organized as follows: data and methods which are discussed in section 2; section 3 presents and discusses the results and section 4 concludes.

2. Materials and methods

2.1. Study area and data collection

This study was conducted in West-Cameroon, one of the ten regions of Cameroon. This region is known to be the barn of Cameroon since it is the main production area of food crops, especially corn. Corn production in West-Cameroon is estimated at nearly 20% of national production of corn (MINADER, 2012). West-Cameroon is divided into eight divisions among which four distinguish themselves in terms of maize production by their high density of production. These are: Hauts-Plateaux, Koung-Khi, Mbamboutos and Mifi.

According to the divisions of the Central Bureau of Census and Population Studies in Cameroon (BUCREP), regions in Cameroon are divided into divisions which are also divided into subdivisions, which in turn are subdivided into Enumerated Areas[3] (ZD) with known geographical boundaries. It is on the basis of these divisions that we gather our sample.

Data were collected in 2012 using the three-stage sampling technique. At the first stage, subdivisions with the highest density in maize production were selected from the four highly dense divisions in maize production, making a total of seven subdivisions. At the second stage, and on the basis of BUCREP's cartographic maps, we randomly selected from the selected subdivisions and in proportion to the population size, 25 ZD among the 282 ZD in the urban area and 17 ZD among the 291 ZD in the rural area. At the third stage, 11 corn farmers were randomly selected from each urban ZD selected and 17 corn farmers in each rural ZD selected. This choice was made in such a way that the number of producers surveyed should be the same in the rural and urban areas. The sampling process ended up with a sample of 564 corn producers. According to the formula of Cochran (1977), this sample size should be sufficient for this study.

Six students trained for this survey were used for data collection. These students were divided into two teams of three. Every day, each team had to go to one selected ZD and within the ZD, they would select, using the systematic sampling method, households (in each household, the surveyor would interview the farmer with the aid of a questionnaire) by steps of 18 households in urban ZD and by steps of 11 households in rural ZD.

Data were collected on the socioeconomic characteristics of the farmers[4] and their farm, the use of agricultural innovations such as improved seeds and chemical fertilisers, farmer's corn selling price during the year preceding the survey and the perception of risks by farmers.

2.2. Modeling and description of variables

As Arslan et al. (2014), Eba et Bashargo (2014) and Turinawe et al. (2014) we employed the Tobit model to examine the intensity of adoption of various technologies. But, in contrast to these authors, especially the work of Arslan et al. (2014) and Turinawe et al. (2014) which various technologies had been examined as in ours, we took into account possible inter-relationships between the various practices by using a simultaneous equation Tobit model for estimating the intensity technologies adoption. In fact, the adoption decision of the farming household for any one practice does not rule out the adoption of the other available practices, but as noted by Isgin et al. (2008), the adoption of a given technology might not be independent of another since the effects of certain technologies might be complementary.

In this paper, we adopt a multivariate Tobit econometric technique to estimate simultaneous equation Tobit model. The Multivariate Tobit model is estimated by maximum simulated likelihood that uses the Geweke-Hajivassiliou-Keane (GHK) simulator.

The intensity adoption equations for each modern input can be represented by:

$$y_i^* = X_i \beta_i + u_i \quad i = 1, \ldots m \text{ (in our case } m = 2\text{)} \qquad (1)$$

[3] An enumerated area is a geographical area that can accommodate approximately 200 households.

[4] In this study, a farmer is a person who operates a farm (farm owner). A farm owner or a farmer is not necessarily the owner of the land where he cultivates.

where y_i^* is a latent variable representing the intensity of adoption of the agricultural innovation i (y_i), X_i is a vector of exogenous variables (These variables are presented in Table 1), β_i is the vector of parameters to be estimated and u_i is a random disturbance with mean zero and variance σ_i^2. The relationship between the latent variable y_i^* and the intensity of adoption for a modern input i (y_i) can be represented by:

$$y_i = y_i^* \;\; if \;\; y_i^* > 0 \qquad (2)$$
$$= 0 \quad \text{otherwise.}$$

Table 1 - Variables definition and descriptive statistics (N=564)

Variables	Variable names	Measure	Mean	Standard deviation
Dependent variables				
intsam	Intensity of use of improved maize seeds	percent of area planted to improved maize seeds	12.906	28.644
intanch	Intensity of use of chemical fertilisers	quantity of fertiliser (in gram) applied per m^2	10.278	14.996
Independent variables				
riskmala	Perception of risk of illness or death of a key member of the household	1 if a risk, 0 otherwise	0.521	0.500
riskprix	Perception of risk of decline in the price of corn	1 if a risk, 0 otherwise	0.943	0.232
riskphyt	Risk perception of pest-disease infestations	1 if a risk, 0 otherwise	0.568	0.496
riskclim	Perception of climate risk	1 if a risk, 0 otherwise	0.941	0.235
riskfina	Risk perception of default to finance a crop production	1 if a risk, 0 otherwise	0.334	0.472
dist_ch	Average distance from the farmer's home to the farm	Distance in kilometres	11.664	
fem	Gender of farmer	1 if the producer is a woman, 0 otherwise	0.824	0.381
fertilbais	Evolution of the farmland fertility over the past 5 years	1 if the farmland fertility has declined, 0 if soil fertility has not changed	0.237	0.426
fertilhaus	Evolution of the farmland fertility over the past 5 years	1 if the farmland fertility has increased, 0 if soil fertility has not changed	0.248	0.432
primary	Educational level of farmer	0 if no education, 1 if has primary education level	0.420	0.494
secondary	Educational level of farmer	0 if no education, 1 if has secondary education level or higher	0.374	0.484
credit	farmer's credit access	1 if access to credit, 0 otherwise	0.342	0.475
div-act	Exercise of the non-agricultural activity by the farmer	1 if has a non-agricultural activity, 0 otherwise	0.404	0.491
asso	Farmer participation to a producer organisation	1 if adhere to a producer organisation, 0 otherwise	0.688	0.464
propr	Ownership of land cultivated	1 if owner, 0 otherwise	0.894	0.309
experience	Agricultural experience of the farmer	Number of years during which the producer has been engaged in corn production	23.608	14.184
experience2	Agricultural experience of the farmer squared	Number of years during which the producer has been engaged in corn production (squared)	758.175	791.978
tailmenag	Household Size	number of persons in the household	6.596	3.056
dist_mark	Average distance from the farmer's home to usual market	Distance in kilometres	2.026	2.320
super	Farm size	Acreage (in m^2)	11493.010	10652.460
pmoy	Average sale price of a kilogram of maize	Amount in FCFA	140.971	45.757
tauxsal	Cost of labour	Amount in FCFA/week	10508	5994
revenu	The annual income of the farmer	Amount in FCFA	598351	1169125
rural	Area	1 if rural area and 0 if urban area	0.5124	0.500
coutfiente	Cost of 50 Kg of manure	Amount in FCFA	1757.307	431.015

Note: In this study, the farmer is the interviewee.

Regarding dependent variables, we examined in this study two main modern inputs which are used to produce corn in western Cameroon, these are: improved seeds of maize and chemical fertilisers. We noted that in average, farmers used 10.278 gram of fertiliser per m^2 and allocated only 12.906 % of their cultivated land to improved seeds. Among those who used chemical fertilisers on their corn, 15.2 grams on average of chemical fertiliser[5] were applied per m^2 of land; which is well below the average quantity regularly recommended for corn in western Cameroon (i.e. 20 to 30 grams per m^2 (IRAD, 2010)).

Table 1 shows that about 82 percent of surveyed farmers were female[6], 89.4 percent owned their lands[7] and about 50 percent reside in rural zone. 42 percent of survey farmers had primary education level while 37.4 percent had secondary education level or higher. The average size of farm was about 1.15 hectares and the farmer's average annual income was about 598,351 FCFA (about 1,196 US $). In average, maize price was about 140 FCFA, the cost of labour and manure were about 10,508 FCFA and 1,757 FCFA, respectively.

Regarding risk variables, in this study, as in the works of Glynn et al. (2009) and Kurihara et al (2014), the perception of farmers of the importance of events that could have a negative impact on their income will be retained as a means of quantifying the principal risks which farmers face. In fact, this perception of risk by the producer is nothing more than an assessment by him of the risk in terms of probability that risk has a negative impact on his income. So, to capture farmers' risk perception, farmers were asked to score their perception of the importance of events/shocks that could have a negative impact on their income based on previous shocks (on a scale of 1 to 5; where 5 signifies high negative impact on their income).

[5] Chemical fertiliser most used in western Cameroon is the composite variety 20-10-10.

[6] This is in conformity with national estimations which reveal that Cameroonian women accomplish more than 75 % of agricultural work and contribute for 60 % of food production (FAO, 2007).

[7] In the western region of Cameroon most of the land belongs to families and all family members including women claim to be co-owners of land.

This variable is converted into a dummy variable, where 1 indicates that there is a risk perception and 0, the absence of risk perception. Because this method of quantification of risk does not require either knowledge of the probability distribution of the loss of income, nor the values of those potential losses that may be incurred by the producer, this method will be used to capture the main agricultural risks which farmers face.
As regards statistics of the risk perception variables, we noted that farmers that perceived risk was 52.1, 94.3, 56.8, 33.4 and 94.1 percent for risk of illness or death of a key member of the household, for risk of decline in the maize price, for risk of pest-disease, for risk of default to finance a crop production and for climate risk respectively.

3. Results and discussion

The significant effect of the perception of some risks (see Table 2) indicates that the econometric specification in an uncertain environment is most appropriate. Table 2 presents the econometric results concerning variables influencing the intensity of adoption of agricultural innovations by corn farmers in western Cameroon. The likelihood ratio test [chi2(1) = 2.95456, Prob → chi2 = 0.0856] of the independence of the disturbance terms is rejected, implying that multiple technology adoption in West-Cameroon is not mutually independent and supporting the use of a multivariate Tobit model (See Table 2). In addition, the binary correlations between the error terms of the two adoption equations show that these practices are complements (positive correlation).
It appears from Table 2 that the cost of labour has a negative effect on the intensity of adoption of chemical fertilisers. In fact, the use of this agricultural innovation is labour intensive, so an increase in labour costs will decrease its intensity of adoption. Conversely, the high cost of organic fertiliser could drive farmers who want to increase their production to increase the intensity of adoption of chemical fertiliser (which is a substitute for organic fertiliser because it is also added to the soil in order to increase the quantity of nutrient in the soil).

Table 2 - Estimation result of the intensity of use of modern inputs model (multivariate Tobit model results)

VARIABLES	Intensity of use of improved seeds (1)		Intensity of use of chemical fertilisers (2)	
	Coefficients	t-statistics	Coefficients	t-statistics
fem	-2.857	-0.201	-0.654	-0.315
dist_ch	-1.417**	-2.078	0.0938	1.052
fertilbais	-40.83**	-2.388	6.424***	3.216
fertilhaus	6.118	0.487	-3.901**	-2.015
primary	28.68	1.593	0.0749	0.0342
secondary	60.96***	3.037	1.757	0.678
credit	1.964	0.161	1.595	0.886
div-act	5.496	0.467	-0.561	-0.332
asso	33.04**	2.382	1.350	0.744
propr	-13.50	-0.714	-6.575***	-2.619
experience	0.748	0.504	-0.387*	-1.828
experience2	-0.0155	-0.578	0.00768**	2.101
super	0.00165***	3.109	-0.000233***	-2.790
pmoy	0.138	1.244	0.000686	0.0374
revenu	0.00769**	2.060	0.00551***	8.111
tailmenag	0.955	0.517	-0.328	-1.197
dist_mark	-2.145	-0.754	0.300	0.908
riskprix	-20.68	-0.893	-3.991	-1.200
riskclim	-44.68*	-1.900	5.763*	1.650
riskmala	29.65**	2.417	-3.623**	-2.182
riskphyt	-15.72	-1.255	0.731	0.427
riskfina	-15.73	-1.264	6.848***	4.028
tauxsal	-0.0353	-0.0346	-0.414***	-2.746
coutfiente	0.0200	1.529	0.00592***	3.127
rural	-12.80	-0.993	-0.660	-0.369
Constant	-121.7**	-2.317	5.056	0.666
Number of observations		562		
Wald chi2(50)		269.25		
Prob > chi2		0.0000		
Log likelihood value		-2535.5003		
sigma1		85.048***		
sigma2		16.359***		
ρ_{12}		0.123*		
LR test of ρ_{12} : Chi2(1)		2.95456		
Prob > chi2		0.0856		

Note: * (**){***} represent statistical significance at 10% (5%) {1%};
Prices of improved maize seed, fertilisers and pesticides were excluded because there is lack of variation in our data for these variables.

In general, risks perception does not allow the combined adoption of agricultural innovations by corn producers in West-Cameroon (Table 2). Indeed, the perception of climate risk has a negative and positive effect respectively on the intensities of adoption of improved seeds and fertilisers. Similarly, while the perception of risk of financing a crop has a positive influence on the intensity of adoption of chemical fertilisers, it has no effect on the intensity of adoption of improved seeds. According to Feder (1980), these results would be related to the facts that poor farmers in developing countries (including Cameroon) face credit constraints; which leads them to intensify chemical fertilisers more (at the expense of improved seeds). However, the perceived risk of illness or death of a key member of the household (as potential labour) leads these producers (with a binding credit constraint) to reduce the intensity of adoption of chemical fertilisers that are labour intensive and to increase the intensity of adoption of improved seeds. All this shows that the presence of multiple agricultural risks combined with the constraints of credits facing Cameroonian producers do not favour the combined adoption of agricultural innovations; yet, according to Perkins et al. (2008), it is the combined use of these agricultural innovations which ensures higher crop yields.

Table 2 also shows that the intensity of adoption of chemical fertilisers do not continually decreases with the increase of agricultural experience of the farmer. Which indicates that it is only at a certain level of experience in agriculture that the farmer understands the need to intensify the use of chemical fertilizers. The proportion of land allocated to improved seeds only increases with the level of secondary education or higher; it is probably at this level of education that farmers understand the agro-economic potential of the use of improved seeds. Similarly, producer participation in one (or more) organisation(s) has a positive effect on the percentage of land allocated to improved seeds. In fact, it is usually within producer organisations that farmers discuss their work with their peers and share information and their experiences on the advantages of using new technologies. It also notes that the ownership of cultivated plots has a negative effect on the quantity of grams of chemical fertiliser used per 2 m of land. In fact, the farmers who own farmland, aware of the potential long-term negative impact related to the intensive use of chemical fertilisers, therefore use this input less intensely.

Contrary to theoretical predictions, farm size negatively influences the intensity of adoption of fertilisers. This might be due to the fact that farmers with larger farm sizes have the possibility to reconstitute soil fertility by allowing some of their land fallow. However, it influences positively the intensity of using improved seeds. This implies that farm size is an indicator of wealth and a proxy for social status within a community which influences positively the intensity of use of improved seeds. Similarly, as an indicator of wealth, the farmer's income has a positive influence on the intensity of adoption of improved seeds and fertilisers. Moreover, we note that the decreased fertility of cultivated land has a positive influence on the intensity of use of chemical fertilisers and a negative influence on the intensity of use of improved seeds. In fact, in the face of declining fertility of cultivated land, poor farmers (with a binding credit constraint) spend their income to the purchase of fertilisers (at the expense of the purchase of improved seeds). The increase in fertility of cultivated land is an unfavorable factor for the intensity of use of chemical fertiliser. This is quite intuitive because the land being fertile, farmers will no longer need to intensify the use of chemical fertilisers.

4. Conclusion

This study determines the factors influencing the intensity of use of agricultural innovations by corn producers in western Cameroon. Rather than univariate Tobit model which is commonly used, the multivariate Tobit model is employed to take account of correlation between the disturbances. The study shows that, beside the perception of many agricultural risks, multiple characteristics related to the producer or to his farm affect adoption of improved maize seed and chemical fertiliser by corn producers in West-Cameroon. Results mainly indicate that, faced to risks perception, farmers in West-Cameroon tend not to adopt improved maize seed in combination with fertiliser. Yet, according to Perkins et al. (2008), it is the combined use of these agricultural innovations which ensures higher crop yields. Furthermore, the price of corn has no effect on the intensity of use of modern inputs. This result might be linked to the presence of multiple agricultural risks that could make farmers insensitive to incentives of output prices. The implication of this is that the policies aimed at setting up sustainable risk management markets could greatly promote the adoption of agricultural innovations by farmers of Cameroon in general and in the western region in particular where the markets of risk management do not exist or are malfunctioning.

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C22

How has farming practices affected the cereal production in Morocco?

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ABSTRACT

The purpose of this paper is to present a new approach to modelling a cereal production function and propose an estimate of farming practices function in Morocco. Cereal production function would be determined by econometric model drawing in particular on the Solow approach (1957), based on five factors- land, water, employment and farming practices. To simplify the model, we aggregate the effects of the three first factors by using a principal components analysis (PCA). We use then the Space state models to provide an estimate for the non observable factor, namely agriculture practices. Such an estimate is a useful tool for examining the farming practices fluctuations and analyzing of its effects on cereal production, in particular, following the Government's adoption of the Green Moroccan Plan in 2008. The data comes from agriculture department and High commission for Planning, from 1991 to 2015. Results show that the improvement by 1% in the agricultural practices leads to a 0.3% increase in cereal production.

Keywords: agriculture, farming practices, cereal, PCA, Kalman filter JEL Classifications: Q1, Q12

PAPER

1. Introduction

The traditional factors determining the agricultural production are labor, capital, land and water. However, the standard approach of modeling the agricultural production generally holds two main factors- capital and labor. The improvements made by the introduction of the third factor land, highlighted by Martin and Mitra (1993), were rare. Most studies have retained the two first factors, assuming constant returns to scale. They have thus used the Solow approach (1957), which expresses the production from factor shares. In this approach, the operating surplus is frequently used to measure the return on capital. However, and taking into account the economic specificities of agriculture in many developing countries, the operating surplus cannot be considered as equivalent to return on capital, but would include also the return shares of land and employment. Furthermore, agricultural practices might also be considered as crucial factor that influences crops output and livestock strength. They play a decisive role in the development of agricultural production, since they achieve higher productivity and contribute to ensure the food security. Overall, the increase of agricultural production could result from the combination of two major sets of factors: the available quantities of traditional factors- land, water, labor and capital and the effectiveness of their contribution associated with the use of agricultural practices.

Agricultural practices consist of all techniques conducted by the farmers to improve crop and livestock productivity. They include irrigation, soil preparation, crop rotation, fertilizers, and pesticides. In Morocco, agricultural practices was continued to progress at a very moderate pace in the 80s and 90s. The fertilizer consumption was limited to 65 kg per hectare of arable land in 2002, instead of 72,8 in Turkey, 164,5 in Spain and 211,3 in France[1]. The number of tractors did not exceed 45 units per 100 square km of arable land. The largest proportion of the crops areas was under rain fed, while less than 15% of cultivated areas were irrigated. The production of rainfed crops, including cereals had not seen a dynamic growth, due to less intensive production system. Thus, the Moroccan government launched in 2008 a new strategy, namely Green Morocco Plan, in order to improve the sector's resilience to climate fluctuations and boost its production and exports through the reorganization of its productive chains, diffusion of good practices at both large and small farms and by adopting a proactive fundraising approach for financing agricultural projects.

This paper aims to present an innovative approach to econometric modelling of cereal production function and propose a new method for estimating agricultural practices indicator in Morocco. The study is carried out over the period from 1990 to 2015. The choice of sample period is related to the availability of data and the fact that the cereal production has been undergoing drastic changes, especially from 2000.

[1] Wolrd Bank Group, 2016

The approach starts with a production function that expresses cereal output as a function of the agricultural practices and the traditional factors. To simplify the model, we have grouped three factors (level and dispersion of rainfall per season, sown areas and employment) using a principal component analysis.

Unlike labor, capital, land and water factors, whose data were collected from the Department of Agriculture and the High Commission for Planning, the agricultural practices factor is a latent variable, which will be recovered by applying the Kalman filter (1960, 1963). An important feature of this filter is to provide an estimate of the unobservable variable "agricultural practices" for the sample period. The second advantage consists on its ability to generate forecasts for the latent variables that can be incorporated in econometric projections. In the next section, we examine the theoretical framework of our econometric model. Section 3 presents an extension of the Kalman filter leading to estimate the unknown model parameters and generate the latent variables. The empirical results will be presented in section 4. We find that agriculture practices and traditional factors are both important in representing changes in patterns of cereal production. Section 5 concludes.

2. Econometric approach

The modeling approach of cereal production has derived from the Solow model (1957). Assuming three production factors (aggregated nature and employment factor, capital and agricultural practices), the cereal production function can be expressed as:

$$Y_t = NL_t^{\alpha} K_t^{\beta} P^{\delta}_t$$

Where Yt is the cereal production, Nl represents the aggregated nature and employment factor, K capital expenditure, and P is the farming or agricultural practices factor. α, β and δ represent respectively the shares of production that remunerate the three factors. These shares should be less than unity. By differentiating the production function with respect to time t, and dividing by Y, the growth rate can be estimated as :

Log(Y)= α log(NL) + β log(K)+ δ log(P)

dLog Y = Y'dNL+ Y'dK+ Y'dP

$$= \alpha\, NL_t^{\alpha-1} K_t^{\beta} P^{\delta}_t + \beta\, NL_t^{\alpha} K_t^{\beta-1} P^{\delta}_t + \delta\, NL_t^{\alpha} K_t^{\beta} P_t^{\delta-1}$$

$$\frac{dlogY}{Y} = \frac{\alpha\, NL_t^{\alpha-1} K_t^{\beta} P^{\delta}_t}{NL_t^{\alpha} K_t^{\beta} P^{\delta}_t} \mathrm{dNL} + \frac{\beta\, NL_t^{\alpha} K_t^{\beta-1} P^{\delta}_t}{NL_t^{\alpha} K_t^{\beta} P^{\delta}_t} \mathrm{dK} + + \frac{\delta\, NL_t^{\alpha} K_t^{\beta} P_t^{\delta-1}}{NL_t^{\alpha} K_t^{\beta} P^{\delta}_t} \mathrm{dP}$$

$$\frac{dlogY}{Y} = \alpha \frac{dNL}{NL} + \beta \frac{dK}{K} + \delta \frac{dP}{P}$$

The decomposition of the production growth shows the contributions of each factor to the growth and their remuneration.

3. Application of the Kalman Filter

The identification of the unobservable variable "agricultural practices" is based on the application of a State Space model. This type of model can distinguish between the specification of observed variables (the signal) and the unobserved variables (known as the state variables). It generally consists of one or more measurement equations describing how the observed variables are explained by the unobserved variables and one or more state equations indicating how these variables are generated from their dynamic of the past and from the residues.

In our study, the state space model highlights a linear decomposition of the dependant variable (cereal production) into three factors (aggregated indicator, capital, agricultural practices). The two first factors are observed and assumed uncorrelated, while the latter is not observable and assumed stochastic. The variable representing the agricultural practices follows a random walk model, taking into account the effects of two exogenous variables (fertilization and seeding use).

The State Space model is expressed as following:

$$\begin{cases} P_t = CP_{t-1} + \varepsilon_t \\ Y_t = A'X_t + B'P_t + \eta_t \end{cases} \qquad \{t \geq 1\}$$

Where Y is the dependent variable determined by the vector of the independent variables X (NL, K) as well as the unobservable variable Pt. The irregular components εt and ηt are uncorrelated white noise. A, B and C are the parameter matrix. $P_0 \approx N(m, \sigma)$

We propose to include two major changes into the state equation. The first concerns the addition of explanatory variables in order to improve the quality of latent variable estimate. Pt equation would give a clear idea of the exogenous variables effects (fertilization and seeding use) taking into account the past effect of the variable changing itself according to random shocks.

The second is related to the dynamic change of Pt assumed following a random walk with drift. This latter change will allow Pt slope to change as a result of random shocks that could affect its level over time.

The new state space model is given by the system of the following equations:

$$\begin{cases} Y = A'X_{1,t} + B'P_t \\ P_t = C'X_{t,2} + P_{t-1} + W_{t-1} + \varepsilon_t \\ W_t = W_{t-1} + \mu_t \end{cases}$$

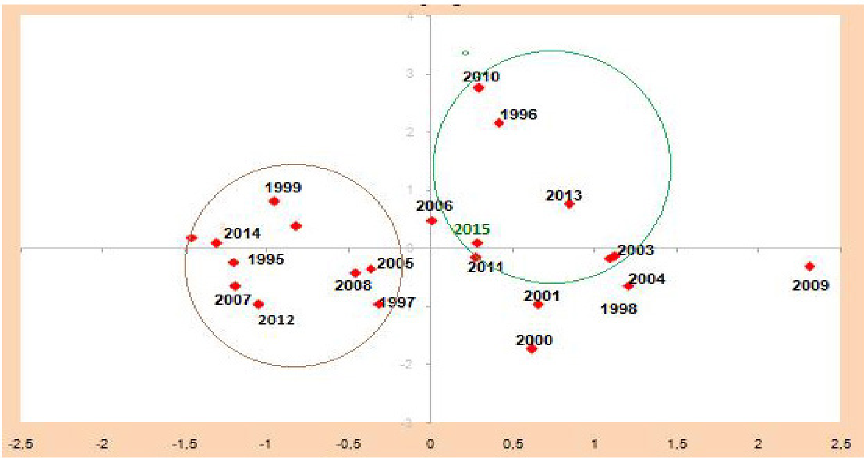
Where ʹt and µt are independent vectors of mean zero Gaussian disturbances variance. ʹt allows to the latent variable P to fluctuate by varying its slope. With the new State Space representation, extraction of the agricultural practices factor would be performed using the Kalman filter, which provides a recursive estimation of the latent variable at time t assuming the conditional distribution of the State vector.

4. Empirical results

In this section, we provide but are not limited to the results of our investigation. It seemed relevant firstly to present the results of principal components analysis conducted on rainfall, employment and areas sown data. The level of rainfall remains a determining factor of cereal production since the irrigated area did not exceeding 9% of the total area sown.

The 7 variables used in the principal components analysis were chosen because of their correlations and contributions to explain the cereal production. This include rainfall level divided into two periods (October to December and January to March) and differentiated in terms of distribution during the winter and autumn season, employment, sown area and the effect of early rains. The results reveal that the two axis resulting from the implementation of the PCA account for about 72% of the variation. The first axis is strongly associated with rainfall dispersion and area sown. Similar years in terms of climatic, land and employment conditions, easily emerge from their proximity from on the plane factor. Overall, and taking into account the first two axes selected by PCA, two homogeneous sets of agriculture campaigns are characterized (poor and good harvests).

Figure1 - similar crop year scatter



Once calculated the aggregated indicator based on rainfall, area sown and employment factors, we estimate the State Space model suggested in the previous section. However, we encountered severe convergence problems suggesting a specification problem. We decided to improve the model by inserting a constant in the equation state. The model is thus expressed as following:

$$\begin{cases} Y_t = \alpha Ag_t + \beta K_t + \delta P_t \\ P_t = a_0 + a_1 engr + a_2 sem + P_{t-1} + W_{t-1} + \varepsilon_t \\ W_t = W_{t-1} + \mu_t \end{cases}$$

The estimation of unknown parameters will be operated from the maximum likelihood method. The results are summarized in the following table:

Table 1 - parameter's estimate

Variable	Coefficient	1991-2015		2000-2015	
		Estimation	Z statistic	Estimation	Z statistic
Aggregated factor	α	0.31	3.37	0.10	2.20
Capital	β	0.28	1.87	0.43	3.42
Practices	δ	0.31	4.73	0.18	3.65
Constant Pt	a_0	-12.8	-0.00	0.18	0.129
Fertilizer	a_1	-6.42	-0.67	-46.36	1.46
Seed	a_2	3.74	1.71	24.57	1.86

The results show that the sign and the size of estimated parameters are consistent with economic theory. An increase of each quantity on the three factors (aggregated indicator, capital and agricultural practices) leading to improved cereal production. The homogeneity hypothesis of production function is also not rejected (the sum of the parameters associated with the three factors is near to unity). However, the results revealed a less prominent role of fertilizers; its z-statistic is not significant. To check the robustness of the parameter, we re-estimated the same model on a more recent period (2000-2015). The results show a fairly significant improvement in the contribution of seed and fertilizer use, especially from the adoption of the Green Morocco Plan in 2008.

The estimate of the Space State model reveals a gradual progress of agricultural practices function, especially during the dry seasons with a significant rainfall deficit. This is particularly true for 2000 and 2007 which were characterized by an important improvement of agricultural practices, in line with the increase of the use of irrigation and certified seeds. Conversely, the campaigns which are marked by good temporal dispersion of rainfall, especially during the winter, were down on the use of agricultural practices, due, in particular, to the large proportion of rainfed areas that do not require irrigation during the wet years.

Figure 2 - agricultural practices indicator

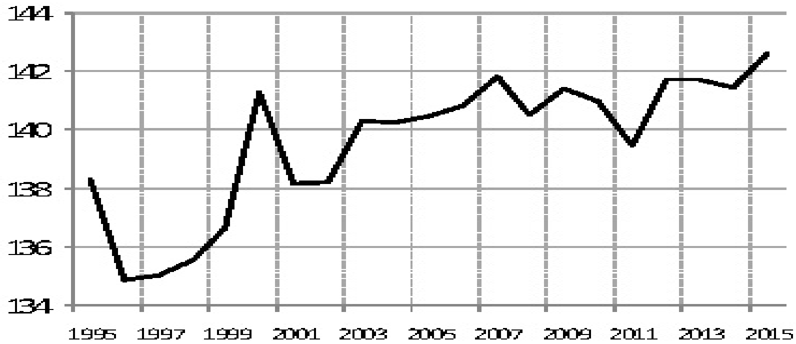
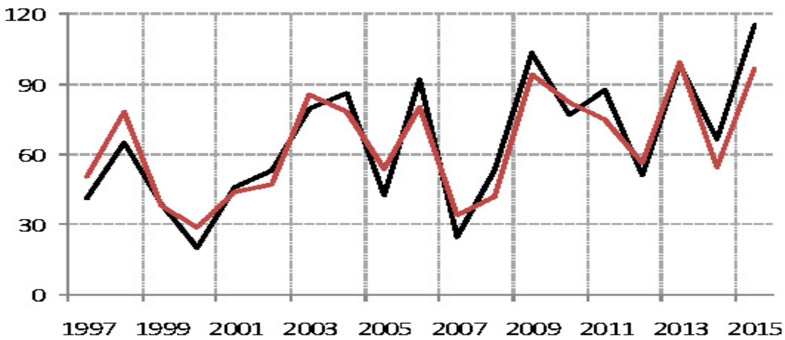


Figure 3 shows the performance of Space Stat models. It reveals a perfect synchronization movement of the original and fitted series on the whole sample period. It shows also the ability of the model to reproduce output fluctuations throughout the sample period. Specifically, the graph shows that the cereal production function cannot be performed from the two only traditional factors- labor and capital, but should also take into account the effect of natural factors, employment and agricultural practices, particularly in countries that are highly exposed to climate disruption.

Figure 3 - cereal production(original and fit series)



5. Conclusion

The principal innovation of this paper is to generate empirical measure of the agricultural practices factor as latent or unobservable variable, while providing cereal production function. The results reveal the crucial role of agricultural practices in improved cereal production in Morocco. Agricultural practices focused on the use of inputs have generally achieved a higher crop yield in recent years, but found liable for accelerated pollution of fresh water, soil and a decline in food safety. The increase of restrictive practices and more geared towards the use of natural inputs and a local knowledge of farmers should answer, in part, to the growing demand for sustainable organic agriculture. However, it marks a major shift in agricultural production function that should give a prominent role to the labor factor (knowledge and technical competence) rather than practiceintensive factors. It should be emphasized that this transformation, highly recommended as part of Sustainable Development Goals (SDGs) could be long and difficult in the short term, as it would be difficult to ensure the nutrition of the entire Moroccan population or meet changes in market access at affordable rates. Moroccan Farmers would continue to use intensive agricultural practices and the cereal production function would be thus continued to be influenced by the effect of inputs (fertilizer, pesticides) in the short term.

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C22

Evolution of farming practices in the French vineyard The use of pesticides 2006-2013

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ABSTRACT

The French surveys on viticulture 2006, 2010 and 2013 form part of a wide range of surveys on farming practices. One of their primary objective is to evaluate the use of pesticides. A good knowledge of their use is a major challenge for sustainable development because of their relationship with environmental and health risks.The first part of this study identifies the main indicators on the use of phytosanitary products and focuses on the treatment frequency index (TFI). Based on the Danish experience, this indicator is built with the normalized doses of pesticides actually applied by the wine producers. It can be easily expressed on a regional scale or on pesticides subdivision. In France, this indicator varies from 9.2 in Pyrénées-Orientales to 21.4 in Champagne in 2013. The second part raises the question of the climate effect on the TFI variations 2013/2010. The weather with its stimulus role in the parasite development can cause an augmentation of the use of pesticides. In 2013 degraded climatic conditions, the TFI has increased in all vineyards. The use of a fixed effect model leads us to estimate a significant climate effect in 7 vineyards out of 13. The weather variations between 2010 and 2013 contribute from 6% in Bourgogne to 31% in Val de Loire to the TFI increase.

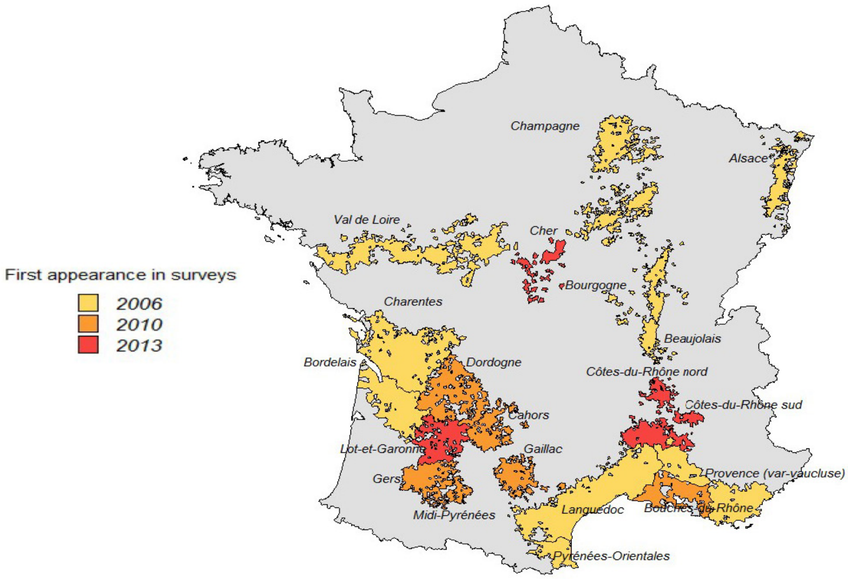
Keywords : pesticides, treatment frequency index, climate effect

PAPER

1. Introduction

Since the mid of the 2000's, the French statistical service has launched a wide range of surveys on agricultural practices. These surveys are a major tool to assess the impact of the French public policy Ecophyto[1] that was developed by the French Ministry of Agriculture in 2008 with the purpose of progressively reducing the use of pesticides while maintaining agricultural performance. The surveys cover nowadays the main crops productions: field crops, fruits, vegetables and viticulture[2]. This paper will focus on the 3 waves of the survey on viticulture implemented in 2006, 2010 and 2013.

Figure 1 - The French vineyards map Farming practices surveys in viticulture 2006, 2010 and 2013.



[1] This public policy is an answer to the Article 4 of Directive 2009/128/EC. A second version of the Ecophyto plan was published in 2015. Among its main objectives is the reduction in pesticides use in two stages: -25% by 2020 and -50 % by 2025.

[2] Wine grapes.

2. Measuring the use of pesticides

The relationship between pesticides and environmental and health risks is beyond doubt and is coming into sharper focus. The permanent crops like vines consume large amounts of pesticides. In 2013, the French vineyard area is about 800 000 hectares and represents a major challenge for the reduction of the use of phytosanitary treatments. To evaluate the practices, several indicators have been developed.

2.1 Number of phytosanitary treatments and sales of active ingredients

A phytosanitary treatment is defined as the use of a commercial product across a cultivated land during a cropping season. A same product applied in two passes counts for two treatments. A mixture of two products applied during a single pass also counts for two treatments. Most of pesticides can be subdivided into the fungicides (against fungi), the insecticides (against insects) and the herbicides (against plants considered to be « weeds »).

The **number of phytosanitary treatments** does not take into account the spread quantities during each pass. Some vineyards can be treated with several passes with low pesticides doses while others are often less treated but with higher doses during each pass. For example, two passes with halfdose count for two treatments whereas a single pass with full dose counts for one treatment. However, the sanitary pressure is the same in the two cases.

An other pressure indicator regularly followed in Europe is the total **quantity of active ingredients** which is sold on a given territory. The main limit of this indicator is the measure of the difference between sale and consumption of pesticides. For example, the storage variations of products from year to year can create a gap between sale and use of pesticides for a given year. Thus, this indicator can decrease even though the pressure on the environment is the same.

2.2 The treatment frequency index (TFI)

The treatment intensity index (TII) is a monitoring indicator of the use of pesticides. It has been developed in Denmark in the middle of the 80's. It is defined at the national level:

$$TII = \frac{\sum_{AI} \frac{SQ_{AI}}{ED_{AI}}}{TCA} \quad (1)$$

SQ_{AI} Sold quantity of active ingredient
ED_{AI} Effective dose of active ingredient
TCA Total cultivated area

In France, the National Institute for Agricultural Research (INRA) and the Ministry in charge of agriculture have developed in 2006 a calculation method based on the Danish experience (Champeaux, 2006 ; Pingault et al., 2009). The French version, the treatment frequency index (TFI), is not built with the active ingredients but with the phytosanitary products. It also takes into account the quantities actually applied by the wine producers instead of the sold quantities. Since 2007, it is implemented as a supporting and evaluation tool for the reduction of the use of pesticides.
For the TFI calculation, the « pesticides » item of the questionnaire allows to identify the applied products during each pass for a given vineyard parcel. For each applied treatment on the vineyard parcel[3], the TFI is the following:

$$TFI = \frac{DA}{ED} * PTA \quad (2)$$

DA Dose actually applied per hectare (from survey)
ED Effective dose for a target (diseases/pests) per hectare (from target framework)
PTA Percentage of treated area (from survey)

Specific cases:

- Some products do not have effective dose (ED). In this case, the TFI is equal to the percentage of treated area (PTA),
- If TFI<0.1 or >2, or if it is a misuse, it will be corrected by imputation (mean based on vineyard and target). Depending on the year, these corrections vary from 2% to 5% of the observations,
- TFI=1 for pheromone dispensers (mating disruption).

Until 2015, the effective dose was defined on a pair (culture, phytosanitary product). When several effective doses were available corresponding to different targets, the calculation method was based on the lowest dose. The methodology has been improved with the use of the triplet (culture, phytosanitary treatment, target) to determine the effective dose.

[3] Rodenticides, repellent products, talpicides are not included.

For the 2006 survey, the target of the used product was not collected. To calculate the TFI, the method has been as follows:

- The pairs (phytosanitary product, target) 2010 were settled.
- The 2010 target was applied to all the 2006 products still existing in 2010. For the 2006 products that disappeared in the meantime, the target has been searched in a reference viticulture basis.

Figure 2 - Examples of the TFI calculation Farming practices survey in viticulture 2013.

Date	Product	Target	Percentage of treated area	Applied dose (KG/HA)	Effective dose (KG/HA)	TFI
2013-03-01	PLEDGE	Herbicide	60	1	1,2	1/1.2*0.6=0.5
2013-05-28	VALIANT FLASH	Mildew	100	3	3	3/3*1=1

The « TFI parcel » is defined as the sum of the TFI.

2.3 Results by vineyard

In 2013, the average TFI varies largely across vineyards ranging from 9.2 in Pyrénées-Orientales to 21.4 in Champagne. The protection of grape wines against microscopic fungi is responsible for around 80% of the phytosanitary treatments. Thus the main source of regional heterogeneity is related to the dispersion of the TFI fungicide.

Between 2006 and 2013, the TFI has increased in all vineyards but in varying degrees. The highest increase has been measured in Bourgogne (+5.6), the lowest one in Alsace (+0.5).

Table 1 - TFI by pesticide subdivision and vineyard between 2006 and 2013

	TFI Herbicide			TFI Fungicide			TFI Insecticide			TFI		
	2006	2010	2013	2006	2010	2013	2006	2010	2013	2006	2010	2013
Alsace	0.6	0.3	0.3	8.8	9.3	9.8	1.1	0.8	0.7	10.4	10.4	10.9
Beaujolais	1.1	1.2	1.4	11.3	14.1	16.6	1.0	0.9	1.0	13.5	16.3	19.0
Bordelais	0.5	0.5	0.4	12.1	12.2	14.5	1.7	1.4	2.0	14.2	14.1	16.9
Bouches-du-Rhône	na	0.2	0.2	na	8.2	9.0	na	0.3	0.2	na	8.6	9.3
Bourgogne	0.8	0.7	0.9	12.7	13.9	17.4	0.7	0.4	1.6	14.2	15.0	19.8
Champagne	1.3	1.2	1.4	17.6	15.7	19.2	0.8	0.7	0.8	19.7	17.6	21.4
Charentes	0.5	0.5	0.7	10.9	12.5	14.7	1.8	2.2	2.8	13.3	15.2	18.2
Dordogne	na	0.3	0.3	na	10.5	12.6	na	1.7	2.2	na	12.5	15.1
Gers	na	0.4	0.5	na	14.5	16.2	na	1.8	2.6	na	16.7	19.3
Languedoc	0.4	0.4	0.5	8.2	9.4	10.5	1.9	1.8	2.2	10.5	11.5	13.2
Provence	0.2	0.2	0.3	6.3	8.3	8.9	0.4	0.5	0.4	6.8	8.9	9.6
Pyrénées-Orientales	0.6	0.4	0.5	5.8	6.4	6.5	2.1	2.1	2.2	8.5	8.8	9.2
Val de Loire	0.6	0.9	1.0	7.2	9.3	11.5	0.6	1.1	1.1	8.4	11.3	13.6

na: not available.
Farming practices surveys in viticulture 2006, 2010 and 2013.

3. Parasite pressure, climate and TFI

Several factors can explain the phytosanitary treatments level: the parasite pressure of the year which is partly related to climatic factors; the farming practices of the wine producers who use more or less pesticides,… The main aim of this paper is to isolate the impact of the parasite pressure on the level and the evolution of pesticides use as measured by the TFI index. The analysis will focus only on the years 2010 and 2013 to use a panel approach and also because some climatic factors, used as a proxy for parasite pressure, are not available for the year 2006. It will be based on 13 vineyards.

3.1 Measuring the parasite pressure

Mildew and oïdium are the major diseases of vine. They develop better with a hot and humid weather. Mildew affects the photosynthesis and causes a lagging maturity and a decrease in the alcoholic degree. Oïdium can cause a decrease in the grape wine quality by reducing the content in phenols and sugar. Repeated attacks of these diseases on leaves and grapes can destroy an entire crop. To evaluate the parasite pressure, two sources are available. The first one relies on quantitative indicators built by a network of regional observers. The pressure level is determined for each vineyard and covers most of the parasites. The second source is based on the farming practices surveys that also collect some qualitative indicators on the parasite pressure (strong/ average/ weak pressure). To answer this question, wine producers rely on their experience about the cultural parcel.

According to the quantitative approach, both « mildew » and « oïdium » pressures have increased between

2010 and 2013 in 2 regions (Charentes and Val de Loire) and both have decreased in one region (Provence). In the other regions, the evolution of parasite pressure is not the same for mildew and oïdium.

Table 2 - Level of parasite pressure 2013/2010

	Parasite pressure 2013/2010		
	More pressure	**Equal**	**Less pressure**
Mildew	Alsace, Bordelais*, Bourgogne, Charentes, Dordogne*, Val de Loire.	Beaujolais, Champagne.	Bouches-du-Rhône, Provence.
Oïdium	Beaujolais, Champagne, Charentes, Val de Loire.	Bouches-du-Rhône, Bourgogne.	Alsace, Bordelais*, Dordogne*, Provence.

**Regional phytosanitary results do not distinguish Bordelais and Dordogne.*
Regional phytosanitary results are not available in 2010 in the following vineyards : Gers, Languedoc and Pyrénées-Orientales. In 2013, "mildew" pressure was described as "average" in Languedoc and "weak" in Pyrénées-Orientales. At the same time, "oïdium" pressure was described as "average" in both vineyards.
Regional phytosanitary results in viticulture 2010 and 2013.

The qualitative approach provides divergent conclusions. Except for Pyrénées-Orientales, the "mildew" is perceived as a growing pressure on average for all vineyards. The "oïdium" pressure also increases except in Alsace, Bouches-du-Rhône, Gers and Pyrénées-Orientales where it is stable. Whatever the level of pressure, the TFI average in 2013 exceeds the one in 2010. Whatever the year, the highest TFI average is obtained when the parasite pressure is felt strong for mildew and weak for oïdium.

Given the difficulty to obtain objective indicators at the parcel level to quantify the parasite pressure effect, we finally opt for an indirect measure: the impact of climatic factors on the TFI. If climatic conditions are not the only determinant for parasite pressure and phytosanitary treatments, they are important parameters in the use of pesticides. In 2013, 44% of wine producers said that weather forecasts and rainfall were the main reasons for the use of pesticides.

3.2 Climatic factors and TFI

The spatialised data base of Meteo-France provides for each parcel the information collected by the nearest grid point (about ten kilometers grid). From April to August, the following monthly parameters can be observed: rainfall (RR), sunshines (INST), average and range temperatures (TMOY, AMPT), wind speeds (FFM) and humidity (HUMOY).

In April and May 2013, the rainfall has increased with respect to 2010 in all vineyards in particular in Bourgogne, Beaujolais and Champagne. During these two months, the average temperatures were significantly lower with important gaps in May (-3°C). In April, the wind was strong in particular in Dordogne and Gers. In May, except in these two vineyards and in Bordelais, it is a reverse trend. In June 2013, the rainfall has decreased and the average temperatures were significantly higher especially in Beaujolais, Bouches-du-Rhône and Provence. In July and August 2013, the weather was very sunny in particular in Alsace, Bourgogne, Champagne and Charentes.

A principal component analysis (PCA) is performed to study the correlation between climatic factors and TFI. The main results are the following:

- Overall, a stronger correlation between climatic factors and TFI for the year 2013,
- A positive correlation between TFI and rainfall and humidity variables,
- A negative correlation between TFI and sunshines, wind speeds and temperatures variables.

Using an ascending hierarchical classification (AHC), we can isolate three large geographical areas in France:

– Mediterranean area: Bouches-du-Rhône, Languedoc, Provence and Pyrénées-Orientales. This area is characterized by abundant sunshine and frequent high winds (in particular in Pyrénées-Orientales). This area has the lowest TFI level and TFI increase between 2010 and 2013 (from 10.7 to 11.9),

– Continental area: Alsace, Beaujolais, Bourgogne and Champagne. This area is characterized by wide temperature variations and abundant rainfall. This area has the highest TFI level and TFI increase between 2010 and 2013 (from 15.4 to 18.7),

– Atlantic area: Bordelais, Charentes, Dordogne, Gers and Val de Loire[4]. This area is characterized by mild temperatures and high humidity. The TFI in this area is a bit lower than in the continental area and its increase between 2010 and 2013 is more moderate (from 14.1 to 16.7).

[4] Val de Loire is classified in the "Atlantic area" but this vineyard is very close to the characteristics of the "Continental area".

4. Measuring the climate effect

The aim of this section is to focus on the impact of climatic conditions on TFI variations in order to obtain a 2010-2013 TFI evolution with controlled climatic factors.

To explain the TFI evolution, the model selects only climatic factors as independent variables. This choice is justified by the fact that farming practices, although important to explain TFI level, do not vary much over time for vineyards. Firstly, the vine is a permanent crop and has fixed characteristics like grape variety, density, no rotation…. Secondly, the main farming practices that can be observed in the surveys like weed control, fertilization, shoot and bud removing, leaf pulling, irrigation vary scarcely over time. Thus, between two years, their impact on TFI variation is rather neutral. Therefore, if the exclusion of farming practices as independent variables could in theory create a bias on the estimated coefficients (omitted-variables bias), their exclusion in the model may be justified for the vineyards.

4.1 Data modeling

The panel is composed of 4 838 parcels. Some atypical data were withdrawn (14 parcels). Several classic functional forms were tested: log-linear, semi-log and linear. Finally, the linear form was chosen.

Multicolinearity and variable selection were treated simultaneously with LASSO (Least Absolute Shrinkage and Selection Operator). Without going into details (Tibshirani, 1996), this method rewords the least squares problem but with an additional coefficient requirement. The coefficients of the most correlated variables are 0. All the average temperatures variables are excluded because of their correlation with the range temperatures variables.

17 variables and 6 cross effects are selected (04=April, 05=May, 06=June, 07=July, 08=August): RR04, RR05, RR07, RR08, AMPT04, AMPT06, AMPT08, FFM04, FFM05, FFM07, FFM08, HUMOY04, HUMOY05, HUMOY07, HUMOY08, INST05, INST07; RR07*INST07, AMPT06*HUMOY06, INST05*FFM05, INST05*HUMOY05, INST07*HUMOY07, FFM04*HUMOY04.

In a first model, we assume that the climatic variables effect is not the same across the vineyards. According to this hypothesis, the model writes:

$$TFI \;=\; \Sigma_{k=1}^{13} \beta_k X \, I_{(Vineyard=k)} \;+\; \beta_{0k} I_{(Vineyard=k)} \;+\; \delta_k I_{(Vineyard=k)} I_{(Year=2013)} \;+\; \varepsilon \quad (3)$$

$I_{(Vineyard=k)}$ Dummy variable for vineyard k
X Climatic factors
$I_{(Year=2013)}$ Dummy variable for year 2013
ε Residual

The number of available observations is however too limited to allow this model to be estimated. In a second model, we relax the constraint of the heterogeneity of the climatic variables effect and we assume that the climatic variables have the same effect whatever the vineyard. Only a vineyard fixed effect remains in the model to take into account specific unobserved variables that affect the TFI.

The second model with fixed effect has the following form:

$$TFI \;=\; \beta X \;+\; \Sigma_{k=1}^{13} \beta_{0k} I_{(Vineyard=k)} \;+\; \delta_k I_{(Vineyard=k)} I_{(Year=2013)} \;+\; \varepsilon \quad (4)$$

$I_{(Vineyard=k)}$ Dummy variable for vineyard k
X Climatic factors
$I_{(Year=2013)}$ Dummy variable for year 2013
ε Residual

The dummy coefficient of vineyard*year gives the TFI difference 2013/2010 corrected by climatic factors.

4.2 Results by vineyard

The estimated model identifies a significant climate effect on the TFI difference in 7 vineyards out of 13: Beaujolais, Bordelais, Bourgogne, Champagne, Charentes, Languedoc and Val de Loire. The weather explains from 6% in Bourgogne to 31% in Val de Loire of the difference between the TFI in 2010 and the one in 2013. For other vineyards, the change in weather conditions between 2010 and 2013 does not seem to have a significant impact on the TFI increase.

Table 3 - Climate effect 2013/2010 by vineyard

	TFI 2010	TFI 2013	TFI difference 2013/2010	Explained part (%) by the weather 2013/2010	Signif. Codes
Alsace	10.4	10.9	0.5	0	***
Beaujolais	16.3	19.1	2.8	30	**
Bordelais	14.2	17.0	2.8	13	***
Bouches-du-Rhône	8.9	9.3	0.4	0	
Bourgogne	15.1	19.8	4.7	6	***
Champagne	17.8	21.4	3.6	13	***
Charentes	15.3	18.2	2.9	27	***
Dordogne	12.6	15.1	2.5	0	***
Gers	17.0	19.4	2.4	0	***
Languedoc	11.7	13.2	1.5	10	***
Provence	9.0	9.6	0.6	0	**
Pyrénées-Orientales	9.0	9.2	0.2	0	.
Val de Loire	11.2	13.6	2.4	31	***

*Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1*

The TFI vineyards are recalculated with the panel data and are different from that observed in table 1.
Farming practices surveys in viticulture and Météo-France data 2010 and 2013.

5. Conclusion

The measure and the understanding of the use of phytosanitary products is a major challenge. In France, the main indicator is the TFI that is built with the quantities actually applied by the wine producers. With a survey every three years, the TFI evolution cannot be easily interpreted: it may be linked to changes in farming practices but also mainly to interannual climate variability. In order to go further in the understanding of TFI variations, this paper focuses on the impact of climatic factors relying on a rich spatialised meteorological data base. We thus introduce in a model several variables describing the climatic conditions encountered by the sampled parcels with a fine grid point.

A fixed effect model leads us to estimate a measure of the "climate-TFI" relationship, excluding the "farming practices-TFI" link. This approach seems admissible for the vineyards because the farming practices do not vary much over time. Otherwise, it would be necessary to add in the model all the farming practices with significant evolutions and check the linear model assumptions. As a consequence, the corrected evolutions between the two years would take into account both climatic factors and farming practices. In that case, an indicator decomposition method would be necessary to estimate an "only climate effect".

In this article, although significant in half of the vineyards, the climate effect appears somehow moderate and leaves unexplained most of the TFI variations. This may be partly explained by the fact that weather conditions are only a proxy of parasite pressure that may depend of many other unobserved factors. Collecting more data on parasite pressure may be useful to go further in the understanding of the use of pesticides.

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C22

Climate-smart agriculture practices in Zambia: an economic analysis at farm level

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ABSTRACT

Climate-smart agriculture (CSA) would enhance the capacity of farming systems to sustainably support food security in the context of climatic changes. CSA practices may constitute an ex-ante adaptation strategy while also generating environmental benefits in the form of climate change mitigation. However, questions arise about the profitability of CSA systems and the possibility of spontaneous adoption at smallholders level. A spatial assessment of benefits and costs of CSA systems as opposed to conventional ones in different agro ecologies in Zambia is proposed here, including opportunity costs of switching from one system to another. Primary data collected through ad hoc household and community surveys have been used. Zambian farmers adopt a wide combination of land management practices, applied to various crops. Isolating the productivity effect of each single practice was complicated by the adoption of various combinations of practices. To assess the extent to which SLM technology packages improve crop productivity and net incomes of Zambian family farms, Minimum Soil Disturbance (MSD) systems was selected as the main distilling factor to compared with „conventional tillage systems for key food and cash crops (maize, groundnuts and cotton). MSD in arid areas of Zambia has shown promising results in terms of land, capital and labor productivity and could represent valid CSA option providing that appropriate choices in terms of labor source (manual versus animal draft power), specific practice (planting basins/potholes versus ripping, legume inclusion in crop rotations and residue retention), crop (maize versus groundnut) and access to fertilizer subsidies are made. SLM technology options can also generate environmental benefits in the form of CC mitigation. To better understand mitigation potential, marginal abatement costs curve have been computed. Results show that negative marginal abatement costs for all MSD options imply synergies between increased farm incomes and climate change mitigation, and represent means of generating "win-win" solutions to address poverty and food insecurity as well as environmental benefit (climate change mitigation). The cost-effectiveness of different land management practices is proposed as synergetic decision criteria allowing policy makers to prioritize support interventions on the basis of the economic efficiency of GHG abatements.

Keywords: Climate change, Food security, Sustainable farming practices

PAPER

1. Introduction

The Zambian agricultural sector has a dual structure which involves 740 large commercial farms co-existing with about 1.4 million scattered smallholder agricultural households, including some 50,000 emerging commercial farmers. Commercial farming focuses on cash crop production including wheat, soybean, tea, coffee, tobacco cotton, floriculture and intensive livestock production, while smallholder farmers mostly cultivate staple crops, including maize, sorghum, rice, millet, beans, groundnuts, sugar cane, vegetables and cassava and practice extensive livestock production. The focus of this research is on the smallholder agricultural households.

Zambian smallholder agricultural producers are mainly asset-poor farmers who use simple technologies (hand hoes and oxen) and cultivation practices (minimal purchased inputs such as hybrid seed or fertilizer). They produce rain-fed maize, groundnuts, roots and tubers, mostly for own consumption on five or less hectares (most smallholders cultivate less than 2 hectares) and productivity tends to be low. Sustainable land management (SLM) technologies could represent an option to increase productivity and develop Zambia's smallholder agriculture untapped potential which can lead to diversified production, increased employment and income, and improved food security.

Various potential SLM technologies are found within crop-livestock farming systems in Zambia. However, while biophysical and land productivity benefits of SLM have been widely investigated (e.g. see Branca et al. 2013), questions arise about the costs and overall profitability of investing in SLM practices, whereby very little empirical evidence exists. Much uncertainty exists about economic costs and benefits, level of inputs use, labour demand and factor productivity of SLM practices compared to direct implementation costs and to indirect opportunity costs deriving from the comparison with „conventional" practices, established as „baseline".

This is essential to understand the barriers and trade-offs of SLM implementation and ultimately its viability in supporting sustainable agriculture intensification at smallholder's level. There are important data challenges associated with this effort. This paper presents the results of a three years field and desk research work carried on in Zambia in the period 2013-15 and aimed at providing evidence about costs, revenues and overall economic performance of both SLM and „conventional" practices for different crops and agro-ecological regions. Results would help in identifying technology options which could potentially be implemented in Climate-smart agriculture (CSA) systems, enhancing the capacity of farming systems to sustainably support food security in the context of climatic changes. Since results may very much differ depending on the agro ecological context - and CSA is not a single recipe but it varies depending on the agro-climatic context and no single blue print technology exist - data collection and analysis has been conducted at an appropriate scale. The study findings would help in CSA adoption decision by farmers residing also in similar ecological conditions where such studies have not been undertaken yet.

Using spatial information about SLM technologies in different agro-ecological regions we look at private costs and benefits of target SLM farm practices in the country; we investigate about the profitability of such practices as opposed to „conventional farming; we verify the potential of SLM to improve crop yields controlling for other determinants; we estimate synergies with climate change mitigation and identify cost-effective abatement options and derive implications for CSA policies and actions.

2. Materials and methods

Agricultural practices targeted for the analysis are „innovative" practices already adopted at farm level (even if only through supporting development projects) and ready to be scaled-up if proven to be economically profitable. Therefore, practices only present in experimental fields and research stations, and not yet implemented at farm level, have been excluded from the research. „Conventional agriculture practices have also been included as profitability of SLM practices will be estimated with reference to a „baseline scenario : it includes ploughing or ridging performed using manual labor and animal or mechanical draft power (tillage system). The list of practices surveyed is reported in Table 1.

Table 1 - Description of target practices

Practice surveyed	Details of the practice
Tillage (conventional)	Ridging with hand hoe
	Ploughing with oxen
	Ploughing with tractor
	Bunding
	Chitemene
	Contour Ploughing
Minumum soil disturbance	Planting basins/potholes
	Minimum tillage (ripping by hand)
	Ripping with oxen
	Ripping with tractor
Agronomy	Crop rotations
	Crop rotations with nitrogen fixing crops (legumes)
	Intercropping (mix cropping)
	Cover crops
Residue management	Crop residues (from the same field or imported from other fields) are left in the field as residue or incorporated with plough & the proportion of remaining residue eaten by animals is less or equal to 30%. No residue burning in the field.
Agroforestry	Trees considered: Musangu (Faidherbia albida), Sesbania, Musekese, Lukina (Leucaena), Moringa (Zakalanda), Masau, Mulubesi
Soil and water conservation structures	Stone bunds, earth bunds, terraces, ditches, grass barriers (e.g. vetiver grass embankments)

Source: own elaboration

Primary data, completed with available secondary information, have been used in the analysis. Ad hoc household (HH) surveys have been conducted. Data have been integrated through key informant interviews and focus group discussions with extension workers and village representatives. Questionnaires have been specifically developed to collect primary data from farming HHs and villages to estimate benefits and costs of agricultural practices and to be used as survey instruments in the country, with reference to 2012-13 cropping season. Only main season and rain-fed crops are considered.

Data was collected at a single point in time through a „one-shot" survey. Multi-stage Stratified Random Sampling (SRS) procedure was used in the study in order to obtain efficient and consistent estimates of the target population. It involved dividing population into Ni homogeneous non-overlapping sub-groups (i.e., strata) and then taking a simple random sample in each subgroup. Each stratum is represented by the group of SLM adopters in each Camp, characterized by homogenous agro-climatic conditions. Since we use different sampling fractions in the strata, we apply disproportionate stratified random sampling. During the first stage, the areas where farmers have been practicing SLM technologies for at least 4 years have been identified. At the second stage, key informants were interviewed in order to obtain information on the location of clusters that have the necessary critical mass of smallholders who have adopted the relevant CSA practices. Third stage involved selection of single HHs to be interviewed. Actual respondents have been randomly selected to be interviewed. Results will be considered as representative of the HHs in the stratum. Crop and livestock production data (socio-economic, agronomic, farm management) have been collected for 1,264 fields cultivated by 695 smallholders over 17 camps located in 8 districts (Mumbwa, Chibombo, Katete, Chipata, Chinsali, Mpika, Kalomo, Choma) in agro ecological regions IIa and III.

Information collected during preliminary field activities confirmed that farmers adopt SLM practices on some fields, and keep practicing „conventional" agriculture on other fields. In the same HH data on both SLM and „conventional" agriculture practice can be collected and comparison between SLM and „conventional" practices is conducted at the field level within each household. For each sampled household, a field managed through SLM was selected as well as a conventionally managed field. This eliminated any potential household characteristics that might influence household productivity but are unrelated to CSA. The direction and success of diverse agriculture practices (SLM vs. „conventional") will therefore not depend on HH structural characteristics (family and farm size, land use, age and educational background, level of capital assets, resource ownership), business organization, skills of farmers and their ability to employ those skills in optimizing the use of available resources. In this way, it can be expected that only the specificities of target practices will influence both the likelihood and potential success of agriculture practice diversification. This controls for the potential bias in observations between adopters and non-adopters. A sub-sample of non-adopters was also selected for being interviewed.

A four-step methodology is adopted for the empirical analysis. First, food security increase of the selected „improved" practices with respect to „conventional" farming has been estimated by using partial budgeting technique and following equations:

$$GM_{jT} = TR_{jT} - TVC_{jT} \qquad (1)$$

$$TR_{jT} = P_j Q_{jT} \qquad (2)$$

$$TVC_{jT} = \sum_{i=1}^{n} P_{xi} X_i \qquad (3)$$

$$GM_{jT} = P_j Q_{jT} - \sum_{i=1}^{n} P_{xi} X_{iT} \qquad (4)$$

Where:

GM_{jT}=gross margin (\$/ha), for crop j and technology T

TR_{jT} = total revenue (\$/ha), for crop j and technology T

TVC_{jT}=total variable costs (\$/ha), for crop j and technology T

Q_{jT}=crop yield obtained under different technologies (Kg/ha)

P_j=farm-gate price of crop j (\$/kg)

X_{iT}=quantity of input i (per ha) used in production of crop j, under technology T

P_{xi}=farm-gate price of input i (\$/kg).

Second, Ordinary Least Squares (OLS) regressions have been run in order to control for the impact of other variables on crop yields and isolate the effect of farming practices. The following log-linear Cobb-Douglas function is considered:

$$lnQ = lnB_o + \beta_1 lnX_1 + \beta_2 lnX_2 + \beta_3 lnX_3 + \cdots + \varepsilon^{\mu_i} \qquad (5)$$

where:

Q=crop yield

Xi=the following variables have been considered: field size (ha), total labor (days), quantity of chemical fertilizers (kg), quantity of herbicides (lt), dummy variable for use of improved seeds (1=yes), dummy variable for adoption of MSD technology (1=yes), dummy variable for AEZs (1=yes).

Third, the potential of climate change mitigation of target practices has been analyzed through a mitigation option model (MOM) developed by Vetter et al. (2014). MOM is based on empirical models and emission factors to calculate the mitigation potential spatially. This analytical modelling work was conducted to determine appropriate "Tier 2" greenhouse gas (GHG) mitigation estimates for a range of cropland mitigation options. Technical mitigation approaches in the MOM were mainly based on the methodology for field related nitrous oxide emissions using Stehfest and Bouwman (2006), an adapted application of IPCC (2006) and further complementing methodologies[1].

Fourth, cost-effectiveness of each technology option is estimated (in terms of $/t CO2e abated). This will represent the marginal abatement costs of each option computed on the basis of the unitary abatement potential and estimated against what would be expected to happen in a „business as usual" (BAU) baseline (Branca et al. 2015). MAC curve for target technologies is built using net incomes from the cost-benefit analysis and the mitigation potential estimated using the MOM model. It reports the incremental costs with respect to baseline scenario (i.e. „conventional" tillage system). MAC curve reports costs of different abatement measures (per unit of CO2e abated) on the vertical axis and the GHG volumes abated (annual emission savings generated by adoption of the measure) on the horizontal axis, showing a schedule of abatement measures ordered by their specific costs per hectare and unit of CO2e abated. The curve is upward-sloping, showing how marginal costs rise with the increase of the abatement effort, therefore indicating which solutions are most efficient. Moving along the graph from left to right worsen the cost-effectiveness of technology options since each ton of CO2e mitigated becomes more costly. Negative abatement costs are found for cost-saving technology opportunities, i.e. the adoption of such measures will increase profits.

3. Results

Tillage practice (MSD or Tillage) is considered the discriminator between SLM and „conventional technologies, the latter representing the baseline scenario of the analysis. This will state the point of view from which costs and benefits will be assessed. MSD is somehow „improved" and represents SLM systems. Since the questionnaires allowed reporting multiple practices applied on the same field, many different combinations of practices have been found and a classification in terms of absolute and relative frequency has been made in order to select only most represented technologies (table 2). Zambian farmers adopt a wide combination of land management practices, applied to various crops. Most farmers rely on conventional agriculture for crop production but are testing SLM technologies on some fields, with the support of government and non-government projects and programs.

Different crops and agro-ecologies are taken into account in the analysis. However, here we report only results related to maize, which is most important grown crop in the country. We find: MSD increases yields in AER IIa where both MSD and „conventional" practices are recorded; maize yield under „conventional till system in AER III is much higher than under MSD; yield results do not substantially change when we look at specific Till and MSD management technologies, i.e. hand hoeing/ridging and ploughing with oxen (till) on one side, and planting basins and ripping with oxen (MSD) on the other. Such results are compatible with the agronomic principles of MSD (and CA in particular), aimed at maintaining soil moisture, with effective benefits in dryer areas. Conservative soil practices provide benefits in terms of increased soil moisture, which are mostly beneficial to yields where water is a limiting factor. Cash costs for fields under MSD are higher than under tillage (conducted adopting conventional hand hoe/ridging practices); they are at about the same level as fields ploughed with oxen; MSD requires more herbicides (used to control growth of weeds which may be a problem when tillage is not practiced) and fertilizers than the alternative „conventional" and manure. Other inputs (manure, seeds) do not show significant differences among technologies. Cash input costs are higher for practices making use of external hired labor (animal draft power for ploughing and ripping with oxen). In dry areas, gross margins are slightly positive for conventional hand hoeing/ridging and MSD. However net incomes are negative for all technologies. Ripping with oxen technology gains better results than till soil management, due to higher revenues gained through better yields. Family labor costs are particularly relevant for planting basins making the technology less profitable than ripping. In any case maize cropped in humid areas is found to have better results (higher revenues and positive net incomes). It is interesting to note that net incomes for hand hoe/ridging and ripping with oxen become positive when farmers benefit of the subsidized fertilizer price. This is the meaning of the column „net income subsidized" in figure 1. It is found that 56% of farmers purchase top dress fertilizers[2] at subsidized price; and 43% purchase basal fertilizer at subsidized price[3].

[1] The covered GHG emission and carbon stock change impacts include: soil organic carbon stock changes on agricultural land, carbon stocks in biomass, direct field emissions of N2O and NO (from fertilizers and crop residues), volatilization of ammonia, Nitrogen leaching and runoff, fertilizer and agrochemical production and application. Different typical fertilizer intensities, crop yields and associated residue quantities are considered as identified through the HH survey data. Target agriculture practices were assessed for their potential to lead to significant mitigation benefits utilizing spatial explicit data with regards to initial soil carbon stocks and further soil input variables at a resolution of 30 arc-seconds using the Harmonized World Soil Database (Vetter et al. 2014).

[2] This fertilizer category includes: Urea or (calcium) ammonium nitrate.

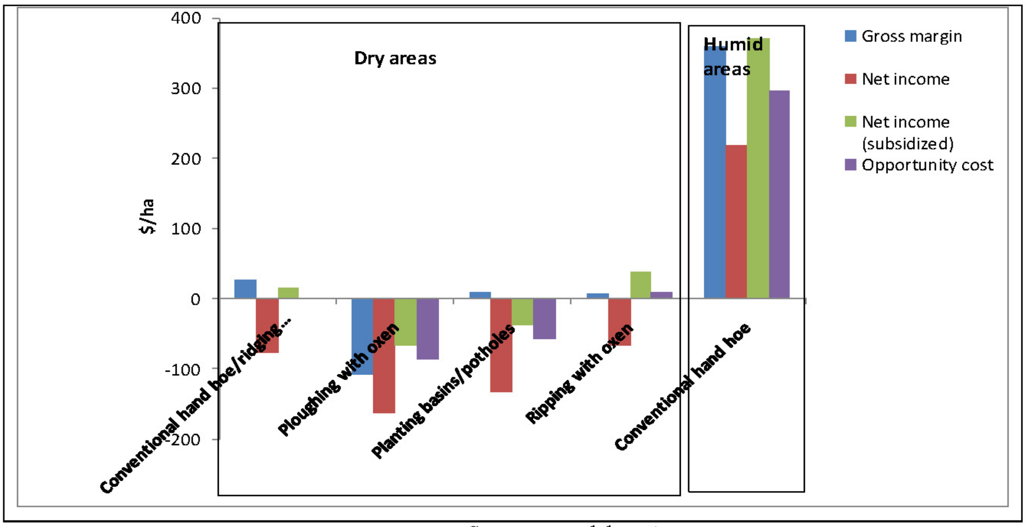
[3] This fertilizer category includes: Compound D, Compound X, Compound R, Compound S, Triple Super Phosphate (TSP), Single Super Phosphate SSP).

Table 2 - Classification of the practices in appropriate technology packages (MSD vs. Tillage systems) and diffusion among farmers in the sample (national level)

			Freq.	Percent
Tillage	T1	+ crop rotation no legumes + residue retention	290	23
	T2	+ crop rotation no legumes	254	20
	T3	+ residue retention	21	2
	T4	+ other combinations	73	6
	T	**Total conventional**	**638**	**50**
MSD	M1	+ crop rotation no legumes + residue retention/cover crop/intercropping	314	25
	M2	+ residue retention	83	7
	M3	+ crop rotation no legumes	114	9
	M4	+ crop rotation legumes + residue retention/cover crop/intercropping (CA)	23	2
	M5	+ agroforestry + other combinations	73	6
	M6	+ other combinations	19	2
	M	**Total MSD**	**626**	**50**

Source: own elaboration

Figure 1 - Maize; gross margins and net incomes, by technology and AER



Source: own elaboration

Albeit the small sample size, productivity analysis confirms the key role of inputs (capital and labor) as well as SLM practices (MSD, residue retention, and crop rotation with legumes) on crop yields in the AER IIa. Results of the OLS estimation of the log-linear production function for maize are reported in table 3. Across SLM practices, however, only MSD (which is defined as either planting basin/potholes or minimum tillage or ripping with oxen or ridging) is significant. However, higher CA yields could also depend on higher fertilization level. In order to check this possibility, we introduce an interaction term between MSD adoption and the amount of inorganic fertilizer used (column 2). The results still show a positive effect of MSD practices on yields (i.e. MSD is effectively increasing yields). Results also show diminishing returns to scale, as expected. We also control for weather variables but results are not significant. Looking at household characteristics, the age of the household head is negatively related to productivity, whereas wealth (measured by a wealth index computed using Principal Component Analysis) is associated with higher maize yields.

Table 3 - Regression results, maize, AER IIa

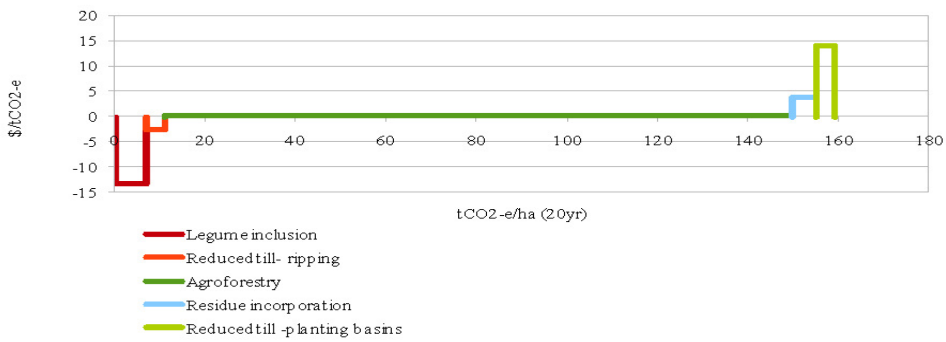
	Log of maize yields (kg/ha) AER IIa	
	(1)	(2)
SLM practices		
MSD (1=yes, 0=no)	0.172**	0.178*
Residue retention (1=yes, 0=no)	0.096	0.096
Crop rotation with legumes (1=yes, 0=no)	0.260	0.260
Weather variables		
Total rainfall during cropping season (mm)	0.001	0.001
Average of dekadal max temperatures during growing season (°C)	-0.127	-0.127
Production inputs		
Log of land (ha)	-0.083	-0.083
Log of family labor (mandays)	0.120*	0.120*
Log of fertilizer (kg)	0.114***	0.115***
Log of herbicide (lt)	0.056***	0.056***
Use of improved in seeds (1=yes, 0=no)	-0.180	-0.179
Household characteristics		
Household size	0.001	0.001
Age of household head	-0.011***	-0.011***
Average years of education of household members	-0.027	-0.027
Wealth index	0.111*	0.111*
Interaction term		
MSD*Log of fertilizer		-0.001
Constant	9.380**	9.377**
Number of observations	*558*	*558*
R2	*0.327*	*0.327*

Std. Err. adjusted for 13 clusters
*note: .01 - ***; .05 - **; .1 - *;*

Source: own elaboration

MAC curve is derived as a histogram where each bar represents a single agriculture technology option. The width of the bar represents the amount of abatement potential (ton of CO2e saved as measured on the x axis). This amount is computed as difference between the mitigation potential of the technology and the mitigation potential of the „conventional technology (baseline). The height of the bar indicates the unit cost of the action (unit cost of abatement measured in US$ per ton of CO2e saved as measured on the y axis). The area (height * width) of the bar shows the total abatement cost of the technology (measured in US$). Land reference unit is 1 hectare and each bar refers to that land unit. The bars have been placed in order of increasing unit cost. Technology with the lowest abatement cost is put as the first option, while the technology with the highest unit abatement cost is put as the last option. In this way the MAC curve shows the range of possible technology options that should progressively be implemented according to a criterion of cost-effectiveness. MAC curve is reported in figure 2.

Figure 2 - Marginal Abatement Cost Curve for maize production in Zambia, AER IIa



Source: own elaboration

MAC curve shows that legume inclusion provides the most cost-effective form of mitigation, followed by MSD (reduced till through ripping with oxen). By contrast, more labour intensive technologies, such as reduced tillage through planting basins or residue retention (mulching) are less cost effective, which is due to their higher cost implications. Agroforestry is able to sequester biggest CO2 quantities bust is less cost-effective than cheaper solutions like legume inclusions and MSD with animal draft power (ripping with oxen). Policy makers should promote the adoption of MSD technology options first, in order to act in a costeffective way and gain efficiency. Marginal abatement costs are negative for cheapest options (-13.2$/t and -2.4$/t for legume inclusion and MSD-ripping, respectively). Adoption of these practices will generate higher benefits than under conventional agriculture, therefore showing a synergy between rural development (increased food security) and climate change mitigation (abatement potential). Marginal abatement cost for agroforestry amounts to only +0.12$/t. This means that costs offset the benefits. This technology requires bigger production costs (seedlings production and planting, labor). Also, they are characterized by a longer implementation period where the costs are borne in the first years (building infrastructure and planting trees), while the benefits are gained in the medium-long term, therefore generating a negative flux of net benefits in the short-term (like the time frame of the present analysis). In terms of the mitigation potential per hectare (width of the MAC curve) AF systems provide a structurally higher potential than all other systems. MSD-planting basins is found to have a positive abatement costs (+14.1 $/t) due to labour intensity related to this practice. Although technologies are alternative options, the areas where such options are implemented can be added together. By summing up the areas of the bars it is therefore possible to derive the total abatement cost of a cumulative abatement target, measured in US$.

4. Discussion and Conclusions

A wide variety of SLM practices characterize smallholder agriculture in Zambia and isolating the productivity effect of individual practices is complicated by the adoption of combinations of practices. We assess the extent to which SLM technology packages improve crop productivity and net incomes of Zambian family farms. Results are compatible with other studies in the area (e.g. see Burke et al. 2011).

Maize grown using MSD technologies in dry areas is found to gain better yields than maize cropped under „conventional" ill methods. This is in line with the agronomic principles of MSD which can generate most benefits in dry areas, improving soil properties, increasing soil moisture and overall organic substance. When controlling for fertilizer and other inputs, MSD still has positive effects on the yield. Maize yields in humid areas (only „till systems") are much higher than yields in dry areas, no matter the technology adopted.

However, overall production costs for maize MSD are higher than for „conventional till". MSD is found to be more capital-intensive than „conventional" agriculture. This is because of the higher use of fertilizers and herbicides to control weeds. MSD is also more labor intensive, especially for some time-consuming practice (e.g. planting basins). Cash cost and labor availability could therefore represent a barrier to adoption and well-resourced farmers are better positioned than low-resourced ones in adopting MSD. Use of improved seed varieties is found not to have a specific role in SLM productivity, as their use is reported to be at the same level as „conventional" farming. MSD gains better incomes when animal draft power is considered (ripping with oxen). MSD represents an improvement with respect to conventional hand hoeing/ridging as it shows higher labor productivity.

SLM implementation has important implications in terms of food security, climate change adaptation and mitigation and should be considered in investments aimed at increasing Climate-smartness of agriculture systems. Supporting farm incomes growth is a way to address food security in Malawi. This requires, in the first instance, an increase in productivity of land and labor in the farming sector. Increasing the productivity of farm labor typically requires the introduction of new technologies (Paarlberg 2010).

MSD in arid areas of Zambia has shown promising results in terms of land, capital and labor productivity and could represent valid CSA option providing that appropriate choices in terms of labor source (manual versus animal draft power), specific practice (planting basins/potholes versus ripping, legume inclusion in crop rotations and residue retention), crop (maize versus groundnut) and access to fertilizer subsidies are made.

This is consistent with the expected agronomic benefits of CA pillars (minimum tillage, crop rotations with legumes and residue management), i.e. improved soil moisture and fertility conditions, with evident adaptation benefits. MSD represents a feasible option to face drought risk for resource constrained smallholders and synergies between food security and CC adaptation (e.g. see Delgado et al. 2011; Kaczan et al. 2013) are highlighted . Such option would be cheaper, of easier adoption and better accessibility than more costly alternatives, e.g. irrigation. However irrigation requires high investments, and is questionable for smallholders with limited access to markets. SLM is a much better option as it requires fewer on-farm and off-farm investments.

Climate-smartness of SLM practices is considered also as concerns CC mitigation. MSD technology options also generate environmental benefits in the form of CC mitigation. Agroforestry has highest mitigation potential per unit of land. Negative marginal abatement costs for some MSD options (legume inclusion and ripping with oxen) show synergies between increased farm incomes and climate change mitigation, and represent means of generating "win-win" solutions to addressing poverty and food insecurity as well as environmental issues (climate change mitigation). The cost-effectiveness of different land management practices is proposed as synergetic decision criteria allowing policy makers to prioritize support interventions on the basis of the economic efficiency of GHG abatements.

Results of the analysis have also interesting social implications: better returns makes profitable to hire labor with positive results in terms of increased food security for HH and Communities. Also, better economic results can drive the transformation from smallholder to emergent farmers. The use of herbicides instead of weeding implies less work for women, with important gender implications.

Adoption of MSD technologies in the field is driven by several factors, e.g. access to inputs, labor availability, profitability and returns, equipment availability . Also, organizations and projects which provide some form of support to farmers willing to participate (e.g. tree seedlings for Agroforestry).

Difference in MSD diffusion has to do not only with climate (MSD is effective in keeping soil moisture, therefore more effective useful in drier areas) but also with policies – in Zambia most CA/CF projects have been focused in AER IIa (next to the railway line and Lusaka area); and in the sample MSD fields are found only in AER IIa.

Farmers are testing the innovative technologies. Given the cost barrier, this support - as well as support provided through the FISP-fertilizer subsidy program - is key. Although it can be argued that production costs can be offset by higher gross margins realized under MSD systems, incurring additional capital costs can be a disincentive for MSD adoption for majority of smallholders in SSA and Zambia in particular.

Several implications at policy and institutional level can be highlighted here. National statistics in Zambia do not systematically collect and record information related to the different farm technologies, land management. The present work represents a contribution in this direction. Classification of practices/ technologies, economic and environmental indicators and data collection methodology could be useful for Institutions involved in agriculture statistics.

Policies to promote appropriate CSA technologies should be differentiated in order to take into account values of land, capital and labor productivity indicators associated to technology uptake in different agro ecologies and climates. For example, higher production costs of MSD could be addressed by policies aimed at making herbicides and mechanization (e.g. rippers) more affordable to farmers; reduce transactions costs throughout the value chain (e.g. real-time market information). Coherent messages should be conveyed through rural extension services.

The results are affected by the way the definition and identification of crops and practices/technologies in the field has been made and data have been collected. The survey has also revealed that many farmers claim to practice residue retention (i.e. they leave crop residues on the soil after harvesting) without any specific management and protection from free grazing. Probably only a few farmers adopt proper „mulching" following agronomy rules developed in experimental fields. Leaving crop residues in the field is one of the three CA pillars. Mulching is a further step that involves crushing the residue and using it to cover the surface of the soil. This is done mostly for tobacco and horticulture on a smaller scale. Few farmers would mulch on a field crop because they would need significant quantities of residues. It is also well known that in Zambia keeping residues in the field is difficult due to some traditional practices (e.g. free grazing, mice hunting and burning). More research is needed on this issue. There are many implications in terms of land tenure, community rules and titling enforcement which are not taken into account here.

Cover crop use is very limited in the sample and it's not used in its proper agronomic function. Intercropping is present and included in MSD, however the comprehension of this question in the survey is doubtful. Agroforestry data have been collected either at plot level (if available) or for the overall HH, depending on what the farmer was reporting. In the latter case, costs have been approximately imputed at field level on the basis of HH size. Soil and water conservation practices are excluded from the analysis due to lack of sufficient data. Cassava was excluded from the analysis, although data were recorded but considered not reliable because of the difficulty in estimating yield and allocating labor and inputs to the crop.

Given the base data collected through a one-shot survey, the analysis adopts a static approach, ignoring the year to year difficulties associated with the transition from one system to another (which may be important in case perennial species are grown, e.g. with Agroforestry). Agronomists argue that switching from „conventional" to MSD technologies (e.g. from till to CA) increases crop yields after a few years of declining or stable yields. Also farmers may need a few years of experience to acquire the additional knowledge and management skills necessary for more diversified operations. Most farmers adopt alternatives gradually. In the sample, an average a number of 3-4 years of adoption is recorded which agronomists consider not enough for „conservative" practices to generate expected benefits. Unfortunately due to lack of data this piece of information is not statistically significant, and was not possible to make a distinction in terms of years of adoption (e.g. up to 2 years and above 3 years). These aspects are not sufficiently taken into consideration here.

The one-shot survey and recalling approach may also affect the results discussed here. This is particularly true for some variables such as labor costs. Although the survey has been conducted at the immediate end of the cropping season, in order to minimize the recalling bias; both recalling and market labor approaches are used in the HH and Community questionnaires respectively; medians are used instead of means; results have been validated using available secondary information; overestimation/ underestimation of some variables may be occurred.

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The set of indicators for assessing progress achieved under the National Action Plan for the sustainable use of plant protection products, in Italy

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ABSTRACT

The Directive 2009/128/EC establishes a framework for Community action to achieve the sustainable use of pesticides. It also establishes that Member States shall adopt National Action Plans for the sustainable use of plant protection products (NAP), which shall also include indicators to monitor the use of plant protection products (PPP) containing active substances (AS) of particular concern. In Italy, within the framework of the NAP, adopted by Interministerial decree of 22 January 2014, a set of 15 indicators has been selected and formally assumed by the Interministerial decree of 15 July 2015. Indicators aim should be assessing progress in reducing the risks and impacts of PPP use on human health, on the environment and on biodiversity. In this paper an overview of the indicators will be presented, underlining those based on data collected in accordance with Regulation (EC) No. 1185/2009 concerning statistics on pesticides.

Keywords: pesticides statistics, Directive 2009/128/EC

PAPER

1. Introduction

The paper presents a set of innovative indicators, selected for measuring and evaluate the results of the National Action Plan for the sustainable use of plant protection products (NAP) adopted in Italy. Section 2 describes the NAP and the corresponding actions, while section 3 presents the methods and criteria used to select the set of indicators. An overview of the indicators will be presented, underlining those based on data collected in accordance with Regulation (EC) No. 1185/2009. In section 4 a brief discussion follows.

2. The National Action Plan and the measures for assessing progress achieved under its implementation

The Directive 2009/128/EC (enacted into national law with Legislative Decree of 14 August 2012, n. 150) stated that a specific action plan needed to be adopted in order to reduce the risks to human health, environment and biodiversity, associated with the use of pesticides. The NAP has been adopted in Italy by Interministerial Decree of 22 January 2014. Main actions proposed by NAP in Italy concern:

1. *Training and requirements for users, sellers and advisors*, regarding specifically the risks associated with the use of plant protection products (PPP);

2. *Information and awareness*, specifically addressed to the public, on potential risks associated with the use of PPP;

3. *Control of equipment for the application of PPP*, and in particular monitoring, regulation and maintenance;

4. *Aerial spraying*, in respect of its ban except for derogations in specific cases;

5. *Specific measures to protect the aquatic environment and drinking water and to reduce the use of PPP in specific areas* (rail and road, areas frequented by the population, protected areas – Natura 2000 sites, parks, etc);

6. *Handling and storage of PPP and treatment of their packaging and remnants*;

7. *Integrated pest management (IPM) and organic farming*, with the goal to increase agricultural area carried out with voluntary and mandatory IPM and organic farming.

Furthermore one specific task regards the identification of a set of indicators, whose aim, in addition to encourage dissemination, is to verify the achievement of the objectives of the NAP and to measure and monitor the results and the effectiveness of actions takeni. A working group (WG) coordinated by the Institute for Environmental Protection and Research (ISPRA) has defined the proposed set of indicators. Article 22 of the Legislative decree no. 150 of 14 August 2012 specifies that the set of indicators should be aimed at "assessing progress in reducing the risks and impacts of PPP use on human health, on the environment and on biodiversity" (ISPRA, 2014).

Most indicators regard, directly or indirectly, farming practices. The application of the NAP hopefully should determine significant improvements in sustainability of farming practices. The overall objective is to reduce the PPP use and especially the risks and impacts in the plant protection treatments. This will require a greater spread of voluntary integrated pest management and organic farming, the decreasing use of traditional aerial spraying, an even better performance of the equipments and treatment methods, an improved skill of operators in carrying out treatments, a greater diversification of the cropping system (higher number of crops grown, more efficient crop rotation criteria, presence and duration of cover crops, use of non-chemical alternatives), etc..

3. The set of indicators: work method and criteria for the selection

The NAP assessment relies on information built on good quality data and indicators. Indicators are selected and/or aggregated variables derived from datasets linked to assessment issues and related to policy objectives or targets.

The WG considered as "indicator" „a measure, generally quantitative, that can be used to illustrate and communicate complex phenomena simply, including trends and progress over time – and thus helps provide insight into the NAP".

The WG selected the indicators according to OECD criteria (OECD, 1993), that are:

a) relevance of information;

b) measurability in terms of immediate data availability and upgradeability;

c) scientific soundness.

Other important criteria for the selection of indicators were existing links to the official statistics. Adherence to principles of official statistics can ensure that the indicator provides objective information, has a scientifically defensible foundation, is consistent over time and from country to country and meets pre-defined quality standards (EEA, 2014).

The indicators were analyzed according to two procedures:

1) compilation of indicators fact sheets (ISPRA, 2010);

2) implementation of a web application to process and fill in the compilation of the indicators fact sheets.

This application program is open to consultation by potential users on/at the ISPRA site: http://indicatori-pan-fitosanitari.isprambiente.it.

The set of 15 indicators has been selected and formally adopted by the Interministerial decree of July 15, 2015. These indicators cover as much as possible the NAP objectives and actions and reflect policy priorities (Table 1). More specifically, the set of indicators is structured into seven main actions which match up the objectives of the NAP (Pallotti A. et al., 2013). However, currently, only five actions are represented by the **specific indicators** processed. The specific indicators are also integrated by **key indicators** and **cross indicators** (Graphic 1).

The selected indicators take into account and exploit existing monitoring programs and databases. Several institutions provide the data and the information and share the responsability for the processing of the indicators (Table 1). In accordance with the Interministerial decree of 15 July 2015, ISPRA, in cooperation with the Italian National Institute of Statistics (ISTAT), the Council for Agricultural Research and Economics (CREA) and the Italian National Institute of Health (ISS), is incharged to coordinate a new WG and to manage the above mentioned web page. According to the NAP updates, single indicators can be improved and the set of indicators can be integrated with new ones, above all with harmonized risk indicators that will be defined at Community level under Directive 128/2009/EC.

The availability of the data and information for the processing of the indicators is not homogeneous. Three main situations are described:

a) the data are available and directly accessible;

b) the data are potentially available, but they need more time and resources to be collected, harmonized and processed;

c) the availability of data depends upon the start and/or the continuation of specific monitoring and survey activities, which require specific programs implementation and adequate financial support.

Some indicators are immediately processable and therefore considered "active", being database already available; others, considered particularly relevant and with appropriate scientific soundness, there will be in the medium and long term whether feedbacks from the NAP actions implementation will be available and/or specific actions will be undertaken.

Futher information on scope and limits of single indicators can be found in Table 1 while detailed general information is available on-line and in the web page dedicated to the information system.

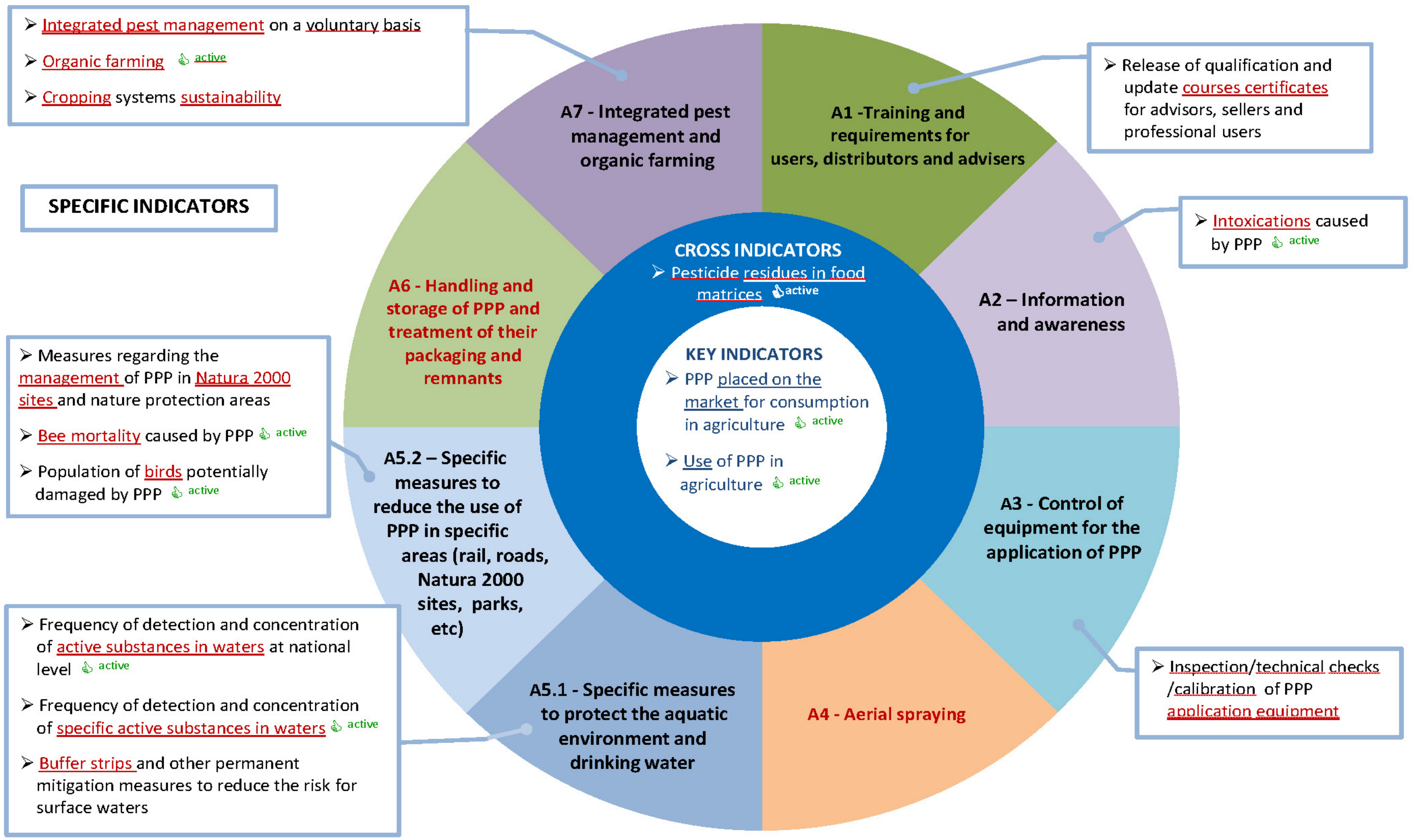
Table 1: *The set of indicators for assessing progress achieved under the NAP, in Italy*

Indicator	Indicator brief description	Institution calculation	Institution data	Indicator status
PPP placed on the market for consumption in agriculture	It allows to assess the amounts of PPP and AS yearly placed on the market for consumption in agriculture, as well as to compare the trends over time and on territorial (regional) basis. Data on placing on the market are considered to be a proxy of PPP sold and used in the field. They do not allow to (a) quantify their use in the various agricultural crops, (b) consider the environmental factors that affect their use in agriculture and (c) analyze their impact on the environment and human health.	ISTAT	ISTAT	*Active*
Use of PPP in agriculture	It provides information on the intensity of use of PPP and AS in individual crops in terms of quantity/ha and potential environmental impact.	ISTAT	ISTAT	*Active*
Release of qualification and update courses certificates for advisors, sellers and professional users	It expresses, in absolute value, the number of brand new certificates and those resulting from updating courses released to advisors, sellers and users of PPP. It allows to assess training achievements trends but does not reflect the effects on human health and the environment, i.e. the effectiveness of training.	MiPAAF	MiPAAF, Regions	*To be activated*
Intoxications caused by PPP	It is based on the number of surveyed/observed incidents and on related poisoning episodes of agricultural workers and general population.	ISS	ISS	*Active*
Inspection / technical checks / calibration of PPP application equipment	It expresses the number of technical checks and calibrations performed in the year. It measures the efficiency of PPP application equipment.	MiPAAF	MiPAAF, Regions, ENAMA	*To be activated*
Frequency of detection and concentration of AS in waters at national level	It provides detection frequency and concentrations of PPP residues in surface and ground waters as well as a national overview of contamination status. It allows to follow the evolution of the contamination due to the use of pesticides and, ultimately, to monitor the effectiveness of specific actions taken for mitigating risk.	ISPRA	ISPRA, Regions / ARPA-APPA	*Active*
Frequency of detection and concentration of specific AS in waters	It measures the contamination of surface and groundwater by residues of "specific/selected" AS.	ISPRA	ISPRA, Regions / ARPA-APPA	*Active*
Buffer strips and other permanent mitigation measures to reduce the risk for surface waters	It estimates the surface area change over time (percent) of the buffer strips (not cultivated vegetated strips and other ecological infrastructure) located along water bodies in order to limit pollution due to runoff, percolation and drift.	MiPAAF	MiPAAF	*To be activated*
Population of birds potentially damaged by PPP	Intended to detect the effects of agricultural practices on biodiversity, it estimates the trend of population of nesting species in agricultural habitats. It is calculated considering the specific ornithological area of the plains, where it is assumed that the use of PPP is more intensive.	CREA/LIPU	MITO 2000	*Active*
Integrated pest management (IPM) on a voluntary basis	It describes the utilized agricultural area (UAA) and the tons of crops produced according to integrated pest management (IPM) on a voluntary basis.	MiPAAF		*To be activated*
Organic farming	It describes the utilized agricultural area (UAA) cultivated according organic farming techniques. It is calculated as the ratio of the organic farming area and the total UAA.	MiPAAF	SINAB	*Active*

Indicator	Indicator brief description	Institution calculation	Institution data	Indicator status
Measures regarding the management of PPP in Natura 2000 sites and nature protection areas	It provides information on the number and type of measures (regulatory, administrative or contractual) on the use of PPP included in Natura 2000 sites Management Plans and in the protected areas (parks, etc.) Plans. It allows to assess over time the implementation of the measures in sites and areas characterized by a percentage of UAA ≥ 20%. It does not detect the environmental effectiveness of the measures taken.	ISPRA	MATTM	*To be activated*
Bee mortality caused by PPP	It shows the number of bee mortality cases attributable to PPP throughout the country. It tries to detect agricultural practices and specific PPP responsible of bee mortality. The mortality data/reports come from SPY-BEENET project (MiPAAF) and the National Health Service (MINSAL).	IZS LT	MiPAAF, MINSAL	*Active*
Pesticide residues in food matrices	It allows to assess the proper use of PPP and to monitor the risks to consumer health associated with food intake. It detects the residue levels of pesticides in or on food of plant and animal origin. Every year 10 vegetables, both from organic farming and conventional agriculture, 2 foods of animal origin and one baby food are sampled.	MINSAL	MINSAL	*Active*
Cropping systems sustainability	It aims to highlight the adoption of preventive measures and non-chemical means. It assumes that the greater is the diversity of cropping system the lower is the presence of organisms harmful to crops. The evaluation of this diversity is based on: number of crops grown, rotation type and presence and duration of cover crops. A further aspect is the use of non-chemical means. Data source is mainly Farm Accountancy Data Network (RICA).	MiPAAF, S.S. S. Anna	CREA	*To be activated*

ARPA - *Regional Agency for Environmental Protection*
APPA - *Provincial Agency for Environmental Protection*
ENAMA – *Italian Agricultural Mechanization Body*
CREA - *Council for Agricultural Research and Economics*
ISPRA - *Institute for Environmental Protection and Research*
ISS – *Italian National Institute of Health*
ISTAT – *Italian National Institute of Statistics*
IZS LT - *Institute of Animal Health and Food Safety for Latium and Tuscany Regions*
MATTM - *Ministry of the Environment and Protection of Land and Sea*
MINSAL –*Ministry of Health*
MiPAAF - *Ministry of Agriculture Food and Forestry Policy*
MITO 2000: *ITalian Ornithological Monitoring*
S.S. S. Anna – Sant'Anna School of Advanced Studies

Graphic 1: *The set of indicators structured into the seven main actions of the NAP*



Special attention deserve the first two indicators in Table 1, as they concern statistics on pesticide.

The Regulation (EC) No. 1185/2009, concerning statistics on pesticides, establishes a common framework for the systematic production of Community statistics on the placing on the market and use of pesticides on specific relevant crops.

The Regulation points out that the statistics shall serve the purposes of Directive 2009/128/EC, in particular, to monitor actions implemented through the application of the NAP.

Harmonised and comparable Community statistics on pesticide are essential for the development and monitoring of Community legislation and policies in the context of the Thematic Strategy on the Sustainable Use of Pesticides.

At EU level, the need for harmonised data, specifically on pesticide use, has been clearly recognised (EUROSTAT, 2008). Once the regular collection of usage statistics on PPP use has been established, it is possible to monitor changes over time in the use on particular crops or in the use of specific pesticides.

As stated by Legislative decree no. 150 of 14 August 2012, these data will be also used for the compilation of the indicators and will make an essential contribution in detecting "trends in the use of certain AS with particular reference to the type of crop, treated areas and pest management practices."

The statistics produced in Italy by ISTAT are essential for assessing policies of the EU on sustainable development and for calculating relevant indicators on the risks related to pesticide use (Table 2). ISTAT produces two types of statistics on pesticides:

- Statistics on the annual amounts of pesticides placed on the market.
- Statistics on the annual amounts of pesticides used on specific relevant crops.

Table 2 - The first Indicator - PPP placed on the market for consumption in agriculture: products and traps, and active substances, distributed for agricultural use, for category (in Kg) - Year 2014

Geografical areas	Fungicides	Insetticides and acaricides	Herbicides	Various	Biologicals	Total	Traps (number)
Plant protection products and traps							
North	32.311.368	13.113.263	14.877.177	5.975.714	-	66.277.522	192.974
Center	8.719.766	1.890.090	2.856.572	2.928.784	-	16.395.212	109.236
South	24.283.832	7.280.423	6.474.763	9.265.091	-	47.304.109	172.250
ITALY	**65.314.966**	**22.283.776**	**24.208.512**	**18.169.589**	-	**129.976.843**	**474.460**
Active substances in plant protection products							
North	17.553.146	2.962.111	4.846.597	2.971.451	168.019	28.501.324	-
Center	4.513.302	338.963	902.276	1.390.162	43.963	7.188.666	-
South	14.857.090	2.290.614	2.049.887	4.433.030	101.440	23.732.061	-
ITALY	**36.923.538**	**5.591.688**	**7.798.760**	**8.794.643**	**313.422**	**59.422.051**	-

Source: ISTAT, Survey on the distribution of pesticides for agricultural use

The usage statistics allow to estimate active substances (AS) contained in pesticides used on each selected crop. Moreover they allow to monitor changes over time in the use of AS on crops, since information for each individual crop are collected periodically and compared with the preceding years. In Italy crops are selected taking into account the most relevant cultures for the NAP. Crops currently surveyed are: grapevine, maize, durum wheat, tomato and potato. Usage statistics are collected through samples of farms and provide information on the pesticides used on two or three crops each year, estimating the total amount of any specific pesticide and the area of crop treated with those pesticides. The data are collected through telephone interviews directed to a representative sample of farmers and growers. The phone calls are preceded by an information letter and are performed by trained personnel. Telephone surveys are used to reduce the cost of the surveys. These surveys are in fact similar in structure to personal interviews, but they avoid travel time and costs. However, for each call it is preferable to cover a single crop per farm.

Some useful information can be obtained from the statistics on the annual amounts of pesticides placed on the market which are compiled by companies and can be used as a proxy for pesticides use data. ISTAT produces an annual census survey and data (totals) are released at NUT3 level. Sales figures may be used to adjust and improve surveys on the use of pesticides. One of the advantages is these statistics are much cheaper to collect as they are compiled directly by companies and not by farmers. The data are generally accurate, as chemical companies normally know the amount of each product placed on the market and are able to provide annual figures. However, due to commercial reasons, these statistics can give rise to confidentiality issues and restrictions on the release and use of data. In fact, when published, data are grouped, masking the specific AS.

4. Discussion and conclusions

The initial objective of the activity was to define a set of innovative indicators for measuring and evaluate the results of the NAP adopted in Italy. The work continued with the revision, consolidation and optimization of the indicators list published in the Interministerial decree of 22 January 2014, regarding the adoption of the NAP. The ultimate achievement on the indicators was the proposed set of 15 indicators, adopted with the Interministerial decree of July 15, 2015.

At present ISPRA, in strict cooperation with ISTAT, ISS and CREA, is coordinating a new WG whose main task is to process the selected "active" indicators and manage the website *http://indicatori-pan-fitosanitari.isprambiente.it*.

The WG also aims, in accord with the NAP updates, to improve the definition and performance of the indicators and to integrate the set of proposed indicators with new ones, above all with harmonized risk indicators that will be defined at Community level by Directive 2009/128/EC. It is expected also that most of the indicators named "to be activated" (e.g. "Release of qualification and update courses certificates for advisors, sellers and professional users", "Inspection/technical checks/calibration of PPP application equipment", "Integrated pest management (IPM) on a voluntary basis", "Measures regarding the management of PPP in Natura 2000 sites and nature protection areas" and "Cropping systems sustainability"), will be processed in a reasonable time, since the data will be soon available partly as a consequence of the NAP actions implementation.

The WG expects a discussion and cooperation with other experts and scientific bodies, in particular universities and research institutes, that have specific expertise in this field and that so far the WG was not able to involve suitably in the work.

Interesting information and proposals are arising, for example, from the assessment of the effectiveness of laws, e.g. environmental monitoring of the Rural Development Plans or evaluation of the measures implemented by the regions according to Directive Habitats and Directive Birds.

At this time, experts are loading the available information on indicators in an information system, accessible via the above mentioned link. A first review of active indicators will probably be on-line early 2017. By the end of 2017, Member States shall submit to the European Commission a report on the achivement of the objectives and targets established in the NAP. The report should take in account also the information and evaluations arising from indicators processing. But, even more relevant, not further the beginning of 2019 (that is within 5 years from the NAP adoption) Member States shall revise NAP and propose a possible review and, if necessary, reformulation of the actions previously implemented.

The information system will represent the opportunity for stakeholders and policy makers of assessing results of NAP actions implementation and progress in reducing the risks and impacts of PPP use on human health, on the environment and on biodiversity.

The selected indicators represent a useful tool for researchers to evaluate the evolution of farming practices and measure the spread of good practices aimed to reduce PPP impacts and risks and to reach more efficient and sustainable crop production systems.

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[i] These actions are complemented by other activities as: promotion of monitoring programs on frequency of detection and concentration of active substances (AS) in surface waters and groundwater and on the PPP residues in food; the definition of priorities and the implementation of research and experimentation in support to the NAP and on higher education; the support of coordination measures to carry on control activities and NAP updating; compilation of technical manuals to support actions implementation; etc.

THEMATIC SET

C23

MONITORING AGRICULTURAL DEVELOPMENT POLICIES AND AGRICULTURALINVESTMENT

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ABSTRACT

Public and private investment in agriculture is of special interest in developing countries for its crucial contribution to the enhancement of the production capacity of the sector through productivity increases. In particular, investment in smallholder family farming is essential for poverty reduction and food security improvement.

Investment in a sustainable agricultural production and productivity includes the improvement in physical capital formation and land, water, and other natural resources; the development of human and social capital; and the environmental protection.

Public investment sets the conditions for private investment. However, innovative public financing models and partnerships between the public and private sector finance in agriculture and in the overall supply chains should be identified.

Moreover, financial markets have come to play a role in many dimensions of food systems and are evident in the phenomenon of foreign direct investment in land.

Suggested topics concerning data gathering and analysis may include:

- Investment and agricultural productivity;
- Investment along the agro-food chain;
- Comprehensive agricultural investment measures;
- Innovative public-private partnership in investment in agriculture;
- Innovative public finance models to increase allocation in agriculture;
- Foreign direct investment in land;
- Role of financial markets in land ownership, credit provision, food distribution systems.

LIST OF PAPERS

What real interest in the assessment of the quality and the efficiency of agricultural investment between COFOG and COFOG revised methodology? Case of Togo from 2011 to 2013

L. Kenao | Ministry of Agriculture | Lome | Togo

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The inverse farm size productivity relationship: some new evidence from sub-Sahara African countries

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DOI: 10.1481/icasVII.2016.c23d

C23

What real interest in the assessment of the quality and the efficiency of agricultural investment between COFOG and COFOG revised methodology? Case of Togo from 2011 to 2013

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ABSTRACT

A guidance note to lead countries on the public expenditure analysis in the agriculture sector has been formulated in order to reach the target of 10% of the share of national budget to agriculture, expressed firmly at Maputo, in 2003. The ambiguousness in the methodologic guidance carried a lack of precision in the estimations of progress accomplished in the achievement of this target of 10%. Thus, agency of NEPAD and Africa Commission Union are engaged in a process to revised the guidance note, in partenership with others partner groups in order to reinforce the analysis and the following of the level and the quality of public expenditure in the Africa's countries. It is in that frame work that the main goal of this study permits to enhance comparative analysis of results from COFOG and COFOG revised methodology in the case of TOGO from 2011 to 2013. This permits to appreciate better the impact of both tools for monitoring the quality of agriculture expenditure which provides more indications on the assessment of the efficiency and efficacity of budgetary expenditure in agriculture sector, in accordance with the Malabo declaration in 2014 on the following the quality of agriculture expenditure. The analysis of agriculture public expenditure with COFOG methodology reveals that the share of public expenditure of agriculture sector in the total expenditure of State increased from 5,7% in 2011 to 6,6% in 2012 and 8,2% in 2013. With the guidance note in 2014 relative to COFOG revised the Maputo rate move to 7,3% in 2011 to 8,5% in 2012 and 9,3% in 2013. It appears that the inclusion of expenditure on service roads, expenses concerned out budgets and excluding debt service payments from the Guidance Note from a the methodology revised COFOG shows better performance in achievement of objectives 10% of the national budget to the agricultural sector. However, a reduction of weight of procedures of financial technical parteners at the level of differents projets in the implementation of National Agriculture Investment and Food Security (NAIFS) will improve more the absorption capacity of agriculture sector. Special attention must be given to the level of public expenditure coming from the official development assistance for the agriculture to better identify and measure their impact.

Keywords: COFOG, Investment, Agricultural

PAPER

1. Introduction

The primary sector namely agriculture is at the heart of economic and social development and national development strategies are built taking into account agriculture. Thus, Togo, several policies have been implemented and are contributing to a successful implementation of PNIASA. It is estimated that a thorough evaluation of agricultural and food security programs must precede any credible process of investment planning also making use of key analyzes, such as analysis and monitoring of agricultural public expenditure continued to inform and guide the implementation of the CAADP process. In the context of recovery of the agricultural development in Togo, to facilitate access to analyzes of the highest quality policies to manage the necessary knowledge in the formulation and implementation of its policies, with technical support IFPRI, and the financial ReSAKSS the International Fund for agricultural development (IFAD) since 2014 a strategic analysis tools is the review of public expenditure in the agricultural sector for the monitoring of agricultural expenditure, the measurement of efforts and progress respecting the Maputo commitment by the Government of TOGO in 2003.

Economic growth in Togo has continued to increase from 4.8% in 2011 to 5.4% in 2013 (GDP Committee, 2014). This macroeconomic performance remains one of the strongest economies in West Africa. This dynamic is drained by the agricultural sector with an average growth of 4.13% between 2011 and 2013. This result is explained by improved macroeconomic management but also by the bonds of investment in infrastructure, the revival agricultural development with emerging economies. Agricultural expenditure is one of the strategic decision-making aspects for the development of the agricultural sector, leading in 2014, the leaders of Africa, at the summit in Malabo to reaffirm their commitment to respect the commitments made in Maputo, especially their commitments in the efficiency of the allocation of a minimum of 10% of public expenditure to agriculture. In this context, national macroeconomic performance will likely be affected by growth and accelerated transformation of agriculture for shared prosperity and better living conditions. The relationship between the analysis of agricultural expenditure according to the methodology of classification of the functions of public administrations (CFAP or COFOG), national development strategies and sector objectives have attracted increasing attention of technical and financial partners, academic researchers such the World Bank, the African development Bank, the United Nations development Programme, the French Cooperation (2006); Maurice Taondyandé, MbayeYade (2013); and others. To this end, there is a lot of research on the analysis of public spending on agricultural support and supply link with national development strategies. The study of the World Bank's Public Expenditure in the agricultural sector in Togo in 2012 found that although agricultural expenditure according to COFOG single methodology increased significantly from 2002 to 2010, they remain below the commitment Maputo. The similar study for Chad for the period 2003-2012 shows that agricultural expenditure represented 5.7% of total public expenditure; 4.1% of agricultural GDP and 1.1% of total GDP (World Bank, 2014). In 2013, the study of the World Bank for Senegal shows that agricultural growth recorded an average performance with a rate of 4.6% between 2005 and 2009. The agricultural sector is small increase its share Total public expenditure financed from own resources, from 9.8% to 10.9% between 2005 and 2009.

The area of monitoring and analysis of agricultural expenditure in Africa is composed of major initiatives which, although different, all have objectives related to the promotion of agricultural development, economic and social development in Africa. The procedure was defined by the African Union and the NEPAD vision has been realized through the results framework of CAADP. In this context, much of the attention of policy makers has been devoted to identify initiatives that verify whether the target of Maputo / Malabo 10 percent of total public spending on agriculture is reached. Thus, among the initiatives, a wide range of definitions and classification methods are used to calculate this indicator. The system of CFAP was regularly employed but with groups of categories CFAP inconsistent from one measurement to the other. In addition, as many African States do not use the CFAP, which also prompted many analysts to aggregate expenditures by specific categories into national accounting systems. However, the target of Maputo / Malabo 10 percent of total expenditure on agriculture is only a tool for achieving a set of development goals (eg CAADP 2003 and UA 2003, 2014). As stated in the Declaration of Malabo 2014, these objectives include the improvement of investment in agriculture, accelerating agricultural growth and agricultural productivity, poverty reduction, mitigating the impact of climate change and mutual accountability. Therefore, the level of agricultural expenditure should be taken into account by policy makers and practitioners of agricultural public spending and development stakeholders, in combination with the quality and composition of expenditure and the ability to analyze their impact [(1)]. To this end, the United Nations highlight the availability of data, along with the statistical and analytical capacities as one of the main driving forces for the political decisions to support the Millennium Development Goals (UN, 2014 p. 6-7). In the scientific literature on agricultural expenditure, that "national governments, particularly in sub-Saharan Africa, have limited budgets and are forced to make difficult funding decisions concerning the provision of social services and support agricultural programs "(Allen et al., 2012, p. vi) is regularly reported, pointing here and there the importance of knowledge systems that can effectively guide policy. The study by the Food and Agriculture Organization of the United Nation (FAO) on the comparative reviews and analysis on "monitoring initiatives and analysis of agricultural expenditure in Africa," it appears that there no single way to monitor and analyze agricultural expenditure, and that policy makers need to consider the contribution of each initiative to the overall objectives of CAADP. Some initiatives focus on building capacity and production analysis on specific policies at the national level while others provide expertise to improve public financial management systems, or publish aggregated benchmarks on spending agricultural public regional or global level. Thus, there are limits to the possibilities of harmonization of monitoring and analysis initiatives in agricultural expenditure. Although agreeing on a common definition of agriculture is certainly possible for a number of initiatives, it would be only part of the solution to improve monitoring and analysis of agricultural expenditure in Africa. In fact, all monitoring initiatives and analysis of agricultural expenditure in Africa are experiencing considerable difficulties in obtaining reliable, updatable data and classifiable under a system like the CFAP. Standards and definitions are shared, of course, necessary.

Thus the aim is to provide clear guidelines and common to the Member States of the African Union (AU), in monitoring public expenditure in agriculture and increase the effectiveness of budget management in the agricultural sector.

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[1] It is widely accepted that the establishment of monitoring and analysis of reliable and sustainable national agricultural systems of public spending is essential to support the development of the agriculture sector through the formulation of policies based on reliable information. For example, the African Union sees the planning based on reliable information as a fundamental strategy for the implementation of the CAADP (CAADP 2010).

This is facilitated monitoring the country's levels and the AU on the share of public expenditure in agriculture compared to total public expenditure in order to establish the status of progress made by countries concerning target of 10% and strengthen the investment based on the evidence and the political justification for levels of appropriate expenditure and the efficiency and effectiveness of agricultural expenditure in order to assess the quality of public expenditure in the agriculture to enhance the value for money. Thus these principles address some key methodological issues on common accounting standards, agriculture defining the functions of government classifications, the distribution of spending in other sectors, as well as consistency and the harmonization of data on the numerator and denominator in estimating the ratio of Maputo. The framework for monitoring the quality of agricultural expenditure implementation provides guidance on assessing the efficiency and effectiveness of budget spending in agriculture, under the terms of the Declaration of Malabo on monitoring the quality of agricultural expenditure. Thus, CAADP continues to provide an agreed framework to promote and support agricultural development in Africa. Thus, the status of implementation of commitments and emerging issues show that since the Maputo Declaration (2003), progress has been made by African countries towards an expenditure in the sector farm of at least 10% of total budget allocations. The experience gained from the implementation and emerging issues related to the target of 10% of expenditures allowed to draw policy lessons. It is in this context to better understand all the contours of the study on "What real interest in evaluating the quality and effectiveness of agricultural investments between simple COFOG methodology and revised COFOG? Case of Togo 2011 to 2013. "It is important to provide some answers to these different questions: between 2011 and 2013, what is the behavior and evolution of government expenditure in the agricultural sector by between single COFOG methodology and the revised COFOG? What is the comparative evolution of the ratio of Maputo by the two approaches? The rest of this article is as follows. Section 2 presents the methodological approach to analysis of agricultural expenditure by COFOG single and revised COFOG NEPAD and the African Union. Here we define the approach of estimation of agricultural expenditure and expenditure of the state in the country, the ratio of Maputo. In Section 3, we present the main results in the empirical application and presents summary statistics of our estimates of agricultural expenditure. Section 4 concludes.

2. Methodologicalreview

2.1. Definition of agriculture public expenditure

The roles of the AU, NEPAD and FAO in the establishment of a monitoring system for agricultural expenditure were asked to develop, pilot and implement a system to monitor compliance with this resolution. In order to introduce the monitoring system for agricultural expenditure, the AU member countries, a number of consultations were held and the first steps were taken. In 2004, FAO, as a specialized partner of the AU and NEPAD in agriculture, organized technical meetings with the participation of the World Bank, the International Monetary Fund (IMF), the African Development Bank (ADB) and NEPAD. It was agreed that the agriculture sector should be defined according to accepted standards internationally based on the Classification of Functions of Government (COFOG), revised by the United Nations in 1989, and incorporated in the IMF Manual Statistics of Finance of the State (GFS) for 2001. However, it was recognized that some exceptions, African governments do not use the COFOG in their budget classification structure, which implies a dimension and a unified definition of the agricultural sector does not exist in the budget and thus, in all countries accounting systems, and a reliable exercise requires the incorporation of such a classification in the budgets of member countries [2].

2.2. Simple COFOG methodology from United Nation, Africa Union

In the calculation and monitoring of agricultural expenditure is recognized as expenses indicator of 10 percent of total government expenditure in agriculture aims to establish a base platform for agricultural expenditure both in terms of absolute amounts as a percentage of total government expenditure, and monitor their movements on time. Actual expenditures (not budget) are subject to the expenditure tracking system. The definition of COFOG is maintained and confirmed again that a broader definition based on COFOG, as previously proposed by the AU member countries in April 2005, and will be used to determine the agricultural sector and spending it covers.

[2] Although considered the ultimate solution, it is allowed the replacement of existing budget classifications by the COFOG system in member countries of the AU require substantial resources and time. Since the introduction of the COFOG system should cover all ministries and public offices, it should change the structure of the allocation and the general accounting plan of the State, and therefore the budget code system and accounts public. The note will be a tool facilitating and unifying the country reports in the calculation of the share of agricultural spending in total government expenditure.

Data collection must be from more than one department. In many countries, data on the agricultural sector starting from the COFOG are budgeted and accounted for on behalf of more than one department or organization. The Ministries of Finance should be actively involved in this exercise with the cooperation of the ministries concerned [3]. In addition, if a university or research center performs work related to agriculture, they should also be included in the agricultural sector. Finally, the multi-sector projects if a mega - project has multisectoral objectives, including irrigation for agricultural purposes, expenses must be included in the agricultural sector if 70 percent or more of the project costs are related to agriculture. Otherwise, they must be included in the sectors responsible for the supply of water or energy, which poses no problem in this exercise.

2.2.1. Estimation of agriculture public expenditure

Let $i, j, k, n, m \in \mathbb{N}$; $i \in \{1, \ldots, n\}$; $j \in \{1, \ldots, m\}$;

M_{ji} = Ministry Spending i involved in agriculture for j;

M_{ji}^{I} = Sectorial expenditure i on internal resources for the year j;

M_{ji}^{E} = Sectorial expenditure i on external resources for the year j;

H_{jk} = Expenditure outside the budget partner k agriculture for the year j;

N_j = Agricultural expenditure for the year j;

$$(1) M_i = M_i^I + M_i^E$$

$$(2) N_j = \sum_{i=1}^{i=n} M_{ji} + \sum_{k=1}^{k=m} H_{jk} = \sum_{i=1}^{i=n} \left(M_{ji}^I + M_{ji}^E\right) + \sum_{k=1}^{k=m} H_{jk}$$

2.2.2. Estimation of total state spending in the country

I_j^I = *Capital expenditure for the year j on internal resource;*

I_j^E = *Capital expenditure for the year j on external resource;*

T_j = *Transfer expenditures of the year j;*

F_j = *Operating Expenses of the year j;*

P_j = *Personal spending the year j;*

I_j^{EH} = *Investment spending on external resources outside of the budget for year j;*

D_j = *Total state spending in the country for year j;*

$$(3)\ D_j = I_j^I + I_j^E + T_j + F_j + P_j + I_j^{EH}$$

2.2.3. Estimation of Maputo ratio

Let year j,

$$(4)\ R_j = \frac{N_j}{D_j}$$

[3] It should be noted that agricultural education at the university level and the level of formal secondary education system under COFOG falls within the education sector, but the training of specialized and lower levels should be within each sector, namely agriculture. It should also be noted that rural development in the system of COFOG is not an independent sector butits operations are distributed among many other sectors, including health, education, transport, etc. Special attention should be given to this issue to include only activities related to agriculture of a Ministry of Rural Development. Similarly, it should be noted that in some countries, the ministries of public works or their equivalent who perform construction projects related to agriculture, should also be involved.

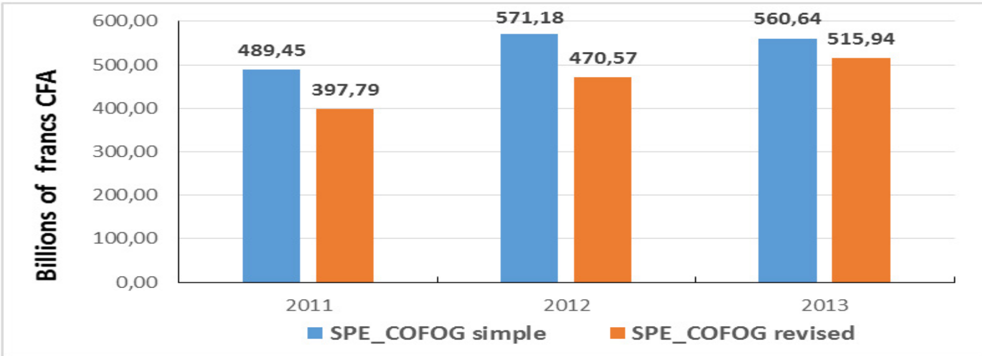
2.3.Méthodology of COFOG révised of NEPAD and African Union

The following guidelines are proposed for the identification, measurement and distribution of the most relevant components to be integrated in the estimated expenditure (numerator and denominator) according to the Guidance Note document of the African Union and NEPAD on the revised COFOG methodology. Indeed, it is with regard to the road serving the important indicator to consider is the proportion of inhabitants and beneficiaries residing in the sphere of influence of the road service for which agriculture is the main source of livelihood. Debt service payments are excluded, the debt service (payment by the state of the interests of its domestic and foreign borrowing) or annuities paid to the state budget are, in principle, of a statutory nature or discretionary spending say no, and states have no control over them. It is therefore proposed that no payment of debt service is included in the total expenditure for agriculture (DEA). For the purposes of this Guidance Note for expenditure outside the budget concerned, it is requested the inclusion of major expenses of Public Aid for outside speaker concerned budget development in the agricultural sector are identified and estimated for both the numerator (total amount of a multisectoral activity) as the denominator (total expenditure of the State). This integration is also consistent with the mutual accountability framework promoted in the CAADP maintenance program [4]. There is a growing demand for institutional accountability, as part of strategic key to improving the quality of expenditure for agriculture and its results as stated in the Declaration of Malabo.

3. Main results and implications

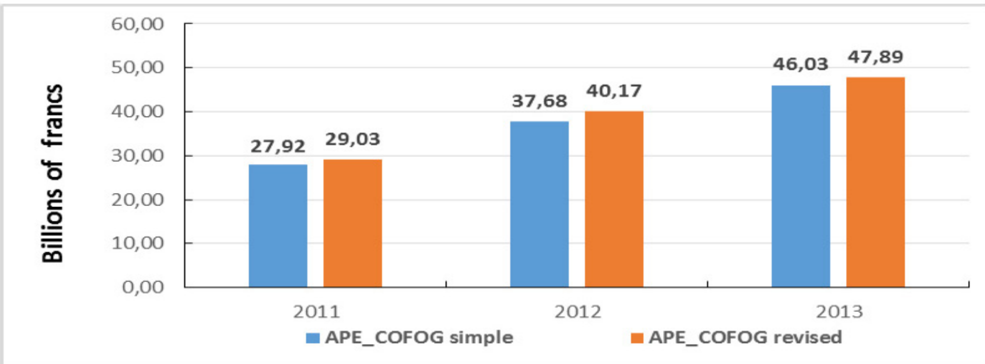
The analysis of the comparative evolution of the budgetary expenditure of the state in the country shows that the level of single COFOG expenditure according methodology is higher than that under the revised methodology COFOG in 2014 of the African Union and the NEPAD. Indeed, the level of state spending as easy COFOG respectively and revised COFOG was established in 2011 to 489.45 against 397.79 billion CFA francs; in 2012 to 571.18 against 470.57 billion CFA francs in 2013 to 560.64 against 515.94 billion CFA francs.

Figure 1 - Comparative evolution of budgetary expenditure in the country



The analysis of the comparative evolution of agricultural expenditure shows that the level of expenditures by COFOG methodology revised slightly higher than under the single COFOG methodology of the African Union and NEPAD. Indeed, the level of agricultural expenditure by COFOG single respectively and revised COFOG was established in 2011 to 27.9 against 29.03billion CFA francs; in 2012 to 37.68 against 40.17 billion CFA francs and in 2013 to 46.03 against 47.89 billion CFA francs.

Figure 2 - Comparative Evolution of agricultural expenditure



[4] In addition, it is important to ensure that the definition and measurement of the ratio of government spending in favor of agriculture and the total expenditure of the state in the country include appropriate adjustments to both numerator and denominator to avoid inconsistent and misleading estimates to contribute also to calculate robust and comparable expense ratios. The Maputo Declaration emphasized the level of expenditure. Recent years have seen an increasing demand from key stakeholders to promote and monitor the quality of expenditure on Agriculture (DEA), including its composition and adding value regardless of its level and its share total expenditures.

The synthesis of the analysis of the main macroeconomic and agricultural development indicators according to the two methodologies reveals differences. Note that the calculation of the agricultural public spending and government spending helped to establish the ratio of Maputo and the relevant ratios. These calculations allowed to turn to international comparisons: (i) on the strict basis of COFOG expenditure; and (ii) on the Maputo target and other targets.The analysis of the comparative evolution of the Maputo ratios shows that the level of the revised ratio according to COFOG methodology is above that falling within easy COFOG methodology of the African Union and NEPAD in the period. Indeed, the ratios of Maputo as single COFOG respectively and revised COFOG was established in 2011 to 5.7% against 7.30%; in 2012 to 6.6 against 8.5 in 2013 to 8.2 against 9.3 billion CFA francs. The index of Togo's agricultural orientation [5] between 2011 and 2013 according to the two methodologies shows disparities. On average over the period, the Agricultural Orientation Index (IOA) as the single COFOG methodology is estimated at 0.17 against 0.21 as the methodology revised COFOG.

Table 1 - Comparative analysis of the agricultural orientation index (IOA)

Rubrique	2011	2012	2013	Moyenne (2011-2013)
COFOG simple				
Ratio of Maputo (A)	5.7	6.6	8.2	6.83
Agriculture DGP (Billionsof francs CFA)	714.87	840.93	800.74	785.51
National DGP (Billions of francs CFA)	1772.58	1989.49	2064.86	1942.31
Agriculture DGP*100/National DGP (B)	40.33	42.27	38.78	40.46
IOA (A/B) simple	0.14	0.16	0.21	0.17
COFOG revised				
Ratio of Maputo (A)	7.30	8.54	9.28	8.37
Agriculture DGP (Billionsof francs CFA)	714.87	840.93	800.74	785.51
National DGP (Billions of francs CFA)	1772.58	1989.49	2064.86	1942.31
Agriculture DGP*100/National DGP (B)	40.33	42.27	38.78	40.46
IOA (A/B)revised	0.18	0.20	0.24	0.21

4. Conclusion

In the CAADP framework, the analysis of agricultural expenditure under the single COFOG methodology and revised COFOG shows that on average the ratio of Maputo between 2011 and 2013 is set at 6.84% to 8.34% against single COFOG revised COFOG. It appears that the inclusion of expenditure on service roads, expenses concerned out budgets and excluding debt service payments from the Guidance Note for the methodology revised COFOG shows better performance in achievement of objectives 10% of the national budget to the agricultural sector.

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[5] The agricultural orientation index is the ratio between the share of agricultural investment in public investment and the share of agriculture in GDP, lets see how government spending on agriculture reflect the importance of the sector in the economy. When the index is less than unity, then public spending in the sector are not up to what it brings to the economy. The higher the index, the higher the expenditure on agriculture are the share of agriculture in GDP.

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Adoption of rural development policies in rural areas: a privilege for the few?

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ABSTRACT

THE AIM OF THE PAPER IS THE ANALYSIS OF THE "CONSUMPTION" OF RURAL DEVELOPMENT POLICIES (RDP) AS THE RESULT OF ENTREPRENEURIAL BEHAVIOURS ADOPTED BY FAMILY FARMS. THE UNDERLYING HYPOTHESIS IS THAT FAMILY FARM'S CHARACTERISTICS INFLUENCE THE CONSUMPTION OF RURAL DEVELOPMENT POLICIES. BY PUTTING FORWARD A FAMILY FARM PERSPECTIVE, WE SUPPORT THE IDEA THAT ANY BOUNDARY BETWEEN PRODUCTIVE AND REPRODUCTIVE WORK IN THE FARM HOUSEHOLD IS ARTIFICIAL AND CONDITION FARM STRATEGY AND APTITUDE TO INVEST. THEREFORE, A RELEVANT ASPECT TO BE EXAMINED CONCERNS FAMILY SIZE, LOCALIZATION IN LIFE CYCLE, AND THE PRESENCE OF ASSISTANTS WITHIN THE FAMILY FARMS. THE RESULTS OF OUR ANALYSIS PERMIT TO EMPHASIZE THE IMPORTANCE OF FAMILY CONTEXT IN THE ACCESS TO RDP AND THE RELEVANCE OF THE FAMILY ASSISTANTS ON FARM'S PROPENSITY TO GET FUNDED.

Resumé:

Cet article analyse l'adoption des politiques de développement rural en l'articulant sur la base des typologies de familles agricoles, de la phase de leur cycle de vie et sur la base de la présence d'assistants familiales dans l'activité agricole. Les résultats confirment cette association, en adressant des suggestions des stratégies de politique économique.

Keywords: Family Farms, Rural Development Policy

PAPER

1. Introduction

This paper is centered around family farms and their capabilities of getting funded by Rural development policies (Rdp). Family farms may be labelled as the backbone of the European agriculture (Crowley, 2013); as a consequence, recent rural development policies are specifically targeted to this special type of business, characterised by the strict overlapping between the productive and reproductive sphere (Errington and Gasson, 1993). Against this background, the unit of analysis of our paper is the family farm business. The aim of the paper is to analyze the adoption of Rdp on behalf of family farms and eventual discrepancies in the access to rural policies, based on demographic, economic and territorial variables. The underlying hypothesis is that family farm's characteristics influence the consumption of rural development policies. By putting forward a family farm business perspective, we support the idea that any boundary between productive and reproductive work in the farm household is artificial and condition farm strategy and aptitude to invest. That means the analysis of access to Rdp on behalf of family farms involves the analysis of a collective decision-making process. Therefore, a relevant aspect to be examined concerns family size, localization in life cycle and perspective of generational renewal.

Against this background diversified strategies (portfolio strategies) are at stakes: differentiation of agricultural products, diversification of farming activity into non-farming activities, along either a supply chain or a territorial strategy. Investments are necessary to maintain farm's profitability and its persistence over time. In order to cope with an even more competitive scenario and to grant family farm's resilience, a mix of strategies has to be carried out (Darkhoner, 2010).

From a methodological point of view, the paper tries to match two different statistical sources, the Italian census of agriculture and a regional database containing information on the adoption of rural development policies in the region Lazio (Italy). This attempt may be considered as innovative, due to the lack of numerous studies in literature on this topic. By crossing the two statistical databases we will try to excavate the socioeconomic characteristics of farms consuming/not consuming rural policies and, as a consequence, we will discover possible cases of policy failures.

2. Theoretical background

As Offutt (2002) points out, *since farm households are demonstrably diverse, analysts would seem obliged to investigate hypotheses about differential response and impact*. One of these differences concerns demographic variables: family contexts are particularly favorable to set up a farm venture (Jervell 2011): an abundant economic literature has emphasised the strict connection between farm household strategies and style of farming (among others, Whatmore, 1994), by demonstrating the persistency of family farms (Sabbatini 2011). Their ability to survive over time witnesses the relevance of F-connection[1] in fostering lower levels of transaction costs and a higher aptitude to adapt (Ben Porath, 1980; Pollack, 1985).

In the last decades, family farms have been characterizing European agricultural landscape: in this types of farms: *the principals are related by kinship or marriage, business ownership is usually combined with managerial control, and control is passed from one generation to another within the same family* (Gasson et al., 1988). The strong relevance of family farms at European level has fostered tailored policies within the framework of the Common Agricultural Policy (CAP) policies. For example, a set of measures is addressed to stimulate generational renewal, income support, farm diversification, quality certification schemes (Davidova, Thomson, 2014). At the beginning of the new programming phase for 2014-2020, new opportunities for farms have been provided, in order to encourage farm's development. The capability to exploit these opportunities may be considered as a question of entrepreneurial capability, in that the access to investment measures involves entrepreneurial skills of farmers (Rudmann, Vesala and Jackel, 2008).

Against this background, our first hypothesis is that life cycle of family farms could influence the strategic choice of measures. Moreover, the eventual presence of family assistants may envisage a collective decision-making process which affects the adoption of Rdp. A second hypothesis to be tested is the territorial discriminant that is the possibility of a differentiated access on behalf of family farms in various rural areas. Finally, possible barriers to Rdp may be related to farms' economic dimension, in that the probability to apply for Rdp may be reduced in cases of farm's low economic dimension.

Even though family farm business has been deeply explored in literature, few analyses have been conducted on the consumption of Rdp, by discriminating life cycle of family farms, role of assistants and farm's territorial localization. This paper tries to fill this gap in literature by providing a first analysis of the access to Rdp on the basis of family composition.

Materials and method

In this paper we define as "consumption of policy" the farmer's ability to obtain funds from rural development policies. Family farms are the object of our analysis, marked out by following methodological steps. The first one concerns a socio-demographic classification of family farms taking into account farm activity and the composition of family work: key-elements of the classification are family composition, its localization in the life cycle and the emphasis on the role of farm's assistants either exclusively employed within the farm (p/e: prevalent or exclusive) or not (np: not prevalent). This is a novelty in the analysis of family farms: the role of farmer's assistant has not yet been explored in recent literature.

As far as the family cycle is concerned the age of reference is 40 years, because it is the threshold to gain access to rural development policies for generational change. Following table illustrates the structure of the family farms, according to their life cycle.

Family farm typology		
Young farmer and a not young assistant *(Y+not Y ass.)* - p/e - np	Mature farmer and a young assistant *(M + Y ass.)* - p/e - np	Older farmer and a young assistant *(O + Y ass.)* - p/e - np
Young farmers with other (assistant may be young or may be not) *(Y + other)*	Mature farmers with other (assistant may be old, mature or may be not) *(M + other)*	Older farmers with other (assistant may be mature, old or may be not) *(O + other)*

The second methodological step tries to link family types and access to Rdp, by focusing attention on the consumption of rural development policies in the region of Lazio (Italy). The measures under observation belongs to the three main axes of regional rural program for the last programming period 2007-2013:

1. competitiveness of the agricultural sector;
2. environment and landscape;
3. quality of life and diversification in rural areas.

[1] Family, friends and firms.

Our analysis concerns the first and the third axes, including measures of investments, through which an authentic entrepreneurial activity is realized. As a matter of fact, the second pillar of the CAP provides for multiannual support to family farms by delivering different types of measures articulated on four axes. Second axis includes surface measures, which offer annual allowances based on farmers' commitments to adopt sustainable agricultural models. In this case, farmers are subsidized for lacking revenues, due to their commitments. Axes I and III comprehend investments measures, aiming at sustaining territorial development. Differently from the previous types of measures, investment measures are strictly linked to an entrepreneurial activity, which foresees risk-taking.

A matching procedure between the regional database and the national census of agriculture has been carried out, by making reference to the fiscal code of the farm. This lets the composition of the funded family farm to emerge.

Information and data are downloaded from the database of region Lazio: more precisely, funded farms are linked to farms from the data warehouse of the last census of Italian agriculture, in order to classify them on the basis of family composition. Therefore, three main aspects have been investigated:

- demographic aspects that is the incidence of family composition on the consumption of Rdp;

- territorial aspects: information concerning number of applications and funds obtained have been gathered and articulated on the basis of family types and farm's territorial localization according to the national strategic plan which distinguishes following homogeneous areas: A) urban poles, B) areas with intensive and specialized agriculture, C) intermediate rural areas, D) rural marginal areas.

- economic aspects, that is the eventual relevance of the economic dimension of the farm (expressed by the standard output) in gaining access to Rdp.

Results

Table 1 shows the results of our analysis, as consequence of the match between regional database and the national census of the agriculture 2010. Table articulates the results on the basis of family composition, consumed measures per axis and type of rural area. On the whole 2.368 farms gained access to rural development policies for the period 2007-2013, 2.41% of the amount of farms located in the region Lazio. Therefore, a very small percentage of farms succeed in getting funded.

The results are articulated on the basis of either demographic profiles or type of consumed measure and standard output of applying farms.

As far as demographic profile is concerned, the majority of funded farms are located in the younger and mature phases of life cycle. Almost 54% are young farmers with various assistants, while 42% are mature families. As expected, elderly family farms evidence a reduced propensity (4%) to adopt rural policies for farm investments. Another reflection is inspired by the higher access to policies on behalf of "other" types of farms, with double percentage in the younger phases of life cycle, and triple in the mature and older phases. However, by observing the average contribution obtained in each typology of farms (tab.1b), the relevance of family farms with young helpers emerges, which doubles in the elderly phases of life cycle.

As far as types of rural areas are concerned (tab.1c), intermediate rural areas and area with intensive agriculture attract the highest share of funds (respectively, 56.8% and 21.9%), while rural marginal areas and, above all urban areas retain lower percentages of funds. By crossing demographic and territorial variables, an interesting element regards the relevance of younger farmers applying in rural marginal areas, where the percentage of application in young farms rises up to 64%. This is an important result in terms of generational renewal in difficult areas. As far as type of measure adopted and Rdp area are concerned, measures of the first axis are privileged, while access to measure for farm diversification (third axis) are not so much consumed[2].

[2] For the evaluation of policy consumption under Axis 3 it is necessary to precise that a part (often considerable) of the resources allocated to this axis is not devoted to farmers, but to other entities, both public and private.

Table 1 – Distribution of farms, average contribution and standard output

	Y+not Y ass.	Y + other	M+not Y ass.	M + other	O+not Y ass.	O + other	Total
A + axis 1	30	78	18	78	2	7	213
A + axis 3	.	.	1	1	.	.	2
B +axis 1 and 3	5	4	1	5	.	1	16
B +axis 1	88	190	52	137	5	10	482
B +axis 3	5	2	2	12	.	.	21
C +axis 1 and 3	28	34	7	19	.	.	88
C +axis 1	238	375	123	396	6	56	1.194
C +axis 3	5	14	9	30	.	5	63
D +axis 1 and 3	3	11	3	5	.	.	22
D +axis 1	57	102	17	70	1	3	250
D +axis 3	1	4	2	8	.	2	17
Total	460	814	235	761	14	84	2.368
	Tab.1b - Family type - AVERAGE CONTRIBUTION						
	Y+not Y ass.	Y + other	M+not Y ass.	M + other	O+not Y ass.	O + other	Total
A + axis 1	98.199	97.695	98.117	56.308	136.079	3.163	79.900
A + axis 3	.	.	53.618	132.338	.	.	92.978
B +axis 1 and 3	174.814	204.817	69.103	369.136	.	378.454	249.161
B +axis 1	73.334	83.088	70.793	60.483	190.310	128.040	75.601
B +axis 3	113.845	84.563	103.724	70.831	.	.	85.513
C +axis 1 and 3	212.535	169.327	131.389	164.634	.	.	179.044
C +axis 1	83.661	70.460	49.783	41.870	40.346	36.550	59.737
C +axis 3	153.486	96.491	77.814	89.250	.	124.880	97.151
D +axis 1 and 3	122.131	182.846	172.346	170.166	.	.	170.253
D +axis 1	79.316	90.283	73.115	36.271	43.528	949	70.233
D +axis 3	84.013	99.299	55.665	102.413	.	107.936	95.748
Total	92.269	85.434	65.499	55.323	107.808	54.416	74.139
	Tab.1c - Family type – Territorial distribution (%) of funded farms						Total
	Y+not Y ass.	Y + other	M+not Y ass.	M + other	O+not Y ass.	O + other	
A	6,52	9,58	8,09	10,38	14,29	8,33	0,76
B	21,30	24,08	23,40	20,24	35,71	13,10	21,92
C	58,91	51,97	59,15	58,48	42,86	72,62	56,80
D	13,26	14,37	9,36	10,91	7,14	5,95	12,20

Source: data processed by the Italian census of agriculture and database of region Lazio

In order to test eventual association among the previous variables, a chi-squared test has been put forward. Results are illustrated in table 2

Table 2 – Chi-squared test

	DF	*Value*	*Prob*
χ^2	8	33,77	<.0001

The analysis of contingencies (table 3) provides useful insights related to the propensity to consume measures on the basis of the territorial location of the farms: as a matter of fact, a clear "attraction" between farms in rural areas (both intermediate and marginal) and measure of the third axis emerges. Similarly, a certain association between the youngest phases of the life cycle and the propensity to invest on farm structural adjustment and farm diversification is evident.

Mature families seem privilege diversification in not farming activities while elderly one, evidence preferences towards "traditional" measures of investments aiming at stimulating farm competitiveness.

Table 3 - Contingencies

3.a rural areas	*axis 1*	*axis 3*	*axis 1+3*
A	18,79	-7,35	-11,44
B	13,19	-1,57	-11,62
C	-20,93	4,50	16,43
D	-11,05	4,43	6,62

3b type of family	*axis 1*	*axis 3*	*axis 1+3*
Y + not Y	-2,5	-9,0	11,5
Y + other	9,7	-15,4	5,7
M + Y	-2,3	3,8	-1,5
M + other	-6,4	17,9	-11,5
O + Y	1,4	-0,6	-0,7
O + other	0,1	3,3	-3,5

A final element of reflection regards an economic discriminant, concerning farms' economic dimension and access to Rdp. Table 4 points out the differences among farms by relating standard output to farm with no application to Rdp. As a matter of fact, table points out relevant differences between economic dimensions of farms without application to Rdp and farms applying to policies, divided into farms with rejected or not application

From the table a systematic higher level of standard output characterizes farms with consumption of Rdp, which raise up in cases of farms with application and accepted investment projects (table 4b).

Table 4 - Standard output in relation to farm without application to Rdp (%)

4a - Farms with rejected application					
	Rural areas				
Family type	A	B	C	D	Total
Y + not Y	105,25	205,53	289,26	188,03	205,65
Y + other	275,13	137,32	716,15	210,24	320,97
M + Y	182,96	260,36	657,33	661,32	433,03
M + other	377,06	385,33	382,31	347,23	368,69
O + Y	474,48	1238,92	364,92	1338,64	438,36
O + other	1699,78	339,71	768,49	271,68	804,26
Total	502,07	342,98	637,02	410,74	493,98
4b - Farms with accepted application					
	A	B	C	D	Total
Y + not Y	213,16	229,48	472,35	329,77	315,41
Y + other	342,63	231,68	462,97	289,37	316,42
M + Y	1103,25	489,63	666,43	519,19	662,53
M + other	767,93	745,21	932,74	1507,52	896,87
O + Y	7411,08	1762,97	771,02	448,17	3009,93
O + other	810,65	1107,95	1001,98	340,11	974,36
Total	933,52	600,81	878,82	914,58	808,30

Source: data processed from the Italian census of agriculture

Conclusions

The role of the Common agricultural policy in fostering family farm's resiliency has been deeply underlined in recent literature (Koutsou, 2011; Davidova, Thomson, 2014). Nonetheless, a set of factors, generally labelled as transaction costs of policy adoption, brings about a low access with respect to the potential demand. This paper has tried to emphasize how some key aspects may condition the consumption of policy: three discriminants, territorial, demographic and economic, emerge:

- as far as territorial variables are concerned, the prevalence of some areas seems evident in terms of both average perceived contribution and percentage of adoption; rural marginal areas, for example, get low shares of funds, despite marginal rural areas need significant investments to revitalize farms and rural territories. Nonetheless, the good percentage of young farmers applying for rural policies may be an encouraging signal;

- demographic variables involve the life cycle of the family farm business and, as our analysis demonstrates discriminates between younger and elderly phases. This is not a novelty in literature, but, as our analysis demonstrates, the consideration of the role of assistants may provide further elements of evaluation by enlightening the relevance of the young assistants in performing access to Rdp;

- finally, an economic barrier seems to filter the access to rural policies with farms with high standard output getting funded. This may cast some doubts on the aptitude of Rdp to add up and targeting funds in a "democratic" way, so letting problems of result paradox to emerge: the less you need, the more you get (Bartoli, De Rosa, 2011).

To conclude, the analysis of adoption of rural policies should be carried out within a complex and articulated perspective, which endogenize either territorial, or economic or demographic variables, by endogenizing, whose relevance should be taken into account at political level.

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Does judicial efficiency improve productivity? Evidence from Italian farms.

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ABSTRACT

Economic literature shows that credit constraints have a negative impact on farm performance. The problem of credit constraints is particularly severe for the Italian agricultural sector given the structure and the legal status of most farms. The difficulties in providing collateral is even greater in the case of sole holders who represent almost 96% of whole Italian farms due to the direct link between farm and private capital. Credit market performance may be affected by judicial efficiency that guarantees the enforcement of contracts. We use court judicial efficiency as an instrument and exploit the great heterogeneity in efficiency of Italian courts across time and provinces to estimate the causal impact of credit constraints on farms' productivity. We find that less credit constrained farms have a higher Total Factor Productivity. We also find that Italian farms, when faced with a less efficient judicial system, are less credit constrained, probably because banks tend to grant mainly subsidized loans.

Keywords: Total Factor Productivity, credit constraints, judicial efficiency

PAPER

1. Introduction

Our study fits into two important current policy debates in Italy: credit constraints and judicial efficiency. In particular, we investigate the impact of the credit market, through judicial efficiency, for the Italian farming sector. As far as we know, there is no study investigating the relationships between judicial efficiency, availability of credit and economic performance of agricultural holdings.

Many contributions to the economic literature deals with the negative impacts that credit constraints have on farm's investment (Carter and Olinto, 2003; Petrick, 2004b), output (Petrick, 2004a), profit (Foltz, 2004; Fletschner et al., 2010) and productivity growth (Guirkinger and Boucher, 2008). Other studies argue sometime, due to some peculiar settings, credit constraints may have a positive effect on farm productivity (Sabasi and Kompaniyets, 2015) and technical efficiency (Maietta and Sena, 2010).

Other studies analyse the debt structure according to debts length and reach contrasting results (Lambert and Bayda, 2005; Mugera 2012). While another important part of the agricultural economic literature aims at measuring and empirically analysing the presence of credit constraints (Petrick, 2005; Blancard et al, 2006). As far as agricultural credit market institutions are concerned, in Italy the main creditors are commercial banks, regulated by the National Central Bank. Data for Italy show that the cost of credit for the agricultural sector is higher than for other sectors and varies geographically, being higher in the central and southern regions.

Previously in Italy farm credit was regulated by special regimes that allowed for better conditions of credit access to farmers and amounted to genuine agricultural policy instrument. With several interventions, among which the Legislative Decree 385/93, the introduction of Basil rules and Legislative Decree 141/2010, those special conditions were greatly reduced and the guarantee scheme became more relevant in the relationships between farmers and the credit system (Adinolfi and Capitanio, 2008).

Italian farms are mostly characterised by small size and sole holder, a legal status for which it is difficult to distinguish between farm and private capital, and are generally not required to publicly disclose their financial situation. This is a problem since, due to the de-specialization process of the Italian banking system aforementioned, the rules for the determination of farm credit worthiness are mainly based on financial statement information[1].

[1] The importance of credit access for the Italian agricultural sector is confirmed by two recent Protocols of Agreement signed in 2016. The first one was signed in January by the Italian Ministry of Agriculture and Bank Intesa Sanpaolo, a leading bank in Italy and the second one was signed in March between Italian Ministry of Agriculture and the Italian Banking Association. The issue of farm credit has also been investigated by a recent cognitive survey carried out by the Agricultural Commission Chamber of Deputies, Camera dei deputati XIII Commissione Agricoltura (2015).

In Italy, the lack of collateral is also reported to be one of the main reasons for rejecting farms' credit applications along with poor credit history of the applicant and insufficient farm business income (Jansson et al, 2013).

Credit market performance is affected by judicial efficiency[2]; an efficient judicial system that guarantees the enforcement of contracts is crucial for the smooth functioning of the credit market, while an inefficient judicial system increases transactions costs and reduces the efficiency of the credit market.

With Italian data, Jappelli et al (2005) showed that improvements in judicial efficiency reduce credit rationing and increase the volume of lending. With an investigation at firm level within the European Union, Maresch et al (2015), show that the better the judicial enforcement system and the higher the creditor protection, the lower the probability that the firms are credit constrained. Fabbri (2010) investigates performances of judicial districts in Spain and finds that differences in the length of civil trials affect the cost of lending.

The mentioned economic literature on the impact of judicial efficiency on credit market does not take into consideration specifically the agricultural sector, for which the Italian bankruptcy law cannot be fully applied (Caiafa, 2012). Moreover, the surveys conducted by the Bank of Italy on the management of debt collection procedures by the biggest Italian banks do not allow to analyse specifically the case of non-performing loans granted to farmers (Generale and Gobbi, 1996 and Carpinelli et al, 2016). Bearing in mind the aforementioned limits, for Italy, the incidence, in terms of amounts, of judicial procedures carried out by banks to recover non-performing loans is estimated around 60% of the 2011-2014 average, the rest being conciliations in extrajudicial settings (Carpinelli et al, 2016).

In this paper, we will use court judicial efficiency as an instrument and exploit the great heterogeneity in the judicial efficiency of Italian courts across time and provinces to estimate the causal impact of credit constraints on farms productivity.

Indeed, Italy provides a good environment to test this causality because the same laws apply across the entire territory but judicial efficiency vary widely across courts.

2. Data and Empirical strategy

The main dataset we use in this paper is the Italian Farm Accountancy Data Network (FADN) for the period 2008-2013. FADN[3] is an annual sample survey carried out in EU Member States for evaluating the incomes and business operation of agricultural holdings and the impacts of the Common Agricultural Policy. Italian farm accounts survey contributes to EU FADN with the major proportion of total Farm Returns and collects also additional information. We restrict our sample to farms specialised in the following general type of farming (TF): field crops, horticulture, permanent crops and grazing livestock.

As the aim of the paper is to investigate the relationship between credit constraint and farms' productivity, we use the Total Factor Productivity (TFP) as measure of farm performance.

In the estimation of production functions one of the critical points is that labor and other inputs cannot be treated as independent variables. To address this issue we employed the estimation procedure suggested by Olley and Pakes (1996) and further developed by Levinsohn and Petrin (2003). We estimated TFP at the level of principal TF using value added as output, and labor, land and fixed tangible assets as inputs[4]. Following the approach of Musso and Schiavo (2008) for identifying and measuring the degree of financial constraint, we built a synthetic index using eight dimensions: size (total fixed assets and total current asset), profitability (return on total assets: operating income over total assets), liquidity (total current assets over current liabilities), self-financing capacity (net income over total assets) and solvency (net worth over total liabilities). Moreover, following Adinolfi et al (2012), we considered the peculiarity of agriculture and added three other dimensions: total utilised agricultural area, land/area (agricultural land, buildings and forest over total utilised agricultural area) and investments/land (new investments over agricultural land, buildings and forest). For each of these dimensions, we computed the distance of the value of farm from the average of all the farms belonging to the same TF, and then, we placed the value of the distance in one the quintiles in which the corresponding distribution is divided. Hence, for each farm we obtained eight scores from 1 to 5, where 1 refers to the smallest values and 5 to the highest ones.

Finally, we sum these eight scores and we obtain a synthetic index where higher values of the index are associated to lower degree of credit constraint. The index ranges from 9 to 38. In order to achieve a better interpretation of our results we standardized the score.

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[2] The judicial efficiency has been widely discussed and several studies have been undertaken by the Italian and international scientific community - for a recent review see Ippoliti 2014.
In Italy the debate on judicial efficiency is particularly current as a result of the territorial organization reform dealing with Ordinary Tribunals, Public Prosecutor's offices and Justices of the Peace offices that aimed at reducing the number of courts, suppressing of 220 courts' detached offices and almost 480 Justices of the Peace offices (Law no. 148/2011 of 14 September 2011 and implemented by Legislative Decrees n. 155, n. 156/2012, n. 14/2014).

[3] The current FADN legal base is Council Regulation (EC) No 1217/2009.

[4] The intermediate inputs used in the estimation of the Levinsohn and Petrin method are proxied by total specific costs and intermediate overheads arising from production. It includes, among others, seed, fertilizer, animal feed, water, electricity, and fuel.

For civil and criminal justice, the Italian territory is divided into judicial areas (Circondari) which define the territorial jurisdiction for each tribunal and public prosecutors' office. These areas mainly coincide with the corresponding provinces' area (NUTS 3) with some exceptions.

Within these areas, the courts of first instance tribunals, 165 ante and 140 post territorial organization reform implemented in 2012, administer both civil and criminal justice. The 26 Courts of Appeal are the second instance courts for civil and criminal cases, their territorial jurisdiction (Distretti) are wider than those of tribunals. We use data provided by the Ministry of Justice and in order to cover the two main degrees of justice, we computed the number of trials pending divided by incoming cases (pending/incoming) both for tribunals (at the level of circondario) and Court of Appeal (at district level). In addition, to avoid potential problems that might arise due to jointly determined choices, we use one year lagged variables. Looking at the judicial efficiency, we find a great amount of geographical heterogeneity, confirming that the degree of efficiency vary greatly among circondari and generally seems to be higher in the North of Italy than in the South. The pending/incoming for tribunals range from 2.6 for Bari to 0.56 for Trento, and the pending/incoming for Courts of Appeal range from 5 for Reggio Calabria to 0.8 for Trento. We finally standardized our two indexes of court efficiency.

One of the key econometric problems when estimating the effect of financial stress on farm performance is its endogeneity, because a high level of financial stress is non-random and depends on farm unobservable characteristics. In order to solve this issue, we used an Instrumental Variable (IV) approach. A good instrument should be exogenous with respect to farm performance but, at the same time, should strongly affect the level of credit constraint. We use our efficiency variables as an instrument and exploit the great heterogeneity in the judicial efficiency of Italian courts across time and provinces to estimate the causal impact of financial constraints on farms productivity. As far as we know, an IV approach has never been used in investigating this relationship. We relied on a classical IV estimation strategy, and tried to define a measure of credit constraints and provided evidence of its effect on productivity. We estimated the following fixed effect model:

$$Y_{ijt} = \alpha + \beta_1 CC_{ijt} + \beta_2 X_{ijt} + \mu_i + \theta t + \varepsilon_{ijt}$$

$$CC_{ijt} = \delta + \gamma_1 Z_{jt} + \vartheta_j + \rho t + \sigma_{ijt} \quad (1)$$

Where Y_{ijt} is the (ln) total factor productivity of farm i in district j in year t, X are a set of farm size[5] dummy, CC_{ijt} is our measure of credit constraints, μ_i is a farm fixed effect, θ_t and ρ_t are year dummies and εijt is a standard error term. In the first step equation, Zjt is a measure of court efficiency of district j in year t, while Z_j are district fixed effects.

The fixed effect method has the advantage of controlling for any latent or not observed constant over time variable that characterizes the unit of analysis (farm and circondari). In our case, for example, the estimated fixed effects model helps to eliminate distortions caused by a possible effect of concentration of technology in the "best farms", those who have the best farm holder or which are located in the more productive areas. However, this approach does not allow us to control for changes in these same characteristics that have occurred in a farm over the period under analysis. With the year dummies, we are able to control for shock common to all the farms in the sample.

3. Results

Table 1 reports the results of the effect of credit constraint on farm productivity. In the column (1), obtained using fixed effect estimator and treating the credit constraint variable as exogenous, the results show that the coefficient of credit constraints is positive and significant: the lower is the credit constraint the higher is the performance of a farm in terms of TFP.

In column (2) we show the reduced form of our estimated equation. We find that an increase in the court inefficiency affects positively the TFP, in other words, an improvement of the civil court efficiency is associated with a decrease in the farm's productivity, and this evidence regards especially the efficiency of the Courts of Appeal.

[5] From the accounting year 2010 farm's size is defined in terms of total Standard Output (SO) of the farm expressed in euro (Reg. (EC) No 1242/2008), previously, until the accounting year 2009, the economic size is measured as the total Standard Gross Margin (SGM) of the farm expressed in European Size Unit (Decision 85/377/CEE). Size is therefore a time varying characteristic. Using farm size we grouped the farms into three classes: Small: SGM <= 19.200 OR SO <= 50.000 which accounts for 34.6% of the sample; Medium: 19.200< SGM<=48.000 OR 50.000< S0 <=100.000 which accounts for 26.2% of the sample; Large: SGM > 48.000 OR SO > 100.000 which accounts for 39.3 of the sample.

Table 1 - Fixed effect, reduced form and IV estimations of the effect of court efficiency on farm productivity. Court efficiency measure: the number of trials pending/incoming cases of court in each circondario and Courts of Appeal (CA). Italy, 2008-2013.

	(1) LOGTFP	(2) LOGTFP	(3) Credit Constraint(*)	(4) LOGTFP
	Treated as exogenous	Reduced Form	First stage	IV
Credit constraint	0.258***			0.301*
	[0.005]			[0.171]
Pending/Incoming Tribunal		-0.000	0.024**	
		[0.007]	[0.011]	
Pending/Incoming Court of Appeal		0.017**	0.034***	
		[0.008]	[0.013]	
Constant	-0.331***	-0.374***	-0.178***	-0.323***
	[0.011]	[0.012]	[0.018]	[0.033]
Observations	25,939	25,939	25,939	25,939
R-squared	0.172	0.012	0.172	0.329
Number of id	11,064	11,064	11,064	11,064
Farm fixed effects	YES	YES	YES	YES
Year fixed effects	YES	YES	YES	YES
Test F			5.92	

Note: (*) Farm credit constraint decreases as our score increases. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

To control for all forms of endogeneity between TFP and credit constraint we use an IV approach. The results of the two stages of our estimations are reported in columns (3) and (4). In the first stage of IV we find that a standard deviation increase in the court inefficiency of tribunals is associated to around a 0.02 increase in our credit constraint index, i.e. the level of financial stress is reduced. In the same fashion, a standard deviation increase in the inefficiency of the Court of Appeal raises the credit constraint index of about 0.034. Therefore, the higher the court inefficiency the lower the credit constraint. This result is counterintuitive, but we may expect that farms could be quite peculiar in their access to credit market. In column (4) we confirm a positive relationship between the loosening of the credit constraint and the productivity of the farms. All columns include, other than farm fixed effects, size dummies and year dummies.

Overall, our results have two important implications. First of all, they confirm a positive role of the loosening of the credit constraint on the performance of the farms. Secondly, an increase in the court inefficiency reduces the credit constraints faced by each farm. This result may be a puzzle, but we have to consider that the farms are quite peculiar in their debt structure. In order to find a plausible explanation for this counterintuitive result, we explored the official data about subsidized loans to agriculture delivered by the Bank of Italy for the period 2008-2013. These loans are supported by specific incentivizing laws that granted interest rates lower than the market's ones. We divided each regional amount of subsidized loans by the number of farms in each region[6]. We then run a fixed effect regression at the circondario level, and found that whenever the judicial system becomes less efficient, the amount of subsidized loans increases. It seems that in those areas where the courts are less efficient, and subsidized loans are available, banks tend to lend money using this channel instead of the unsubsidized ones. Farms benefit from the subsidized loans that are cheaper and their productivity increases.

4. Conclusion

Our study fits into two important current policy debates in Italy: credit constraints and judicial efficiency. In particular, we investigate the impact of the credit market, through judicial efficiency, for the Italian farming sector. As far as we know, there is no study investigating the relationships between judicial efficiency, availability of credit and economic performances of farms. We exploit the heterogeneity in the judicial efficiency of Italian courts across time and provinces to estimate the causal impact of financial constraints on farms productivity. We find that the loosening of the credit constraints increases the performance of the farms. Secondly, an increase in the court inefficiency reduces the credit constraints faced by each farm. This result may be a puzzle, but we argument, with caution, that probably a relationship between the judicial system and the structure of farms debt does exist. Whenever the inefficiency increases, and subsidized loans are available, banks tend to lend money using this channel instead of the unsubsidized ones. Farms benefit from these subsidized loans, that are cheaper, and their productivity increases. This puzzle deserves further investigations and future research should try to discover if this relationship varies according to type of farming, farm size or owner characteristics. We also believe that further progress in solving this puzzle could provide a better understanding of the relationship between credit and agriculture and shed light on agricultural policy implications.

[6] Provided by National Statistics Office for the years 2007-2010-2013. We than interpolate to have information for the missing years.

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The inverse farm size productivity relationship: some new evidence from sub-Sahara African countries

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ABSTRACT

The inverse farm size productivity relationship (IR) for short implies that diseconomies of scale characterize agriculture systems for several possible reasons, including the failure of land and labor markets to equalize production efficiency across farm size distribution. From the policy perspective in turn, should smallholders be found to be more efficient, policies to facilitate the redistribution of land from large towards the small farms would be justified not only on equity but also on efficiency grounds. While many consider IR as a "stylized fact" of rural development and a guiding principle of the major land reform in the former Soviet Union, and the Eastern European countries, others find it difficult to accept without further questions for several reasons. These include the fact that in most empirical studies IR appears as smooth tendency for land productivity to decline with farm size and thus is not limited to a different pattern of resource uses between large and small farms. While different reservation wages could account for family versus non-family farms, this would not explain why land productivity appears to decline within small family farms as well. Some empirical evidence also suggests that land quality and farm size are inversely correlated, so that ignoring this relation may be the cause of a basic specification error. Finally, several studies have indicated that total factor productivity does not show any negative correlation with farm size.

In this paper, we investigate the relationship between productivity and farm size from the point of view of the option value of land and its relation with management quality and efficiency. We use LSMS-ISA national representative datasets of five sub-Saharan African countries, which provide standardized location details of sampled communities allowing the data to be linked to any other geo-referenced data . We are thus able to control for many exogenous common and comparative geo-spatial measures of land quality, infrastructure and access to markets, climate conditions, soil and topography. We also use an estimation strategy, based on quantile regressions at the household level, that allows us to test IR existence and verify signs' switches across the entire distribution of farm size, and between countries located in different agro-ecological zones. Our findings indicate that, as suggested by a model combining land option values and farm size related management quality, while IR may be important for certain ranges of farm efficiency and size, it is by no mean an ubiquitous characteristic of agriculture. Whether the relationship between productivity and size is positive or negative may thus depend crucially on other factors, including soil quality, agro-economic zones, and the efficiency of farm management.

Keywords: Farm size productivity relationship, quantile regression, sub-Saharan Africa

PAPER

1. Introduction

The finding that land productivity and size of the land operated (both owned and rented) appears are related negatively has been historically established by a variety of studies starting in the late 70s (e.g. Berry and Cline, 1979, Kutcher and Scandizzo, 1981, Binswanger et al., 1993).

The literature has emphasized different explanations for this empirical regularity:

1. factor market imperfections in land and other market such as credit and modern inputs;
2. omission of soil quality measurements that are inversely correlated with farm or plot size but positively associated with yields;
3. measurement errors in self-reported area and quantity of crop production typical of household survey agriculture data;
4. risk and uncertainty.

The finding, however robust across many studies (Bharadwaj, 1974, Carter, 1984, Feder, 1989), seems at the same time puzzling, for several reasons. First, it is not limited to small versus large farms, but in most studies, there is a smooth tendency for land productivity to decline with farm size. This result seems to contrast to the equalization of factor prices predicted by market equilibrium theory and not simply explained by lower reservation wages for family farms, because land productivity appears to decline within all ranges of family as well as non-family farms. In this respect, Feder's (1985) alternative explanation appeals to a more general transaction effect, reminiscent of Coase's theory of the firm. According to this explanation, smaller farms are based on more intense use of family labor, because of its higher efficiency and motivation than hired labor and the fact that supply of working capital is directly related to farm size. Srinivasan (1973) explains the inverse relationship by yield risk, by defining utility over income , and imposing restrictions on the coefficients of risk aversion and on how risk enters production, under constant returns. Hazell and Scandizzo (1974) provide a rationale for producers to reduce planned production in response to the negative correlation between supply and prices, and Barrett (1993) shows that IR can emerge from price risk if farmers are net buyers of the crop produced, since in this case, risk aversion implies labor overemployment to protect consumption.

As Savastano and Scandizzo(2009) have shown, a relationship between productivity and operated area may arise because of the investment required by the decision to increase one's farmland . Under dynamic uncertainty, in fact, the amount of land operated by a farmer will depend on the timing of the exercise of the option to invest in land development. With decreasing returns to scale, this will imply a non monotonic relationship between revenue per ha and operated land. If land is available on the market in fixed quantities (i.e. supply of plots for rents or sale , or entire farms of discrete size), and/or investment is lumpy, small farms will exhibit lower revenue thresholds for investment, and thus lower revenues per ha than larger farms. This implies, in particular, that the relationship between productivity and size may exhibit turning points, as farmers switch from one type of investment to another (e.g. from land improvements to irrigation) as their operating land increases as a result of previous investment decisions.

Some empirical evidence (Bhalla, 1979, Bhalla and Roy 1988, Benjamin, 1995, Dyer, 1997), suggests an inverse correlation between land quality and farm size, so that ignoring this relation may be the cause of a basic specification error. This implies that if various characteristics of land such as fertility, water and nutrient availability, soil structure and composition are taken into account, the negative correlation between average land productivity and size might be drastically altered or disappear. In an insightful study on the impact of Kenya extension service, Evenson and Mwabu (1998) found that productivity response to acreage, measured through quantile regression, was not significantly different across quantiles, but displayed a concave shape, first rising and then falling with the size of the cultivated area.

More recently, other studies suggest that correcting for land and crop quantity measurement errors strengthen the IR (Carletto et al., 2013; Deininger et al., 2012). Finally, several studies have indicated that total factor productivity does not show any negative correlation with farm size, and results, if anything, seem to suggest a tendency toward increasing with the scale of the enterprise.

The contribution of our paper to the existing literature is threefold:

1. We analyze the existence of the IR in a cross-country context making use of comparable national representative surveys.

2. We avoid the problems posed by the endogeneity of key farm variables, by using a number of exogenous variables available in the geo-referenced dataset of the LSMS-ISA project. For example, instead of controlling for soil quality self-reported information of farmer, we use exogenous soil quality variables.

3. We control for other omitted variable bias and measurement errors in self-reported area of farmers by using the GPS information of land area collected by the enumerators.

Our results , using evidence for five sub-Saharan African countries (Malawi, Niger, Nigeria, Tanzania and Uganda) suggest the following conclusions:

- Consistently with findings of the existing literature, land quality and its components appear to be significant explanatory variables of land productivity, and so are several other exogenous variables linked to urban and market influence, such as distance from the roads, temperature and rainfall.

- Effects of farm size on average land productivity remains significant across all specifications.

- However, this relationship is both nonlinear and switches signs across farm size groups. More specifically, average land productivity (ALP) exhibits an inverted U-shaped relation with farm size for the first three deciles of the land productivity distribution, with ALP first rising and then falling after a threshold farm size. Vice versa ALP shows the opposite pattern of a U-shaped relationship for the rest of the distribution, first decreasing and then increasing after reaching a lower threshold.

- This pattern is confirmed by quantile regression and by testing the ALP – farm size relationship within and across quantile groups.

- Farms in the lower tail of the ALP distribution thus experience IR only once they have reached a critical size. Vice versa, farms at the upper end of the distribution experience IR only if they are below a critical size, which, in general, tends to be larger (and some time much larger) than the critical size of the lower end farms.

- Thus, small and large farm behavior tend to diverge, since farms in the lower deciles of the land productivity distribution experiment the IR for a smaller range of farm sizes than farmers of the higher deciles.

2. Conceptual Framework

The agricultural enterprise poses two different problems to the theory of the firm. First, contrary to reasonable expectations on the division of labor and the role of capital, in most cases the family farm appears to be the dominant form of organization of the productive unit in agriculture. Second, similarly, but more dramatically than for the other types of firms, the existence of profit represents a puzzle for the family farm, since its determination as a residual in a highly competitive market does not follow a clear economic logic . Perhaps the best discussion of this twofold question, within a more general framework of the fundaments of the theory of the firm is the treatment by Demsetz (1995), who discusses the issue of the existence of the firm by contrasting Coase's transaction theory with its own. Demsetz aptly starts its treatment by noting that rather than with the existence of the firm, the early literature was concerned with a related, but separate event, the existence of profit in a perfectly competitive market. Given that profit existed, the institutional theory tried to find a justification in the entrepreneur. In two significant cases, that of Frank Knight (1925) and Ronald Coase (1937). Both these authors laid the foundation of a productivity theory of the firm, based on the idea that the reason for the firm's existence was to increase productivity by providing managed coordination, thereby reducing risk in the case of Knight and reducing transaction costs for Coase. Demsetz's own theory is based on two related concepts: specialization and interdependence, where the development of a business firm is seen as a process of specialization that separates production from consumption, thereby creating interdependence with other firms and households.

For Boserup (1965), Binswanger and Rosenzweig (1986) , and Binswanger and McIntyre (1987), the process of agricultural development is characterized by population pressure which brings about the family farm system, chiefly because of hired labor transaction costs that create diseconomies of management. The family farm, in other words, while equally productive in reducing other transaction costs external to the firm (a la Coase) is superior in increasing productivity by internalizing labor supervision costs without increasing transaction costs internal to the firm. According to the family farm theory (Roumasset, 1995), in particular, it is the very organization of the farm that is determined by labor transaction costs, rather than by any technical economy of scale. On the other hand, Eastwood, Lipton, and Newell (2010), henceforth ELN, on the basis of a simple maximization model, with homogenous farmers, claim that development will bring about an increase in family reservation utility and thus in equilibrium farm size, but the increasing availability of cheaper capital and technological progress can go either way. Moreover, removal of any of the hypothesis of the simple model (e.g. infinite supply of family farmers, homogeneity of land etc.) tends to open the way for different results, pointing to the impossibility of a unique prediction on the effects of development on the farm size. A similar conclusion can be reached for the relationship between efficiency and farm size, with a plurality of possible outcomes, depending on the various components of scale economies and diseconomies, including indivisibilities and transaction costs, that may directly and indirectly interest the farm.

While the outcomes of increasing farm size may be many, it seems legitimate to ask whether there is a fundamental tendency, as postulated by Coase (1937), for the farm to grow in response to the need to reduce market transaction costs and, if not, why or because of which fundamental constraints or counter-tendencies. This question is dictated by the general issues considered by Coase , but also by the seemingly ubiquitous finding of an inverse relationship (IR) between land productivity and farm size. The answer to the above question, however, requires an answer to a more general question, namely: is the farm , and the family farm in particular, defined by its relationship with transaction costs, within the bigger picture of the relationship between the firm and the market? In this respect, most of the literature cited, with the partial exception of ELN, appears to regard transaction costs as an element of possible scale diseconomies in determining the optimal size of the farm, and not as a constitutive element of the productivity mission of the firm as an institutional agent, as claimed by the institutional economic literature . Rather than asking whether small farms reduce transaction costs, for example, Pingali (2010) focuses on the opposite question on whether and how to reduce the transaction costs faced by small farms. On a different note, ELN note that there is no theory that predicts optimal farm size to minimize unit transaction costs, because of multiple equilibria, deriving from non convexities of the transaction cost functions. They claim that these multiple local optima may give rise to sudden jumps from self cultivation to much larger forms of operations, in effect , because labor transaction costs become less important than capital transaction costs.

These arguments seem also to exclude a tendency toward an optimal farm size, but rely on a particular interpretation that essentially assimilates transaction costs to the costs of accessing factor markets and managing factor usage. A more general interpretation, however, considers transaction costs all costs related to ex ante and ex post exchange , including the choice of the trade partners, bargaining, monitoring and enforcing the related contracts. For Coase (1972), the firm acts as an agent capable to reduce these costs by substituting a structure of command and control to the decentralized structure of the market , and by appropriately standardizing the contracts themselves.

Within this interpretation, as a nexus of contracts, the family farm presents different organizational features from a commercial farm which may indeed reveal a tendency to settle around an optimal size , that , if not reached , or once reached, may give rise respectively to scale economies and diseconomies . The organization of the family farm , in fact, is based on a structure of implicit contracting grounded in familiarity (in the literary sense) , trust and mutual exchange, with community monitoring and enforcement, a strong role for tradition procedures, routines and rights, and equal importance of utilitarian exchange and ritualized gift giving. As Demsetz (1995) argues, furthermore, the family farm is also typically organized in a way that promotes a certain degree of self-sufficiency, and thus tends to substitute the contracts between producers and consumers with a standard in house arrangements, which often include family and non family labor.

Family farms may thus be more effective in enhancing productivity, than other types of organizations, especially when market transaction costs are high, and they pursue their mission with a panoply of instruments, characteristic of traditional societies, some of which survive within "familistic" cultures also in more advanced and indeed non agrarian urban contexts (Putnam, 1967). We should expect their contribution to productivity increases , however, to be uneven, and led by different drivers, depending on the features of the environment that they face, their different objectives, and the relative importance that the instruments at their disposal assume . Management ability is certainly a component of a successful performance, but a number of family characteristics may conjure up to determine winners and losers including the human and non human capital (Sen's re-known "capabilities") with which the family is endowed.

Classes of different performances may thus emerge across the spectrum of family farms , depending on the fact that they may have diverse subsistence and marketing goals and because of characteristics that may be at the same time too many and too subtle to observe. Within each class, a tendency to optimize may be present, with several local optima that determine local IRs in different intervals of productivity and farm sizes. In more dynamic terms , the implications of development and transaction costs for the family farm may be rather different than those of the firm. In both cases an increase in market transaction costs (MTC) may increase the incentives to internalize the production of goods and services, but while this typically means a more vertically integrated enterprise for the firm, it will simply tend to enhance the push for self sufficiency for the family farm and thus increase its optimal size. Symmetrically, an increase in internal transaction costs (ITC) , such as information and supervision, will reduce the incentive to integrate the value chain for a firm that is already well positioned in the market, while it may reduce optimal farm size by increasing specialization and market dependence for the family farm.

Decisions about family size are also likely to be affected by transaction costs, so that the family farm, unlike the firm, may react to changes in MTCs and ITCs with two instruments, i.e. the number of people in the family and the scale of operations. Thus increases in the ratio between MTCs and ITCs may be expected to encourage larger family sizes, because a higher degree of self-sufficiency requires larger operating sizes, higher diversification and more general skills, with factors somewhat trapped within the farm or its quasi market circle of mutual help of extended family systems . Here, we should expect first a direct relationship between productivity and farm size and then IR emerging in response to excessive increases lead by the forces unleashed by the harder drive toward self sufficiency. Vice versa a decrease in the MTC- ITC ratio will encourage smaller and more specialized enterprises, higher integration with the market and higher factor mobility, with IR pushing toward a contraction of farm sizes along these lines. Thus, even though consistent with the Coasian premises, the process of de-agrarianization may be itself a cause of the IR, since it is to some extent the opposite of the process originally described by Coase, with many different types of smaller farm- firms emerging from the rather homogenous population of traditional family farms to exploit the reduction in market transaction costs made possible by development.

Because the family farm has low supervisory costs from higher motivation of its members (Feder, 1985) and of the gratuities that they can experience as parts of an extended family business, the reduction in external transaction costs may be expected to have different effects on differently performing farms. For highly productive family farms, that are performing better than their peers because of higher quality management or other non observable farmers' abilities, increases in marketable surplus and development of commercial agriculture may be a chance to be exploited immediately, even before undergoing a transformation to more specialized units, operating exclusively for the market. While increasing farm size may be necessary to exploit the new market opportunities, increasing internal transaction costs (ITC) should be expected with negative effects on productivity until a certain threshold of successful transformation into commercial farming has been achieved.

For the less productive family farms , on the other hand, the opportunities created by lower MTCs may be met with size expansion without major increases in supervision costs at first, either because of underemployed family labor, or because of other benefits from MTC reduction, such as access to modern inputs, extension and better prices. Beyond a certain threshold of expansion, nevertheless, it is reasonable to expect that ITCs will become prevalent again and that larger farm sizes will be associated with lower productivity.

These considerations also suggest that farmers may operate in different ways, especially in the extreme distribution of farm productivity residuals, due to unobserved cognitive and physical abilities (Evenson and Mwabu, 1998), previous experience with investment or other performance- related characteristics. Thus, for example, at the low extreme of the productivity distribution (or the distribution of its residuals after accounting for the exogenous variables), productivity could increase as farmers take advantage of larger operating areas to overcome other performance disadvantages due to low endowments of skills and knowledge. At the high extreme, on the other end, supervision costs may become more important and larger sizes may reduce the competitive advantage of abilities and motivation of family farmers (Feder, 1985).

If factor productivity is distributed normally, with a constant variance, aside from identification problems, OLS will generally provide an estimate of the relationship based on mean response. In other words, OLS will allow us to estimate a response coefficient that will quantify the average response of the dependent variable (e.g. land productivity) to farm size increases. If the distribution of the response around the mean , estimated according with OLS, is not satisfactorily described by a single variance, however, quantile regression (Koenker and Basset, 1978) promises a more robust and appropriate estimate, especially if variance is systematically related to the increase in the response variable (heteroscedasticity). We can also conjecture that the relationship between productivity and alternative measures of size (land available, land under cultivation etc.) may be considerably different for farmers who, for various reasons that cannot be captured by the econometric model, have to operate at low productivity levels, with respect to farmers that operate at high productivity levels.

3. The Option Model

We follow Savastano and Scandizzo (2009) and assume that landowners hold the option to invest in additional land i q at a given rate $r^* = \frac{r}{\rho}$. Yield is assumed to follow a Brownian process as identified by the equation:

$$(1)\quad dy = \alpha y dt + \sigma y dz$$

Assume that the farmer contemplates the possibility of investing in farmland q_i, Farm operating profit from developing land, π, is determined according to the following equation :

$$(2)\quad \pi_i = \frac{y}{\delta} f(q_i; m_i) - \frac{c}{\rho} f(q_i; m_i)(1 - e^{-\rho T})$$

In (2) , $\delta = \rho - \alpha$, and without loss of generality, we set $\frac{c}{\rho}(1 - e^{-\rho T}) = r$ and consider only land a decision variable. Revenue per unit of output, i.e. the random variable y is supposed to follow a geometric Brownian motion as described in (1). In addition, $f(q)$ is a neoclassical production function with the standard properties $f_i > 0$, $f_{ii} < 0$, $i = q, m$, with management m positively related to both average and marginal productivity : $f_{qm} > 0$, $f_{qqm} < 0$. We also make also the following assumptions: (1) the production function is linear homogenous in the two inputs of land and management ability, (2) management is exogenously given for the farmer, (3) the farmer can develop land at the cost c , which includes all on farm investment. This cost is sunk and the investment is irreversible, (4) the operating profit flow is such that the farmer does not have the option to suspend or abandon the cultivation.

The objective of the farmer is to maximize the expected present value of profit. The discount rate is given and equal to ρ . The farmer cultivates his own original plot of land, given his endowment of management capabilities, and has to decide whether to develop land on the basis of costs and benefits of cultivating additional pieces of land.

Given these conditions, as shown more generally by Dixit and Pyndick (1994), the optimal policy is described by an upward-sloping threshold curve $y = y(q,m)$. In the region above the curve, it is optimal to develop more land in a lump to move immediately to the threshold curve. In the region below the curve, inaction, and therefore, cultivating the previous amount, is optimal. The farmer waits until the stochastic process of y moves vertically to $y(q)$, and then develops land just enough to keep from crossing the threshold. Assuming that there is a continuous supply of land, the farmer cultivates his own initial level and has the option of develop additional pieces of land. As shown by Savastano and Scandizzo (2009), the threshold value of production at which the farmer will invest in additional land development is:

(3) $$\frac{y^*}{\delta} = \frac{\beta_1}{\beta_1 - 1}\frac{r}{f_q(q_i;m)}$$

The parameter $\beta_1 > 1$ derives from the solution of the dynamic problem of the farmer under uncertainty and is an inverse function of the variance of the process in equation (1). Thus, equation (3) simply states that the threshold of investment will be at a level of marginal productivity of land that significantly exceeds its development costs.

Since the production function is homogenous of degree one, we can write:

(4) $f_q(q_i;m_i)q_i + f_m(q_i;m_i)m_i = Q_i$

(5) Thus, average land productivity (ALP) for the new developed area can be computed as follows:

(6) $$ALP_i = \frac{Q_i}{q_i} = [f_q(q_i;m_i) + f_m(q_i;m_i)\frac{m_i}{q_i}]\frac{y}{\delta}$$

Substituting (3), we obtain:

(7) $$ALP_i = \frac{\beta_1}{\beta_1 - 1}\frac{ry}{y^*} + f_m(q_i;m_i)\frac{m_i}{q_i}\frac{y}{\delta}$$

From this equation we can directly derive the following results:

(8) $$\frac{\partial ALP}{\partial y^*} = -\frac{\beta_1}{\beta_1 - 1}\frac{ry}{y^{*2}}$$ (8) $$\frac{\partial ALP}{\partial q_i} = \frac{y}{\delta}[f_m\frac{1}{q_i}(\frac{\partial m_i}{\partial q_i} - \frac{m_i}{q_i}) - |f_{mm}|\frac{\partial m_i}{\partial q_i}]$$

ALP will thus be lower the higher the threshold value, but it will increase or decrease with operating size depending on the balance of the diffent effects of management quality. As operating size increases, in fact, if management and farm size are positively related (that is, larger farms tend to have better managers or $\frac{\partial m_i}{\partial q_i}$>0) management will be spread over a larger farm, thereby reducing its impact, but the overall effect may still be positive because of the positive marginal effect that increasing operating size will be in attracting better managers. In general, the fact that the threshold and the management effects may display opposite tendencies to increase or decrease as farm size rises suggests two conclusions:

(1) ALP will display respectively a negative (the IR) or a positive correlation with farm operating size, depending on whether the threshold effect (the higher incentive for larger farms to hold undeveloped land as an option) prevails or is overwhelmed by the management effect (the tendency of ALP to increase with farm size since larger farms attract better managers).

(2) Depending on the functional form of their relationship, the two tendencies may equal each other , once a threshold of farm size is reached, after which the net effect on ALP will be reversed.

(3) Both tendencies and the level of the threshold will depend on the management quality and thus can be expected to vary across farmers, depending on the distribution of management quality and the extent to which a market for managers succeed in allocating them to larger farms.

These conclusions support the idea that the IR relationship may indeed be present in many farming systems, but we should expect it to be neither ubiquitous nor monotonic. In particular, if farmers face dynamic uncertainty by holding a waiting option for land development and unobservable management quality is positively correlated with farm size, both a reverse and a direct effect of operating size on average productivity may be present at any one time. This in turn implies that the net impact of increasing operating size on land productivity will depend on whether a threshold is crossed where the two effects exactly balance each other.

4. The Estimation Problem

Consider the relationship between land productivity and farm size in the stylized form:

$$\frac{y_i}{x_i} = \beta_0 + \beta_1 x_i + \gamma Z_i + \epsilon_i \qquad (9)$$

where y_i is some measure of production for the ith farm, x_1 is a correspondent measure of farm size (e.g. operated area), z_i a set of exogenous variables, and e_i a random disturbance. It is important to underline the fact that equation (9) is not a production function, but the result of farmers' choices, on the basis, inter alia, of an underlying technology. If we assume that farmers have adjusted production (either through optimization or through any other common behavioral rule) to the circumstances outside their control, including exogenous variables, states of nature etc., the coefficient β_1 in (1) should be zero. In other words, all systematic differences in production per acre between farms should be accounted for by differences in the z_i variables or in the random term εi. A β_1 different of zero, on the other hand, would imply the existence of systematic differences across farmers that are not accounted for in the equation: these differences could be due to different behavioral rules, different abilities in following the same rules or different levels of information or other omitted variables that are correlated with farm size.

It is also important to notice that a non zero β_1 may be caused by discontinuities in the behavioral function that underlies farmers' adjustment to the exogenous variables. These discontinuities are implied by most of the explanations of the inverse productivity relationship based on anthropological differences between "family" and " non family" or systematic divergence in behavior between "small" and "large" farms (e.g. Feder, 1989; Cornia, 1985). However, if IR is the result of these discontinuities, it should only concern the differences across the two extreme groups of farmers, and not the differences within the groups themselves.

In order to test for the existence of either an inverse or a direct relationship (IR) between land productivity and farm size , we use both OLS regression models and quantile regressions (Koenker and Bassett , 1978). While OLS focuses on modeling the conditional mean of the response variable without accounting for its distribution, the quantile regression model accounts for the full conditional distributional properties of the response variable (or is residual after accounting for the exogenous variables) thereby differing on the assumptions about the error terms of the regression model.

In the case of equation (1), the OLS model is based on the assumption that the error term is normally distributed with zero mean and constant variance: $\epsilon_i \sim \text{i.i.d.}\, N(0, \sigma^2)$

The consequence of the mean zero assumption of the error term implies that the model fits the conditional mean, namely $E[y - \gamma Z|x] = \beta_0 + \beta_1 x_i$ which can be interpreted as the average value of productivity, after accounting for the effect of the exogenous variables Z, corresponding to a fixed value of the covariate x (i.e. farm size). The linear regression model describes how the conditional distribution behaves by utilizing the mean of a distribution to represent its central tendency, a choice that appears appropriate under the assumption o homoscedasticity , namely of constant variance for all values of the covariate x.

The quantile-regression model (QRM) estimates the potential differential effect of a covariate (farm size) on various quantiles in the conditional distribution. A conditional quantile is a statistic corresponding to the probability level of a given distribution, according to a function (the quantile function) defined as $q(p) = \{y: \Pr(Y \leq y) = p\}$. By considering the different quantiles, the QRM estimates how the effect of a covariate varies with the distribution of the response variable and accommodates heteroscedasticity. The QRM corresponding to the LRM in Equation (9) can be expressed as:

$$y_i = \beta_0^{(q)} + \beta_1^{(q)} x_i + \gamma^{(q)} Z_i + \epsilon_i^{(q)} \tag{10}$$

The parameter vector, $[\beta_0^{(q)} \beta_1^{(q)} \gamma^{(q)}]$ is obtained by minimizing the sum of absolute deviations from an arbitrarily chosen quantile of a farm yield across farmers. In the case of Equation (2) this sum can be expressed

as:

$$\text{Minimize: } \sum_i \left| y_i^q - [\beta_0^{(q)} + \beta_1^{(q)} x_i + \sum_j \gamma_j^q Z_{ij} \right| \tag{11}$$

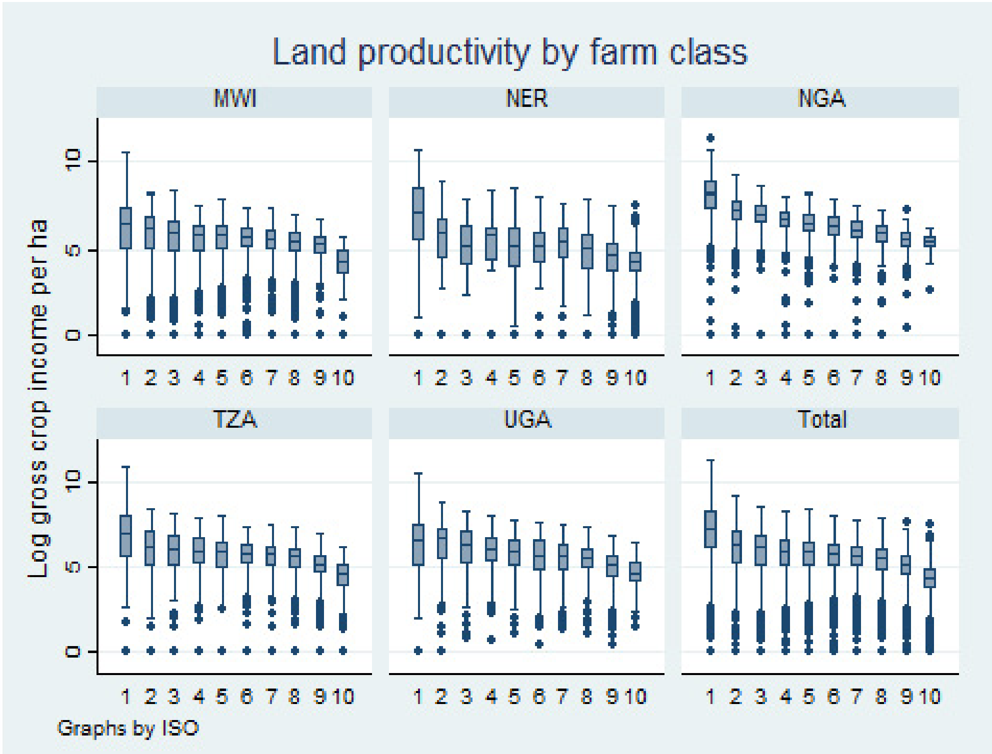
where y_i^q = average productivity for farmer i at quantile q, (i =1, ...n); x_i= farm size Z_{ij}^q = covariate j for farmer i (j = 1,....K).

The solution to Equation (11) is found by rewriting the expression as a linear programming problem over the entire sample (see Chamberlain, 1994) and solving for he values of the parameters. Both the squared-error and absolute-error loss functions are symmetric, as the sign of the prediction error is not relevant. While OLS can be inefficient if the errors are highly non-normal, quantile regression is more robust to non-normal errors and outliers. QR also provides a richer characterization of the data, allowing to consider the impact of a covariate on the entire distribution of y, not merely its conditional mean.

Figure 1 summarizes key aspects of our sample data on land productivity and farm size into a single form. On the horizontal axis farm size classes are reported by increasing size, while the vertical axis measures average land productivity. The top of the rectangular box shaded in the figure marks the 75th percentile of the data range, while the bottom "hinge" marks the lower 25th percentile. The "whiskers" extend another 1.5 times the interquartile range of the nearest quartile. The horizontal line in the middle of the box marks the median of the data for each group. Intuitively, the range of the box delineates observations that are typical. The whiskers contain values that are somewhat atypical relative to most observations, while the dots mark observations that are extreme, with a large number of suspiciously small values with a tendency of dispersion even if we are in the log scale of crop income.

The diagram appears to show a clear tendency for productivity to decline with increase in farm size. This effect is accentuated if we consider the upper and lower tails of the productivity distribution. This crude correlation, however, may be misleading for two reasons: first, it does not consider the effects of the other covariates that are expected to influence farm productivity; second, in the same diagram, dispersion appears to be decreasing with farm size, with a much wider range of values for the smallest size. By characterizing the entire distribution of crop income for each farm class, even for the simple correlation, the plot thus suggests that the relationship between productivity and farm size may not be the same for different levels of productivity, and that group means or medians do not necessarily represent group behavior .

Figure - Log gross crop income (land productivity) by percentiles of land operated



5. Data and Descriptive Statistics

We use data from LSMS-ISA surveys in Malawi, Niger, Nigeria, Tanzania and Uganda, all collected in 2010-2011. These are large multi-purpose household surveys, national representative, with detailed information on agricultural production. Table 1 reports some descriptive statistics from the surveys, showing mean values of broadly comparable magnitude across countries, except for Nigeria, which appears to have a much smaller average operated area and larger yield and labor intensity than the other countries.

Descriptive statistics for the surveys in our sample provide a number of insights pointing in particular to a wide distribution of land ownership, but similar level of crop intensity, difference in rural population density and market access, large productivity gaps across producers, sizable variation in infrastructure, and agro-ecological conditions.

In terms of area operated by farmers (defined by area owned, plus area rented in, and net of area rented out and under fallow), we note that the average across the five countries is 2.1 ha, with the lowest in Malawi (0.73 ha), and the highest in Niger (5.21 ha). With 267 and 218 person per sq. km, Uganda and Nigeria are, respectively, the two countries with the highest rural population density. Somewhat surprisingly, Uganda, with an average rural population density four times the level in Tanzania, has an average operated area quite close to Tanzania's 2.3 ha. While a larger farm size could be expected to compensate for lower population density, labor constraints prevent farmers to make the necessary investment (mechanization, tractor plowing or anima draft), to increase farm endowment. In terms of agriculture intensification, we observe that the majority of the countries have reached a stage of permanent agriculture, as the crop intensity (defined as gross cropped area divided to net cropped area) is larger than one.

The geo-referenced structure of the LSMS-ISA datasets allow us to link geo-variables matched by staff at the World Bank to the external datasets of the *FAO's Harmonized World Soil Database v.1.2* (soil nutrient availability) and use soil quality controls in our regressions. The soil database is the result of a collaboration between the FAO with *IIASA, ISRIC-World Soil* Information, Institute of Soil Science, Chinese *Academy of Sciences* (ISSCAS), and the *Joint Research Centre of the European Commission* (JRC)[1].

[1] The Harmonized World Soil Database is a 30 arc-second roster database with over 15 000 different soil mapping units that combines existing regional and national updates of soil information worldwide (SOTER, ESD, Soil Map of China, WISE) with the information contained within the 1:5 000 000 scale FAO-UNESCO Soil Map of the World (FAO, 1971-1981). The resulting database consists of 21600 rows and 43200 columns, which are linked to harmonized soil property data and display the composition in terms of soil units and the characterization of selected soil parameters (organic Carbon, pH, water storage capacity, soil depth, cation exchange capacity of the soil and the clay fraction, total exchangeable nutrients, lime and gypsum contents, sodium exchange percentage, salinity, textural class and granulometry). http://www.fao.org/fileadmin/user_upload/soils/docs/HWSD/Soil_Quality_data/Rooting_conditions.jpg

Among all the variables tested, two variables are mostly significant in the regressions to indicate lack of soil quality. They are: (i) a dummy constraint oxygen availability equal to 1 if the categorical variable "Oxygen availability to roots" is equal to severe and very severe constraints and zero otherwise; (ii) a dummy "Constraint excess salt", equal to 1 if the categorical variable Excess salts is equal to severe and very severe constraints and zero otherwise.

We use urban gravity and distance to the nearest market or the major road as proxy for urbanization and access to infrastructure respectively. To compute urban gravity we use light intensity data produced by the defense Meteorological Satellite Program (DMSP) of the National Geophysical Data Center, and we convert them into urban gravity using the same approach of Binswanger and Savastano (2015). The proxies for market access are taken from the geospatial dataset of the LSMS-ISA surveys, which include average households' distance to the nearest market and major road[2]. We note large disparities in terms of market access, with an average household distance to reach the nearest market of 35 km for the five countries, with a minimum of 8 km in Malawi to a maximum of 86 km in Tanzania. Also, as a proxy for urbanization, we note that urban gravity is the largest in Malawi and Nigeria and the lowest in Niger and Tanzania.

Table 1 - Descriptive Statistics (Averages)

ISO	MWI	NER	NGA	TZA	UGA	Total
Gross crop income per ha (US$/ha)	507.57	265.2	2229.82	478.52	468.2	733.58
Land operated (owned+ rented in-rented out-fallow) (ha)	0.73	5.21	0.8	2.33	1.45	2.10
Rural population density (pers./sq. km) (2005)	182.5	60.4	218.3	59.9	266.9	157.6
Gross cropped area (ha)	0.74	5.8	1.6	2.03	2.4	2.514
Net crop area (ha)	0.67	4.9	1.3	1.95	1.0	1.964
Crop intensity	1.02	1.19	1.23	1.07	1.89	1.28
Annual Precipitation (mm)	1085.54	375.94	1369.17	1089.87	1225.23	1064.8
Annual Mean Temperature (°C * 10)	218.28	282.03	263.59	227	218.82	233.61
UG: travel time negative exponential, with borders restriction to cities with 500K	142.49	41.36	113.23	49.96	53.59	105.23
HH Distance in (KMs) to Nearest Market	7.96	62.72	71.33	82.67	31.21	35.85
HH Distance in (KMs) to Nearest Major Road	9.69	12.92	17.21	21.73	7.31	12.41
Dummy constraints to oxygen availability to roots[1]	0.1	0.15	0.17	0.12	0.28	0.14
Dummy Excess salts[1]	0.04	0.09	0.03	0.06	0.04	0.05
Pastoral farming system[2]	0	0.49	0.03	0	0.01	0.06

Source: Authors' computation from LSMS-ISA household surveys. [1] Dummy for oxygen availability and excess salt have been computed from the continuous geospatial variable of the LSMS-ISA. A dummy is equal to 1 for higher constraint to soil fertility. Both raw data are derived from the FAO's Harmonized World Soil Database v.1.2 (soil nutrient availability): The dummy for pastoral farming system is drawn from the Harvestchoice dataset, and follow the classification of the farming Systems in sub-Saharan Africa according to FAO's methodology and based on Dixon, J. and A. Gulliver with David Gibbon, Principal [3]Editor Malcolm Hall. Improving Farmers' Livelihoods in a Changing World. FAO/World Bank. 2001

Using both OLS and Quantile regression we estimate the following function at the household level:

$$\ln \frac{Y_i}{v_i} = b_0 + b_1 \ln x_i + b_2 \ln Z_i + u_i$$

where $\frac{Y_i}{v_i}$ represents an indicator of farm productivity (gross crop income per ha , in which case $x_i = v_i$, or total labor productivity) for each household i, x_i is the total area operated, Z_i denotes a vector of exogenous geo referenced households characteristics such as variance of precipitation and temperature, urban gravity, distance to the major road or market, soil quality controls and u_i is an error term.

Table 2 presents the main results from the estimation for the pooled sample. The OLS estimates show a significant negative elasticity for the relationship between gross income per ha and land operated, with a value not significantly different of one and no significant quadratic response. The first (10%) quantile regression estimates, however, "deconstruct" this result as corresponding to the combination of a positive, more than proportional, linear response and a negative, smaller than unity quadratic response. For the other three quantiles considered (the 25^{th}, the 50^{th}, and the 80^{th}), a similar, but reversed sequence, of a negative linear and positive quadratic response is estimated. Moreover, both the quadratic and the linear coefficients increase across the quantiles.

[2] The source for the variable distance to the main road is OpenStreetMap-Tranroad, while the source for the distance to the nearest market is USAID – FEWSNET.

[3] The quantiles represent intervals of the probability distribution of land productivity

The IR hypothesis, therefore, appears to be rejected for all but the very first quantile, where, however, it is reversed after a threshold of operating size is reached. Vice versa, for the other three quantiles, productivity tends to decrease with the cultivated area, according to the IR hypothesis, but also this relationship is reversed, and the threshold of reversal is larger and larger as we move from the 25^{th} to the 80^{th} quantile.

In this regression, the elasticity of productivity with respect to the urban gravity index is low and essentially the same (between 0.01 and 0.03) for all quantiles, except the 20th for which it is not significant. The estimates of the weather impact are somewhat surprising with a large negative effect of the variance of temperature and a smaller positive effect of rainfall variability with both effects tending to vanish for the top quantiles. The elasticities with respect to the distance from the market and the main road are variable and larger. They follow a quadratic relation with a positive linear (in the logs) and a negative quadratic coefficient. The presence of pastoral farming systems appear to impact negatively on average land productivity, only for the lower half of the quantiles, while appears to have no effect in the quantiles in the top 50%. In sum, the results show that performance classes differ significantly in their response to key exogenous variables and that this response from productivity to infrastructure (UG, road and market distance), tends to be nonmonotonic.

Estimates on individual countries confirm the results (see Tables 3-7), which are summarized in Table 8 . They suggest distribution dependency of both the form and the intensity of the productivity response to the increases in operating area. We find that productivity effects of acreage increases are different at different levels of productivity and are highest, but with opposite signs, at the extreme ends of the distribution of yield residuals, with very similar patterns of decline, for the linear terms, and increase for the quadratic ones over the distribution (see Figure 1, 2 and 3). This may be due to various causes, such as, for example, that unobserved farmer ability acts as a complement for land increases at low level of yield residuals and as a substitute at higher yield residuals. More generally, it could be because the endowments of critical, unaccounted, components of human and non-human capital are correlated with productivity increases.

Tables 9 and 10 and Figures 2-6 show that the disparities in the coefficients estimated for the individual countries correspond to much smaller differences in the ranges over which the IR relationship holds for low performers and to huge differences for medium and high performers. These differences, on the other hand, appear to depend also on the other control variables. In the case of soil quality, for example, they are especially effective in the case of the lower performers of Malawi and throughout the quantiles in Uganda[4]. In general, however, for the lower performant farms of the first two quantiles, IR appears to take over at about the same level of operating area for values not significantly different of each other and from the pooled sample estimates. This means that land productivity for low performers tends to increase with operating area up to about a level of 2-5 has and then to decline according with the IR traditional evidence. For the highest performers (farms in the top three deciles of the productivity distribution), the results are the opposite, with productivity declining up to an operating size level of 5 to 80 has and above, after which increasing returns to scale appears to settle. The much wider range of the switching levels of operating area appears to depend on the range of the operating size variable that is much larger than the average for Niger and Tanzania.

The U shaped pattern at the lower tail of the productivity distribution suggests that a larger operating size may be a positive factor for low performers, but only up to a point after which the other causes of the IR relation become prevalent (i.e. only if farm size does not become "too large"). For the upper deciles, on the other hand, the IR relationship appears to hold over a much wider range, although in many cases appears to reverse itself for moderately large operating areas. As Tables 9 and 10 and Figures 4-6 show, the size of the operating area at which the IR relationship prevails for the first two deciles is small, although often above the average, depending on the country. For the upper tail of the distribution, on the other hand, the land size at which the IR relationship reverses itself is only moderately larger except for a few outlayers, so that most large farms essentially do not display any IR.

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[4] Note that the soil quality variables represent negative qualities and their coefficients have generally the expected negative sign. However, because of the possible correlation with farm size, their signs could also be positive or zero, as the following shows. Consider in fact the model:

(1) $y = b_0 + b_1 x + b_2 z + u$

Where y is average land productivity (LP), x is operating size (OS) and z a soil quality (SQ) variable. The OLS estimates of the coefficients are:

(2) $b_1 = (s_{zz}s_{xy} - s_{xz}s_{zy})/(s_{xx}s_{zz} - s_{xz}^2)$

(3) $b_2 = (s_{xx}s_{zy} - s_{xz}s_{xy})/(s_{xx}s_{zz} - s_{xz}^2)$

(4) $b_0 = \bar{y}$

If both OS and SQ are positively correlated with LP, while OS and SQ are negatively correlated with each other (i.e. larger farms have poorer soils), b_1 and b_2 will be both positive. On the other hand, if SQ is positively correlated with LP and OS ($s_{zy} > 0$, $s_{xz} > 0$), then the signs of the two coefficients become ambiguous.

Table 2 - Dependent Variable: Log Gross Crop Income/ha

VARIABLES	(1) OLS Pooled	(2) Q10	(3) Q25	(4) Q50	(5) Q90
Log land operated	-0.92***	1.25***	-0.86***	-1.72***	-2.70***
Sq. Log land operated		-0.61***	0.04	0.26***	0.56***
Variance of precipitation	0.14***	0.56***	0.22***	0.17***	-0.02
Variance of temperature	-3.72***	-15.96***	-4.85***	-1.27***	1.45***
Log UG	-0.02***	-0.03	-0.04***	-0.03***	-0.03***
Log distance to market	0.34***	1.16***	0.30***	0.19***	0.25***
Lo distance to market sq	-0.05***	-0.16***	-0.04***	-0.03***	-0.04***
Log distance to road	0.33***	0.58***	0.46***	0.27***	0.10***
Lo distance to road sq	-0.07***	-0.10**	-0.10***	-0.07***	-0.03***
Dummy Constraint Oxygen availability to roots	-0.31***	-0.84***	-0.29***	-0.13***	-0.08***
Dummy Constraint Excess salts	-0.33***	-0.96***	-0.58***	-0.13**	0.21***
Pastoral farming system	-0.24***	-0.27	-0.30***	-0.13**	-0.06
Country dummies					
MWI	-0.14*	0.39	0.17	-0.12**	-0.28***
NGA	1.02***	1.44***	1.11***	0.73***	0.72***
TZA	0.04	-0.08	0.08	0.01	0.17***
UGA	-0.20**	-0.46	-0.24*	-0.18***	0.14**
Constant	4.95***	-1.15*	3.89***	5.72***	8.05***
Observations	18,410	18,410	18,410	18,410	18,410
R-squared	0.18				

**** p<0.01, ** p<0.05, * p<0.1. NER is the comparison group*

Table 3: Results for MWI

Y = Log Gross Crop Income/ha	Q10	Q20	Q30	Q40	MALAWI Q50	Q60	Q70	Q80	Q90
Log land operated	11.22***	1.38**	-0.11	-1.44***	-2.02***	-2.52***	-3.00***	-3.49***	-4.30***
log land operated sq	-5.37***	-1.02***	-0.39*	0.15	0.45***	0.68***	0.88***	1.15***	1.52***
Log mean area of land operated by quantile	-7.93***	-0.35	-0.09	1.21*	1.27***	1.60***	1.94***	2.23***	2.90***
Dummy rent in land	-0.11	0.15	0.08	0.08	0.07	0.07	0.06	0.04	0.01
Log UG	-0.33**	-0.28***	-0.28***	-0.20***	-0.15***	-0.11***	-0.10***	-0.08***	-0.07***
Log UG Sq	0.05**	0.04***	0.04***	0.02***	0.02***	0.01***	0.01***	0.01**	0.00
Log distance to road	0.13	0.35**	0.32***	0.30***	0.27***	0.20***	0.21***	0.14***	0.13***
Lo distance to road sq	-0.02	-0.09**	-0.09***	-0.08***	-0.07***	-0.06***	-0.06***	-0.04***	-0.04***
Log distance to market	1.26**	0.44	0.18	0.02	0.07	0.07	0.11	0.10	0.05
Lo distance to market sq	-0.20	-0.06	-0.02	0.01	-0.01	-0.01	-0.02	-0.02	-0.00
Dummy Constraint Oxygen availability to roots	-2.06***	-1.05***	-0.53***	-0.15**	-0.01	-0.04	-0.01	-0.04	-0.02
Dummy Constraint Excess salts	-1.93***	-3.39***	-1.51***	-0.96***	-0.58***	-0.31***	-0.09	-0.04	-0.07
Agro Pastoral farming system									
AEZ_TEXT==Tropic - cool / humid	1.01***	0.56***	0.52***	0.45***	0.39***	0.35***	0.36***	0.30***	0.26***
AEZ_TEXT==Tropic - cool / semiarid	0.59*	0.06	0.04	0.09	0.13**	0.09*	0.10**	0.15***	0.12**
AEZ_TEXT==Tropic - warm / arid	-0.16	-0.13	-0.08	0.01	0.02	0.03	0.02	0.01	-0.01
Constant	12.05***	4.29*	5.36***	3.96***	4.26***	4.13***	3.88***	3.80***	3.17***
Observations	9,157	9,157	9,157	9,157	9,157	9,157	9,157	9,157	9,157

*** p<0.01, ** p<0.05, * p<0.1
Source: Authors' estimate based on MWI 2010-2011, LSMS-ISA project

Table 4: Results for NER

Y = Log Gross Crop Income/ha	Q10	Q20	Q30	Q40	NIGER Q50	Q60	Q70	Q80	Q90
Log land operated	3.07***	0.76**	-0.27	-0.37*	-0.78***	-1.17***	-1.39***	-1.84***	-2.11***
log land operated sq	-0.96***	-0.31***	-0.13*	-0.11*	0.03	0.12**	0.16***	0.26***	0.27***
Log mean area of land operated by quantile	-0.85	-0.48	0.18	0.06	-0.18	-0.06	-0.04	0.18	0.60*
Dummy rent in land	0.50*	0.28	0.14	0.21*	0.18	0.24**	0.20**	0.27**	0.19
Log UG	0.36*	0.18	0.12	-0.03	-0.06	-0.07	-0.07	-0.03	0.03
Log UG Sq	-0.07**	-0.03	-0.02	0.01	0.02	0.02*	0.02*	0.01	0.00
Log distance to road	0.97***	0.77***	0.67***	0.49***	0.45***	0.26***	0.24***	0.22**	0.15
Lo distance to road sq	-0.19***	-0.14**	-0.12***	-0.10***	-0.09***	-0.05**	-0.05**	-0.04	-0.03
Log distance to market	1.51***	1.01***	0.75***	0.72***	0.61***	0.45***	0.46***	0.42***	0.48***
Lo distance to market sq	-0.26***	-0.18***	-0.13***	-0.11***	-0.10***	-0.07***	-0.07***	-0.07***	-0.08***
Dummy Constraint Oxygen availability to roots	0.21	0.16	0.15	0.21*	0.18	0.13	0.15*	0.23*	0.11
Dummy Constraint Excess salts	-0.69*	-0.28	-0.24	-0.28*	-0.16	-0.05	-0.01	0.01	0.19
Pastoral farming system	0.58*	0.18	-0.03	-0.12	-0.17	-0.20*	-0.21**	-0.31**	-0.49***
Agro Pastoral farming system	0.99***	0.51*	0.14	-0.05	-0.18	-0.20*	-0.25**	-0.39***	-0.53***
AEZ_TEXT==Tropic - cool / humid	-0.45*	-0.52**	-0.56***	-0.35***	-0.14	-0.01	0.19**	0.44***	0.78***
Constant	-0.61	2.19*	2.77***	3.72***	5.11***	5.76***	6.16***	6.49***	6.41***
Observations	1,963	1,963	1,963	1,963	1,963	1,963	1,963	1,963	1,963

*** p<0.01, ** p<0.05, * p<0.1
Source: Authors' estimate based on NER 2010-2011, LSMS-ISA project

Table 5: Results for NGA

Y = Log Gross Crop Income/ha	Q10	Q20	Q30	Q40	NIGERIA Q50	Q60	Q70	Q80	Q90
Log land operated	-3.03***	-4.45***	-4.54***	-4.65***	-5.10***	-5.46***	-5.57***	-5.67***	-5.95***
log land operated sq	1.01*	1.48***	1.59***	1.63***	1.84***	1.97***	2.01***	2.08***	2.15***
Log mean area of land operated by quantile	0.43	1.93*	1.33*	1.28**	1.67***	1.99***	1.87***	1.61***	1.98***
Dummy rent in land	-0.06	-0.11	-0.17**	-0.06	-0.04	-0.04	-0.02	-0.02	-0.09
Log UG	-0.26*	-0.16**	-0.13***	-0.08**	-0.06*	-0.06*	-0.06**	-0.07**	-0.04
Log UG Sq	0.01	0.01	0.00	0.00	-0.00	-0.00	0.00	0.00	0.00
Log distance to road	0.25	0.14	-0.01	0.01	0.02	0.03	0.02	0.06	-0.02
Lo distance to road sq	-0.04	-0.02	0.01	0.01	-0.00	-0.01	-0.01	-0.01	0.01
Log distance to market	0.54	0.41	0.31	0.29*	0.21	0.14	0.17	0.07	-0.00
Lo distance to market sq	-0.08	-0.06	-0.05	-0.04*	-0.03	-0.02	-0.02	-0.01	-0.00
Dummy Constraint Oxygen availability to roots	-0.12	-0.21*	-0.09	-0.02	-0.00	-0.01	-0.03	-0.01	-0.07
Dummy Constraint Excess salts	0.03	0.02	0.07	0.02	0.01	-0.08	-0.11	-0.03	-0.02
Pastoral farming system	-1.12*	-0.77***	-0.58***	-0.62***	-0.57***	-0.36**	-0.42***	-0.46***	-0.69***
Agro Pastoral farming system	-0.23	-0.21	-0.20**	-0.21***	-0.14*	-0.18**	-0.20***	-0.20***	-0.29***
AEZ_TEXT==Tropic - cool / humid	0.56	0.60	0.33	0.09	0.07	0.10	0.04	-0.14	-0.27
AEZ_TEXT==Tropic - cool / semiarid	-2.29***	-0.51***	-0.45***	-0.28***	-0.25***	-0.21**	-0.21***	-0.23***	-0.24***
AEZ_TEXT==Tropic - cool / subhumid	-0.11	-0.15	-0.25***	-0.25***	-0.29***	-0.23***	-0.20***	-0.23***	-0.13**
Constant	5.24	3.54*	5.42***	5.69***	5.47***	5.28***	5.66***	6.53***	6.34***
Observations	2,813	2,813	2,813	2,813	2,813	2,813	2,813	2,813	2,813

*** p<0.01, ** p<0.05, * p<0.1
Source: Authors' estimate based on NGA 2010-2011, LSMS-ISA project

Table 6: Results for TZA

Y = Log Gross Crop Income/ha	Q10	Q20	Q30	Q40	TANZANIA Q50	Q60	Q70	Q80	Q90
Log land operated	7.49***	7.86***	6.35***	2.62***	0.91***	-0.14	-0.78***	-1.27***	-2.11***
log land operated sq	-2.17***	-2.25***	-1.80***	-0.79***	-0.38***	-0.14***	-0.01	0.09*	0.31***
Log mean area of land operated by quantile	-4.35***	-4.51***	-4.32***	-2.65***	-1.61***	-0.82***	-0.31	0.07	0.37
Dummy rent in land	0.44**	0.68***	0.53*	0.39	0.37**	0.30**	0.20*	0.23*	0.18
Log UG	0.03	-0.19	-0.57**	-0.44*	-0.36***	-0.21**	-0.21**	-0.06	0.13
Log UG Sq	-0.02	0.02	0.05	0.04	0.04*	0.02	0.02	-0.00	-0.03**
Log distance to road	0.20	0.34**	0.09	0.16	0.16	0.08	0.04	-0.05	0.04
Lo distance to road sq	-0.04	-0.07*	-0.03	-0.04	-0.04	-0.02	-0.01	0.01	-0.01
Log distance to market	0.04	0.34	1.23**	0.93*	0.73**	0.76***	0.79***	0.54**	0.18
Lo distance to market sq	-0.00	-0.05	-0.16**	-0.12	-0.10**	-0.10***	-0.11***	-0.08***	-0.03
Dummy Constraint Oxygen availability to roots	-0.05	-0.40**	-0.44	-0.37	-0.37**	-0.15	-0.18*	-0.05	0.16
Dummy Constraint Excess salts	0.01	0.15	0.25	0.37	0.25	0.18	0.26**	0.21	0.08
Pastoral farming system	0.93	0.19	-0.32	-0.63	-0.85	-1.03	-1.41	-1.68	-1.80
Agro Pastoral farming system	0.75	0.97	0.73	0.55	0.41	0.22	0.37	0.19	0.21
AEZ_TEXT==Tropic - cool / humid	1.65***	2.75***	2.72***	1.36**	0.74**	0.57**	0.75***	0.49**	0.21
AEZ_TEXT==Tropic - cool / semiarid	-0.00	-0.26	-0.31	-0.33	-0.32	-0.20	-0.14	-0.03	-0.01
AEZ_TEXT==Tropic - cool / subhumid	0.01	0.06	0.20	0.14	0.13	0.13*	0.13**	0.15**	0.20***
AEZ_TEXT==Tropic - warm / arid	0.55	1.58***	1.44**	0.92	1.12***	0.86***	0.71***	0.42	0.02
AEZ_TEXT==Tropic - warm / humid	-0.97***	-0.82***	-0.97***	-0.70**	-0.61***	-0.64***	-0.40***	-0.32***	-0.29**
Constant	7.97***	8.10***	7.85***	7.60***	7.19***	6.47***	6.04***	6.37***	7.02***
Observations	1,853	1,853	1,853	1,853	1,853	1,853	1,853	1,853	1,853

*** p<0.01, ** p<0.05, * p<0.1

Source: Authors' estimate based on TZA 2010-2011, LSMS-ISA project

Table 7: Results for UGA

Y = Log Gross Crop Income/ha	Q10	Q20	Q30	Q40	UGANDA Q50	Q60	Q70	Q80	Q90
Log land operated	8.31***	3.79***	1.09**	-0.39	-0.79***	-1.37***	-1.70***	-2.18***	-2.37***
log land operated sq	-2.67***	-1.39***	-0.51***	-0.14	-0.04	0.11	0.18**	0.36***	0.42***
Log mean area of land operated by quantile	-8.64***	-4.01***	-2.45***	-0.97	-0.56	-0.03	0.42	0.56	0.51
Dummy rent in land	0.80***	0.65***	0.40***	0.22*	0.15*	0.14*	0.15**	0.13**	0.12*
Log UG	0.08	0.07	0.09	0.08	0.11	0.14**	0.07	0.05	0.06
Log UG Sq	-0.03	-0.02	-0.02	-0.02	-0.02*	-0.02**	-0.02*	-0.01	-0.00
Log distance to road	0.18	0.18	0.40*	0.23	0.16	0.16	0.16	0.27***	0.26**
Lo distance to road sq	-0.02	-0.04	-0.11*	-0.06	-0.04	-0.05	-0.05	-0.08***	-0.07**
Log distance to market	0.79	1.42**	1.25***	1.51***	1.42***	1.35***	1.00***	0.88***	0.50**
Lo distance to market sq	-0.14	-0.23**	-0.20***	-0.25***	-0.24***	-0.22***	-0.17***	-0.15***	-0.09**
Dummy Constraint Oxygen availability to roots	-0.49***	-0.39**	-0.27**	-0.23**	-0.22***	-0.19**	-0.21***	-0.23***	-0.16***
Dummy Constraint Excess salts	0.76	0.20	0.03	0.01	0.13	0.06	0.21	0.16	-0.02
Pastoral farming system	-0.02	-1.55**	-1.38***	-1.76***	-2.03***	-2.08***	-1.94***	-1.46***	-1.45***
AEZ_TEXT==Tropic - cool / humid	0.51***	0.48**	0.43***	0.42***	0.42***	0.39***	0.37***	0.31***	0.35***
AEZ_TEXT==Tropic - cool / semiarid	-0.48**	0.20	0.49***	0.72***	0.81***	0.78***	0.69***	0.66***	0.65***
AEZ_TEXT==Tropic - warm / arid	0.54	0.90	0.82**	0.75**	0.71***	0.59***	0.48**	0.30*	0.34*
Constant	15.43***	8.44***	7.23***	5.35***	5.25***	4.78***	4.82***	5.17***	6.15***
Observations	1,976	1,976	1,976	1,976	1,976	1,976	1,976	1,976	1,976

*** p<0.01, ** p<0.05, * p<0.1

Source: Authors' estimate based on UGA 2010-2011, LSMS-ISA project

Table 8 - Summary table for land coefficient: Testing IR by individual countries

Y = Log Value of Gross Crop Income/ha

		Q10	Q20	Q30	Q40	Q50	Q60	Q70	Q80	Q90
MWI	Log land operated	11.22***	1.38**	-0.11	-1.44***	-2.02***	-2.52***	-3.00***	-3.49***	-4.30***
	log land operated sq	-5.37***	-1.02***	-0.39*	0.15	0.45***	0.68***	0.88***	1.15***	1.52***
NER	Log land operated	3.07***	0.76**	-0.27	-0.37*	-0.78***	-1.17***	-1.39***	-1.84***	-2.11***
	log land operated sq	-0.96***	-0.31***	-0.13*	-0.11*	0.03	0.12**	0.16***	0.26***	0.27***
NGA	Log land operated	-3.03***	-4.45***	-4.54***	-4.65***	-5.10***	-5.46***	-5.57***	-5.67***	-5.95***
	log land operated sq	1.01*	1.48***	1.59***	1.63***	1.84***	1.97***	2.01***	2.08***	2.15***
TZA	Log land operated	7.49***	7.86***	6.35***	2.62***	0.91***	-0.14	-0.78***	-1.27***	-2.11***
	log land operated sq	-2.17***	-2.25***	-1.80***	-0.79***	-0.38***	-0.14***	-0.01	0.09*	0.31***
UGA	Log land operated	8.31***	3.79***	1.09**	-0.39	-0.79***	-1.37***	-1.70***	-2.18***	-2.37***
	log land operated sq	-2.67***	-1.39***	-0.51***	-0.14	-0.04	0.11	0.18**	0.36***	0.42***
Pooled	Log land operated	1.42***	-0.62***	-1.12***	-1.50***	-1.74***	-1.94***	-2.15***	-2.39***	-2.67***
	log land operated sq	-0.67***	-0.03	0.10***	0.20***	0.26***	0.31***	0.37***	0.45***	0.54***

*** p<0.01, ** p<0.05, * p<0.1

Following controls included but not reported:

- Log mean area by quartile of land operated
- Dummy rent in land
- Log UG, and square
- Log distance to road
- Log distance to market
- Dummy Constraint Oxygen availability to roots
- Dummy Constraint Excess salts
- Pastoral farming system
- AEZ dummies

Table 9 - Summary table for switching land size levels (has)

	Q10	Q20	Q30	Q40	Q50	Q60	Q70	Q80	Q90	Max Operating area	Average size	SD
MWI	2.84	1.97	0.87	121.51	9.44	6.38	5.50	4.56	4.11	13.83	0.73	13.8
NER	4.95	3.41	0.35	0.19	-	130.97	77.00	34.41	49.77	38.25	5.21	38.3
NGA	4.48	4.50	4.17	4.16	4.00	4.00	4.00	3.91	3.99	7.35	0.8	7.35
TZA	5.62	5.74	5.84	5.25	3.31	0.61	0.00	-	30.06	65.47	2.33	65.5
UGA	4.74	3.91	2.91	0.25	0.00	-	-	20.65	16.80	13.72	1.45	13.7
Pooled	2.89	0.00	-	42.52	28.39	22.85	18.27	14.23	11.85			

Note: The sign – indicates that the switching level is outside the sample range.

Table 10 - Differences of country regression switching values from pooled regression

	Q10	Q20	Q30	Q40	Q50	Q60	Q70	Q80	Q90
MWI	-0.04	-0.92	-2.02	118.62	6.55	3.49	2.61	1.67	1.23
NER	2.06	0.52	-2.53	-2.70		128.09	74.11	31.53	46.88
NGA	1.60	1.61	1.28	1.28	1.11	1.11	1.11	1.02	1.10
TZA	2.73	2.85	2.95	2.36	0.43	-2.28	-2.89	1156.40	27.18
UGA	1.86	3.91	-267.52	-42.27	-28.39	483.52	94.15	6.42	4.95

Figure 2

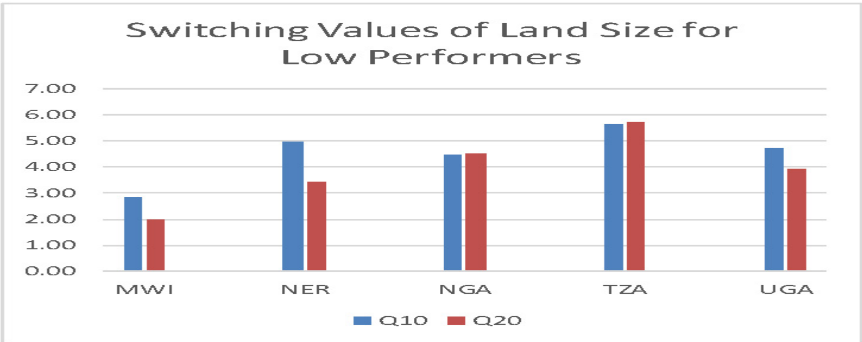


Figure 3

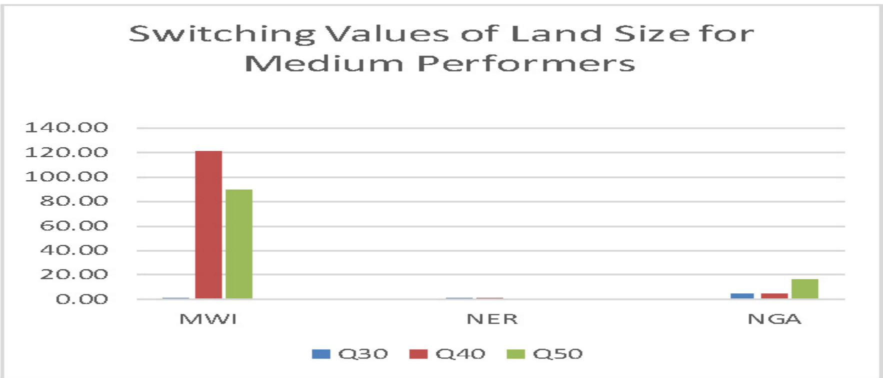


Figure 4

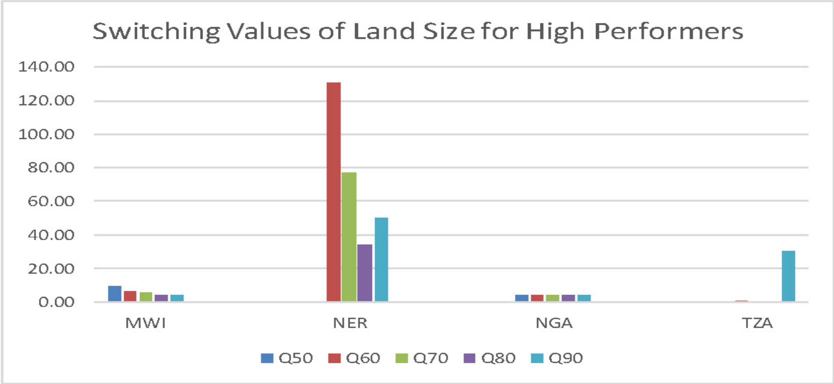


Figure 5

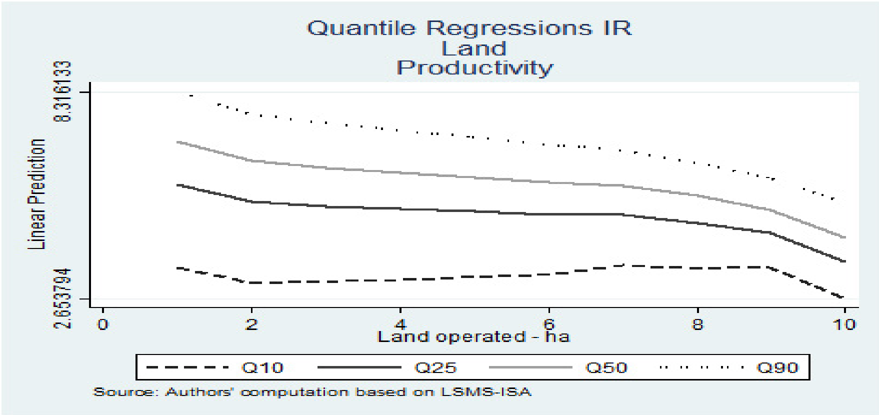
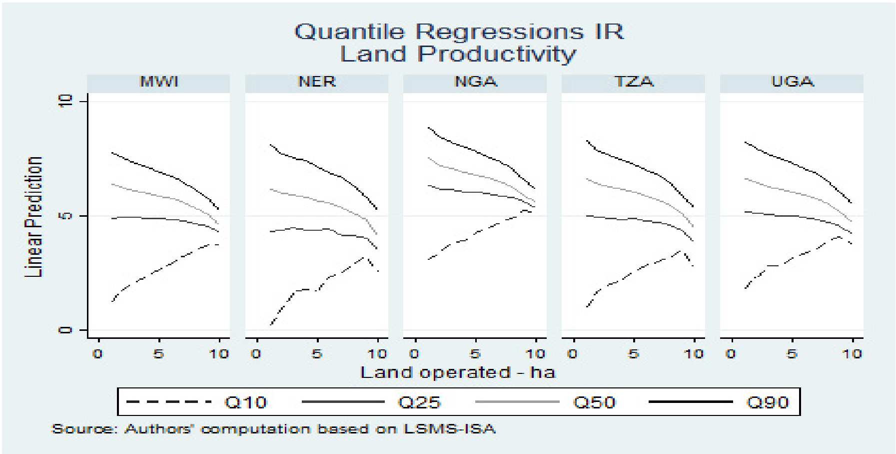


Figure 6



6. Conclusions

The inverse relationship (IR) between land productivity and land size has been the object of a voluminous literature , raising both objections and explanations. In this study, after a brief review of some of the main arguments, we have presented evidence from five recent farm surveys that in part rebut and in part confirm the existence of the relationship. The survey data used are from detailed household interviews and contain a number of accurate georeferenced information on farmers' location, distance from the markets, distance from the main road, and land quality. In order to test the IR hypothesis, we have used a specification entirely relying on exogenous variables and estimation procedures according to the quantile regression model.

The results of our analysis, show that for all countries, except Nigeria, and for the pooled sample, IR holds only for the top 6-7 quantiles of the productivity variable (the yield residual once we consider the effect of the exogenous variables), while for the bottom quantiles a positive relationship tends to hold. These results appear to hold across different specifications and both for the pooled sample and the individual countries. They suggest that at the two ends of the yield residual distribution, farmers' performance is influenced by land size in a markedly different way. As already noted, although in a different context by Evenson and Mwabu (1998), this may be due to the fact that individual management factors do matter and that in the two areas of the distribution, different complementary and substitute relations may exist between land sizes and unobserved human capital variables, such as farmers' abilities, skills and experience. In turn, these results are consistent with a revised version of Savastano and Scandizzo (2009) option model, where management quality is supposed to be positively correlated with farm size.

Our results also suggest the existence of a U shaped relationship between productivity and farm size. This relationship implies a turning point for the lower quantiles of the yield residual distribution at which a positive relationship becomes negative and one for the upper quantiles where IR becomes positive. Both turning points are for small to medium farm sizes, but the ones of the lower quantiles tend to be smaller than those for the upper quantiles. Thus, while there is some significant negative relationship between productivity and operating size for low performers over a relevant range of farm sizes, higher performers tend to display IR only over a range from small to medium farm sizes.

In sum, our results confirm that IR may be an ubiquitous relationship, as found in much of the literature, but indicate that its form, shape and importance may significantly differ across the spectrum of farm productivity performance. At the low end of the yield distribution, IR appears to prevail, once a minimum threshold of farm size is reached, while at the higher hand, IR only appears to be mainly a characteristic of farmers with operating sizes not exceeding medium size thresholds. The literature on transaction costs and the role of the firm suggests that these differences will require a deeper analysis of some of the critical factors determining the performance of the farm as a "productivity agent" and of the role played by management and capabilities in shaping farmers' choices.

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THEMATIC SET

D24

STATISTICS ON WATER RESOURCES AND WATER USE EFFICIENCY

Session Organizer
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ABSTRACT

Today's water-related challenges depend on timely, detailed water data and information. Quantifying water applied to agricultural areas for irrigation and for watering livestock by use and source is a long-standing challenge. Raising information-gathering capacity and improving data quality on agricultural water management will contribute to improving water-related policy making affecting cost, water quality, profitability and environmental effects. This session will present practical approaches or techniques to surveys that contribute to improvements in water statistics. It will provide examples of how technological advances can be used to facilitate the job of survey data producers and enhance the experience of data users.

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D24

Livestock water accessibility index and its linkage to household welfare

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ABSTRACT

In this paper, we introduce the concept of Water Index for Livestock. In fact, water accessibility for livestock is as much important as drinking water accessibility in countries like Niger, where land is unsuitable for crop production, and where 29% of thepopulation relies on animal breeding activities. Although some works have looked at the issue of human access to drinking water, less attention has been paid to the issue of water accessibility for animals. There is a need to explore the latter as water requirements for human being are not the same than for livestock by far, especially in terms of quantity and water supply provision. Better access to water for animals is likely to improve the welfare of population especially in rural area because improving animal performance in farming and milk production. This paper provides an assessment tool of the water accessibility for livestock in Niger and investigates the relationship between livestock accessibility to water and agricultural productivity, poverty, and ultimately food security. Our multidimensional index includes manywater related dimensions and is a mean to evaluate livestock and crop security which in turn might have an impact on agricultural households.

We used available agricultural survey data in Niger and define a multidimensional index integrating all the relevant dimension through an objective weighting scheme by applying a general covariance structure model which includes a Confirmatory Factor Analysis, and therefore deals with measurement issues.

The results show heterogeneity in livestock accessibility to water across the country and indicate significant and positive relationships between this accessibility index and household welfare indicators.

Keywords: Water, Multidimensional index, Livestock, Natural resource, Welfare, Niger

PAPER

1. Introduction

In a country where a large share of the population, especially the poor, depends on livestock, it makes sense to link livestock conditions to household livelihood conditions. In the context of aridity and climate change, water needs of domestic animals become harder to satisfy. This will not be without consequences for households.This paper aims to investigate the linkages between animal water access and household welfare, proxied through inverse poverty perception measure. We will develop a suitable framework for the assessment of livestock water accessibility and household welfare nexus. Due to the multidimensionality of the concept of water accessibility, we use appropriate approach to include all the relevant dimensions and take into account measurement dimensions. As for the human water accessibility index, water accessibility for animal is difficult to measure because of the huge number of aspects that might enter into account. From the study we can learn how water access can be linked to household welfare. The water index is a composite index that integrates many dimensions related to the difficulty of cattle to find water.Similarly, we adopt the same multidimensionality concept to define the measure of welfare and food insecurity.

A predicted increase in demand for livestock products in developing countries might generate new market opportunities and boost income for poor households(Delgado et al. 1999). In parallel to this projected demand side effect, improving animal water availability can contribute to raise animal productivity, livestock production, and ultimately household welfare.

Animal water accessibility need be analyzed due to this water requirement resulting from the future demand and from the high contribution of livestock in the livelihood of individuals, especially the poor and those living in rural areas.

2. Method and data

The study is based on the 2011 National survey on household life conditions and agriculture in Niger. This survey covers around 4000 households. The data collection was done in two steps with a first round during the cultivation and the preparation of cultivation areas from mid-July to mid-September 2011, and the second round during the harvesting period in November and December 2011. The survey was based on three questionnaires: the household questionnaire that collected information on socioeconomic characteristics of households, the agricultural questionnaire to get data on farming activities, and the community questionnaire that provided information on the available infrastructures at district level.

Our methodology is described below.

$$WA_S = \gamma\, WA + \varepsilon$$

$$F_S = \delta\, F + \upsilon$$

$$W_S = \rho\, W + \omega$$

$$W = \varphi\,(WA, F, X) + \mu$$

$$F = \psi(H) + \varsigma$$

Where *WA* represents the multidimensional and latent Livestock Water Accessibility index, WA_S the observed water accessibility indicators. Wis the household welfare variable, measured as a latent variable derived by using household own perception of poverty W_S. *F* is latent variable measuring the food insecurity prevailing at the household level.X and F represent household socioeconomic and environmental characteristics. Household welfare depends on their food security level, their health stock as well as on their livestock water accessibility status. The parameters y,*∂* and *p* are the loading factors that link the latent variable to the observed variables.

3. Results and discussions

The results are presented in the table below.A complete description of the variables is provided in the appendix. The lower part presents the estimates of the measurement model for all the latent variables. All the manifest variables are positively correlated with the associated latent variables. The upper partpresents the structural model. It shows the determinants of householdwelfare and includes the specific relationship between the animal water accessibility index and the welfare variable. The results show that animal water accessibilityimpacts positively and significantly household welfare.Animal water accessibility is essential for livestock production and might impact household welfare through improving livestock productivity, provision of goods and service, and income diversification.
We found that household welfare perception household is positively correlated to food insecurity. The latter is not affected by animal water accessibility at the household level. Household headed by women tend to have the worst appreciation of their welfare and tend to be more food insecure. Household with more elders have a lower welfare level.
Promoting development programs that increase directly or indirectly animal water accessibility can be make important contribution to poverty reduction given the enormous potential of livestock to contribute to livestock.

4 Conclusion

Using household level data from Niger, the analysis show a positive effect of livestock water accessibility on household welfare but not food security. In fact, animals are not self-consumed in general, even in case of severe threat of food insecurity. Animal water accessibility might improve animal health and therefore their labor productivity or increase available animal products. These often sold at the local market place to ensure substantial revenue for household.

Table 1 – Modeling welfare, food insecurity and animal water accessibility

VARIABLES	WELFARE	FOOD INSECURITY
STRUCTURAL MODEL		
FOOD INSECURITY	-0.125***	-
	(0.0159)	
RURAL	-0.0579	0.0237
	(0.0501)	(0.0784)
H_HEALTH	0.0181*	0.0268*
	(0.00926)	(0.0152)
HEAD LITERACY	0.0980***	-0.0661
	(0.0291)	(0.0478)
HEAD SEX	-0.176***	0.204***
	(0.0445)	(0.0728)
AGE AVERAGE	-0.00383***	-0.00359
	(0.00144)	(0.00238)
LABOR	-0.00371	0.00874
	(0.00510)	(0.00837)
PHONE VIL.	-0.0703	-0.210***
	(0.0486)	(0.0800)
AGRI EXTENSION VIL.	0.0371	-0.0102
	(0.0477)	(0.0786)
LAND	0.00374	0.00355
	(0.00668)	(0.0109)
WATER	1.111**	-0.801
	(0.479)	(0.573)
MEASUREMENT MODEL		
	WATER	
AVG TIME WATER / RAIN.	1	(0)
AVG TIME WATER / DRY	2.344***	(0.857)
FEED MARKET FOR CATTLE	3.268***	(1.103)
WATER TAP / RAIN	1.088***	(0.360)
WATER TAP / DRY	1.089***	(0.359)
WATER AMOUNT	3.966***	(1.379)
	WELFARE	
D.POVERTY PERCEPTION	1	(0)
D.POVERTY PERCEP NEIG	0.720***	(0.0632)
D.POV PERCEP NIAMEY	0.421***	(0.0557)
D.POVERTY PERCEP RICH	0.810***	(0.0609)
	FOOD INSECURITY	
EAT LESSEXP FOOD	1	(0)
FOOD QUANTITY REDUCTION	1.176***	(0.0329)
REDUCE # MEALS REDUCTION	0.813***	(0.0258)
FOOD REDUCT. ADULT TO CHILD	0.570***	(0.0202)

D.: decreasing perception of poverty e.g. non-poor perception

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D24

Measuring Water-use in Response to Climate Change: An Analysis of the Efficiency of Italian Crop Production System

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ABSTRACT

Official meteo-climatic statistics show the variability of weather conditions. Their effects on socio-economic and natural environments should be analyzed in multi-dimensional studies. Among sectors, agriculture is expected to be the most sensitive as well as water resources availability. The aim of our analysis is to measure the performance of Italian regions in crop production by estimating both production technology - including a measure of irrigation water used as input - output elasticities and returns to scale and productive efficiency or technical efficiency where rainfalls and temperatures are proxies of CC conditions in the period 2000-2010 at Italian regional level, using the stochastic frontier approach (SFA). The scarce official statistics on irrigation water in agriculture make our analysis challenging. Our results point out the need i) to strengthen official statistics on irrigation water to improve the analysis on inputs of farmer's crop production in Italy; ii) to update meteo-climatic and hydrological measures according to the official international guidelines.

Keywords: Climate Change, Crop Harvested, Irrigation Water, Stochastic Frontier Efficiency.

PAPER

1. Introduction

As climate is an essential component of the natural ecosystem, the exasperation of weather conditions can have some effects on socio-economic and natural environments. Several sectors can be affected by climate change (CC) and climate variability but water resources and agriculture are expected to be the most sensitive. Both the IPCC (2014) and the OECD (2014) confirm that the increase of greenhouse gases (GHGs) will cause positive changes modifying the speed of crop growth and negative changes in temperatures and rainfalls. Hence, CC will alter the water cycle, changing temporal and spatial redistribution of water resources, such as the frequency of occurrence of droughts and floods, which are expected increasing in many areas. These changes in rainfall and temperature patterns may affect crop water requirements and more generally crop production system since water is the most critical input for sustainable agricultural development – as irrigated areas will increase in forthcoming years. CC can affect the amount of water available (supply-side) and of crop water requirements (demand-side) due to changes in rainfall patterns. Whether understanding of how CC can influence local water availability is widely analyzed, CC effects on crop production function considering water resources used for irrigation as an input are not well deepened. The majority of studies has focused on climate projections investigating the impacts of CC on global agricultural water requirements (Döll, 2002; Zhang and Cai, 2013); on water resources and water availability for Africa (Kusangaya et al. 2014) for China (Tao et al., 2003); on groundwater recharge rates (Döll et al., 2002; Taylor et al., 2012). A brief review of studies mainly based on the Ricardian method to evaluate the impact of CC on rural areas is described in Dasgupta et al. (2014). Other studies have investigated the economic effects of CC on agricultural sector (Giupponi and Shechter, 2003) based on long-term analyses at the aggregate level, i.e. continental or national scales (Xiong et al., 2010). In contrast, few studies have performed short-term analyses at a sub-regional level. In the case of agriculture, models based on discrete stochastic programming model have been used to forecast the effects of changes in water availability on agriculture due to CC (Dono and Mazzapicchio, 2010). A three-stage discrete stochastic programming model has been used to represent the choice process of the farmer based on the expectation of possible scenarios of rainfalls and higher minimum temperatures for a specific irrigated area of Italy in the next future.

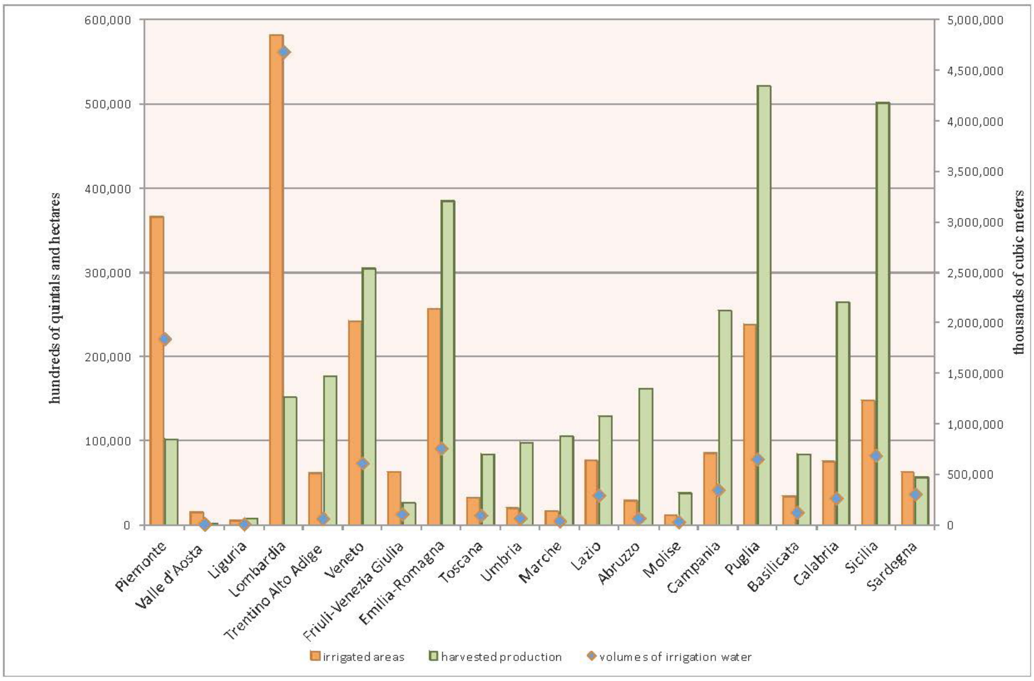
These variables affect the availability of water for agriculture and the water requirements of irrigated crops (Dono et al., 2011). Our study is a critical contribution within the literature on the impacts of CC on agriculture. The chosen model considers a crop production function for Italy where water resources are considered as inputs. By using an empirical analysis such as the Stochastic Frontier Approach (SFA), the technical efficiency of crop production and the inputs' efficiency have been estimated at local scale while meteo-climatic statistics show that CC has been taking place in these last decades. The inadequate official statistics on water resources for irrigation in agriculture make our analysis challenging. Comparability issues and data-lacking both at spatial and temporal scale forces us: i) to consider only the period 2000 2010; ii) to construct an ad hoc variable to measure the volume of irrigation water to complete our panel data and iii) to provide estimates at regional level instead of at farmer's level. By applying the SFA methodology, we can as well estimate efficiency at regional scale in the Italian crop production system. Empirical estimate results can be useful tools for policy makers in defining the optimal climate mitigation and adaptation policy actions in agriculture. In addition, our results recommend the urgency of increasing collection of data and official statistics production at local level on irrigation water volume and on meteo-climatic and hydrological measures, issued by Istat. Therefore, multidimension phenomenon datasets fitting for the purpose of CC effects could be improved by either integrating already existing datasets from different sources (such as administrative archives, official statistical surveys, trade associations, land reclamation authority) or developing ad hoc sections within existing surveys more respondent to the economic needs of measuring the efficiency of 3 farmers and their capability to adapt to CC. The paper is organized as follows. In Section 2 we briefly analyze data used for the crop production function in the SFA model. In section 3, we present our empirical model and the main results. Finally, we summarize the findings of our research.

2. Italian crop production and CC related data

Agricultural sector is one of the most susceptible as changes in meteorological conditions heavily affects crop production trends, yield variability and reduction of areas suitable to be cultivated, specifically in the Mediterranean countries. Many studies have evaluated the effects of CC on agriculture in Europe taking into account important regional differences (Reidsma, et al., 2007, Olesen and Bindi, 2002; Iglesias et al., 2009). CC is expected to intensify problems of water scarcity and irrigation requirements in all the Mediterranean regions and thus in Italy (IPCC, 2014; Goubanova and Li, 2006; and Rodriguez Diaz et al., 2007). The geographical position of Italy at the centre of the Mediterranean basin and its historical high agricultural vocation make Italy vulnerable to the negative consequences of CC. Italy is the second largest producer of "*fruit and vegetable*" in Europe after Spain offering a wide range of high quality and typical Mediterranean products, officially recognized as IGP and DOP. Weather conditions could lead to inefficiency in the agricultural sector, even because it includes many small firms with a lower capability to adapt to a new climatic situation. In the last twenty years, changes in weather conditions occurred in Italy and a rise of water used for irrigation especially in the South, traditionally suited to agriculture activities, have contributed to threaten crops and reduce areas suitable for cultivation.

To evaluate climate-related impacts on the agricultural sector across Italian regions, long run time series of data should be necessary. Forced by data availability, the focus of our analysis is mainly on the Italian regions' efficiency in the period 2000 to 2010, analyzing the short-term effects of CC on Italian agriculture. To estimate CC effects on the efficiency of agricultural yields at Italian regional level (NUTS2), a dataset of CC and agriculture sector at regional level has been collected by using official statistics, mainly produced by Istat. All variables are measured in physical units.

Figure 1. - Volumes of irrigation water, irrigated areas, harvested production Italian Regions, Year 2010 (thousands of m3, hectares, hundreds of quintals)



These statistics regard both inputs and output of the production function and inefficiency determinants as proxies of CC. A panel dataset has been collected on the following variables: i) agricultural harvested crops production and production areas (source Istat survey of Estimate of Crop, Flower and Plot Plant Production and Area); ii) irrigated areas, seeds and fertilizer used, days of work of farm employees (source Istat Survey on Agricultural Holding Structure and Output, V and VI Agricultural Census, Survey on seeds and Survey on fertilizer); finally iii) temperatures and rainfall (source Meteo-Climatic and Hydrological Istat Survey). To develop our analysis, two aspects have to be considered. Firstly, although meteo-climatic and hydrological official statistics have been produced until 2014, meteo-climatic time series have been updated only for Italian regional capitals. This reason forces us to base our analysis on 2000-2010 time series containing statistics suitably spatialized. Secondly, because of the lack of data on volumes of irrigation water used in agricultural crops, we constructed a proxy. In the SFA model, we should have included the variable "*volumes of irrigation water*" jointly with "*irrigated areas*" but official statistics on volumes of irrigation water used by crop in Italian agriculture was provided, once in 2010, in occasion of Istat VI Agricultural Census. Figure 1 compares *irrigated areas* and *total harvested production with volumes of irrigation water* and underlines the multifaceted situation for each Italian region. What is the most amazing consideration is that Lombardy uses about 42.26% of the total of irrigation water to obtain only 4.39% of the harvested production with respect to the total 4 production. While, in the opposite case, we find Emilia-Romagna and Puglia, where respectively they use only 6.84% and 5.90% of total volume of irrigation water to obtain a harvested production of 11.17% and 15.13% with respect to the total harvested crops. Quite certainly, this situation could be the consequence of meteo-climatic variability, different typologies of crops cultivated, irrigation technology used, and environmental conditions in each region.

Starting from the Census, we constructed *ad hoc coefficients* for 2010 by dividing volumes of irrigation water with respect to irrigated areas (K_{ij}=*irrig_waterij/irrig_areaij*) by each crop (i) and Italian region (j). To fill our dataset, we reconstructed the variable "*volumes of irrigation water*" for each year considered in our analysis, by multiplying the 2010 Kij coefficients for irrigated areas by crop and region.

3. Empirical model and main results

By applying the SFA proposed by Battese and Coelli (1995) to our sample, the performance of Italian regions in crop yields is evaluated by estimating production technology and productive efficiency. The production technology allows the study of production inputs (labour and physical capitals), output elasticities and returns to scale, while the productive efficiency, or technical efficiency, allows the analysis of getting the maximal output from available resources, given the level of inputs. This efficiency can be directly affected by observable exogenous variables such as CC conditions (rainfalls and temperatures), which reflect the heterogeneity of Italian regions in the agricultural sector. Two are the advantages of using the SFA methodology. Firstly, production inputs and efficiency factors are estimated simultaneously using two distinct functions. Secondly, distances from the efficient frontier between those due to systematic components and those due to noise are disentangled. The main idea is that the maximum output frontier for a given input set is assumed to be stochastic in order to capture exogenous shocks beyond the control of individuals.

The parametric estimation of the SFA is based on the standard Cobb-Douglas (CD) production function, whose practical advantage - with respect to more flexible forms such as the translog function - is the limited number of variables required. Expressing output and inputs in natural log values, the CD function can be written as:

$$(1)\qquad \begin{aligned} ln(Y)_{it} &= \beta_0 + \beta_1 ln(Kseed)_{it} + \beta_2 ln(Kfert)_{it} + \beta_3 ln(Kvol\_irr)_{it} + \beta_4 ln(Kirrig\_area)_{it} \\ &+ \beta_5 ln(Citrus\_area) + \beta_6 ln(Fruit\_area) + \beta_7 ln(Vegetable\_area) + \beta_8 ln(L)_i + v_{it} - u_{it} \end{aligned}$$

where Y is the agricultural yield measured by the ratio between harvested production (in kilos) and cultivated areas (in hectare), physical capitals are measured by Kseed which represents the amount of seeds used for the cultivations, *Kfert* which stands for the tons of fertilizers used in agriculture, Kvol_irr which is the irrigation water volumes, Kirrig_area which means the hectares of irrigated areas, Citrus_area which represents citrus plant cultivated areas (in hectare), Fruit_area which is fresh fruits cultivated areas (in hectare), Vegetable_area which means vegetables cultivated areas (in hectare), and L is labour force measured by the days of work in farms. While the technical inefficiency model is characterized by several observable explanatory variables as follows:

$$(2)\qquad \begin{aligned} u_{it} &= \gamma_0 + \gamma_1 Rainfall_{it} + \gamma_2 Temp\_min_{it} + \gamma_3 d\_North-west_{it} + \gamma_4 d\_North-east_{it} + \\ &+ \gamma_5 d\_Centre_{it} + \gamma_6 d\_South_{it} + \varepsilon_{it} \end{aligned}$$

where Rainfall is measured by the deviation of annual total rainfall average from the CLINO 1971-2000 rainfall average value and Temp_min is defined as the deviation of annual minimum temperature average from the CLINO 1971-2000 minimum temperature average value. The dummy macro-areas are as usual: North-west, North-east, Centre, South while Islands is missing due to collinearity.

The stochastic frontier estimation allows us to measure the value of productive efficiency of harvested production in each Italian region. The technical inefficiency of the i-th region in the t-th period is given by:

$$(3) \qquad TE_{it} = e^{(-u_{it})} = e^{(-z_{ti}\delta - \varepsilon_{ti})}$$

The technical inefficiency values will oscillate between 0 and 1, being the latter the most favourable case. If TEit<-1 then the observable output is less than the maximum feasible output, meaning that the statistical unit is not efficient.

In Table 1, we present both the CD stochastic production function estimated coefficients and the technical inefficiency equation estimated coefficients. The coefficients of the CD function can be interpreted as the partial output elasticities, which show the percentage change of output in response to one percent change in an input. Not all the estimated output elasticities are positive.

Physical capitals measured by fertilizers used (Kfert), seeds used (*Kseed*), and areas cultivated with citrus plant (*Citrus_area*) and with fresh fruit (*Fruit_area*) show positive and significant elasticities, indicating that these specific capital inputs are productive inputs for increasing agricultural annual yields (Tasnim et al., 2015). The estimated values of the coefficients of irrigated areas (*Kirrig_area*) and vegetable cultivated areas (*vegetable_area*) are negative and significant. There is no scope of increasing production by further increase of those inputs. The input labour force (L) shows a positive coefficient and significant in the annual Italian regional agricultural yields differently from Tasnim et al. (2015). The elasticity of irrigation water volume (*Kvol_irr*) is positive and significant showing that an increase in the demand of water for irrigation has positive effects on agricultural yields. Moreover, since output elasticities for irrigation water volumes and for irrigated areas show the greatest values, the empirical findings confirm that water for irrigation remain the most important factor in the crop production function. The returns to scale (RTS), calculated as the sum of the output elasticities, measure the percentage change of output due to a one percent increase in all inputs. The RTS coefficient is smaller than unity, meaning that the Italian regional crop production presents decreasing returns to scale. Considering the inefficiency model, rainfall variable shows a negative and significance sign, while minimum temperature variable coefficient is positive but not significant.

Table 1. – Estimates of the Cobb-Douglas production function and of the inefficiency model

Stochastic production frontier model			Technical inefficiency model		
	coef	**p-value**		**coef**	**p-value**
Kseed	0.028	0.211	*Rainfall*	-0.004***	0.001
Kfert	0.297***	0.000	*Temp_min*	0.082	0.169
Kvol_irr	1.035***	0.000	*d_South*	-1.876***	0.000
Kirrig_area	-1.137***	0.000	*d_Centre*	-1.789***	0.000
Citrus_area	0.520***	0.000	*d_North-east*	-7.028***	0.000
Fruit_area	0.308***	0.000	*d_North-west*	-1.759***	0.000
Vegetable_area	-0.602***	0.000	constant	2.767***	0.000
L	0.182***	0.001			
constant	-11.918***	0.000	**Returns to scale**	0.632	
sigma_v	-2.535***	0.000	**TE_{it} Scores:**		
sigma_u	-4.291***	0.000	Mean	0.471	
lambda	2.406	0.000	Standard Deviation	0.287	
N. of obs.	200		Minimum	0.027	
Log-Likelihood	-7.228		Maximum	0.986	

note: *** p<0.01, ** p<0.05, * p<0.1.

The more is the deviation of the annual total rainfall average from the 1971-2000 rainfall average value the more efficient is the crop yields for Italian regions. Therefore, Italian regions in term of agricultural yields become more inefficient when the annual rainfall value diminishes with respect to the 1971-2000 rainfall average value. This is in line with the IPCC (2014) analysis where in the Mediterranean area the annual rainfall average will tend to decrease in the next future.

Instead, the more is the deviation of the annual minimum temperature average from the 1971-2000 minimum temperature average value the more is the inefficiency of Italian regions in crop yields, even if this effect is not statistically relevant. Italian regions' agricultural crop yields decrease due to more inefficiency caused by an increase of annual minimum temperature. This negative effect, foreseen and analysed even by the IPCC (2014), implies that an increase in temperature will influence negatively crop yields in the Mediterranean basin. The negative signs of the estimated coefficients of geographical dummies indicate a positive effect on efficiency, meaning that regions belonging to one of those macro-areas – South, Centre, North-east and North-west of Italy – with respect to Islands are more efficient. The summary statistics of estimated technical efficiency (TE) scores are even reported in Table 1. The TE scores show a low mean value meaning that Italian regions in mean are quite distant from the efficient frontier.

In Table 2, by splitting our sample on Italian macro-areas, the analysis of variance (ANOVA) is proposed in order to test for differences in the means of technical inefficiency. Results confirm that differences in the Italian macro-area means of technical inefficiency are significant. Thus, regions belonging to North-east like Trentino-Alto Adige, Friuli-Venezia-Giulia and Veneto are the more efficient where the mean is 0.98. On the opposite case, Sardinia and Sicily, belonging to Islands macro-area, are the worst efficiency regions in terms of agricultural yields and they are the weaker regions in case of changing weather conditions.

Table 2. – Anova of TE by Italian macro-areas

Region Code	mean
North-east	0.98
South	0.42
Centre	0.37
North west	0.34
Islands	0.07
F	488.51
Prob > F	0.00

4. Conclusions

In the 2001-2014 period, Italy recorded a special "warming" because the annual mean temperature (equal to 15.1°C) has increased of about 1°C with respect to CLINO 1971-2000 temperature. In the same period, Italy recorded a change in rainfall pattern, because the total annual mean precipitation has been equal to 740.8mm, a reduction of about 1.1% with respect to the same CLINO period. Such weather changes has had a negative influence on agriculture production that is the most susceptible sector to changing weather conditions and have contributed to rise volumes of water used for irrigation, especially in the South. In our empirical and short-term effects of CC analysis, economic impacts of CC on Italian regional agricultural production and technical efficiency have been analyzed for the period 2000-2010. Among inputs, irrigation water volume, the most important factor in the crop production function, shows a positive and significant elasticity. Therefore, an increase in the demand of water for irrigation has certainly positive effects on agricultural crop yields. Moreover, the inefficiency model shows that when rainfall declines and annual minimum temperature increases, Italian regions become more inefficient. Results confirm that differences in the Italian macro-area means of technical inefficiency are significant. Regions belonging to North-east are the more efficient while Sardinia and Sicily, belonging to Islands macro-area, are the worst efficient regions in terms of agricultural yields. They could be the weaker and more vulnerable regions in facing changes in meteo-climatic and hydrological conditions. As CC affects many dimensions, official statistics on different thematic issues need to be integrated and harmonized to provide a solid basis for empirical analyses on CC impacts on agriculture. Strengthening the production of official statistics at adequate temporal and spatial scale on irrigation water to ameliorate the analysis on water resources required by farmers is needed.

Updating meteo-climatic and hydrological variables according to the latest official international guidelines to develop long-run CC analyses. Aiming the target to develop CC Related Statistics (CCRS) and new indicators following the 2014 UN Conference of European Statisticians Recommendations[1] is a necessity coming from international institutions. Therefore, multidimension phenomenon datasets fitting for the purpose of CC effects could be improved by either integrating already existing datasets from different sources, such as administrative archives, official statistical surveys, trade associations, land reclamation authority, or developing ad hoc sections within existing survey questionnaires more respondent to the economic needs of measuring the efficiency of farmers and their capability to adapt to CC. In a context characterized by uncertainty inherent in climate variability, the role of policy is crucial in managing water resources across space and time to prevent agricultural yield fluctuations causing welfare loss.

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D24

Outliers identification and handling: an advanced econometric approach for practical data applications

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ABSTRACT

Before implementing any statistical analysis it is crucial to check whether outliers are present in the dataset because their existence imply a distorted analysis that leads to unreliable results and incorrect policy decisions. To overcome that, this paper proposes and advanced econometric approach based on a linear regression framework that is capable of identifying and handling vertical outliers under three alternative scenarios. This methodology, that can be generalized to any other dataset, is applied to a real irrigation dataset on 15 countries sorted out in two groups in order to compute reliable summary statistics on unit irrigation costs that help governments, international organizations and water management in implementing cost efficient water investment decisions as well as knowing how much to pay on average, at maximum, and at minimum, for a given irrigation investment project type located in a given country. Once vertical outliers are handled, two main conclusions are found. First, unit irrigation costs tend on average to be lower for Middle-East countries rather than Afro-Arab countries. Second, is not shown that large scale irrigation investment projects are on average more expansive than small scale irrigation investment projects since it depends on both the country and scenario chosen. Although, the first result is in line with the reality that gives to Afro-Arab countries higher average unit irrigation costs, the second result confirmed at pooled and country level has not been sufficiently addressed by the literature and opens to new different water policy recommendations.

Keywords: Outliers, Unit Irrigation Costs, Method of Moments (MM) Estimator

PAPER

1. Introduction

Outliers are atypical observations, present in virtually every dataset, that can strongly distort any statistical analysis producing unreliable results that lead to incorrect policy decisions. This is especially true, as the pioneer Edgeworth (1887) work has shown, when Ordinary Least Squares (OLS) estimator is used as a tool for outliers identification. This happens for two main reasons. First, being this estimator an equal weighted sum of dependent variable observations, it treats with an equal weight observations that are potential outliers from observations that are not potential outliers while discrimination should be needed instead. Second, being also the OLS estimator based on a minimization of squared residuals that means practically minimizing their variance, when outliers are present the variance of the residuals increases considerably and the OLS estimator is largely influenced as well. It implies distorted estimates as well, unreliable results and incorrect policy decisions. These reasons imply that the OLS estimator does not represent a good tool, in reality is the worst, to identify outliers unless a prior different estimator or analysis concludes that these atypical observations are not present. In fact, something which is not typical cannot be identified using an estimation tool that is typical and constructed under a series of regularity conditions. Then, as pointed out by Huber (1964), Rousseeuw and Yohai (1987), Yohai (1987), Maronna (2006) an other outlier identifying tool is needed.

Furthermore, outliers are mainly of four types according their influence on the OLS estimator. Vertical outliers are those observations that are outlying respect to the space spanned by the dependent variable but not outlying in the space spanned by the regressors. Horizontal outliers are those observations that are outlying respect to the space spanned by the regressors but not outlying in the space spanned by the dependent variable. Good leverage points are observations that are outlying in the space spanned by the regressors but that are located close to the regression line. Bad leverage points are observations that are both outlying in the space of explanatory variables and located far from the true regression line. As mentioned, these types of outliers influence OLS estimates in different ways. Vertical outliers affects OLS estimates and in particular they affects the estimated regression intercept. Horizontal outliers affects OLS estimates and especially they affects the slope coefficients of the regression. Good leverage points does not affect the OLS estimates because they are points located closely to the regression line but it affects statistical inference since they do inflate the estimated standard errors. Bad leverage points affects significantly the OLS estimates of both the intercept and slopes coefficients.

In addition, outliers do not come alone especially in survey data but are almost always accompanied by missing values, large number of variables, sampling weights and measurement errors. Handling each of these data features requires further analysis and study.

This paper outperforms all these challenges proposing an advanced econometric approach for outliers identification based on regression framework estimated using Method of Moments (MM) rather than OLS in a three scenarios context. This methodology, that can be generalized to any other dataset, is applied to a real irrigation dataset in order to compute reliable unit irrigation costs that can help governments and international organization in formulating specific territorial policy recommendation and advices, to enhance the water population conditions as well as suggesting the right price per hectare that an international investor should efficiently pay for an given irrigation investment project in a given region or country.

The rest of the paper is organized as follows. The next section presents the dataset used as well as some basic variables' assumptions, Section (3) describes the methodology used to identify and handling outliers, Section (4) applies the methodology described before computing reliable summary statistics on unit irrigation costs at pooled, region and country level as well as by irrigation type level in a three scenarios context, Section (5) concludes summing up the main paper findings and finally Section (6) gives possible further extensions.

2. The dataset

The dataset is collected by aggregating specific country irrigation portfolios spreadsheets. The aggregated dataset consists of two main variables:

• Total = is the total irrigation investment cost (expressed in unit of United States Dollars (USD));

• Hectares = is the surface (expressed in hectares) covered by each irrigation investment project.

Regarding the total cost variable, since each investment project can be devoted to more than one types of irrigation project, indeed, large scale (LS) projects, small scale (SS) projects and rehabilitation and modernization (RM) projects, it has been calculated exactly the proportion of the total cost devoted to each type or irrigation project. It has been assumed the total cost variable is free from measurement errors. Regarding the hectare variable, it is known just the entire irrigation investment surface while the surface devoted to specific type of irrigation projects remains unknown. Further, it has been assumed both that the hectare variable is properly measured and free from outliers. It implies that, just vertical outliers are present in the real dataset and just statistics to identify vertical outliers are needed. Finally, the total number of countries involved are 15 sorted out in Middle-East countries and Afro-Arab countries while the total number of irrigation investment projects here considered are 225.

Given these assumptions about variables, the main question of interest is how calculate reliable summary statistics on unit irrigation costs at pooled, region and country level and by type of irrigation project. Because having reliable unit irrigation costs it is crucial to implement correct water and agriculture policies at these territorial levels and for these investments types.

3. The cost analysis: the methodology used

Given the variables' assumptions, the summary statistics on unit irrigation costs have been worked out after identifying outliers respect to the cost variable. Once vertical outliers has been identified, the mean, the standard deviation, the maximum value and the minimum value of unit irrigation costs are computed at pooled, region and country level and by type or irrigation project in a three scenarios context.

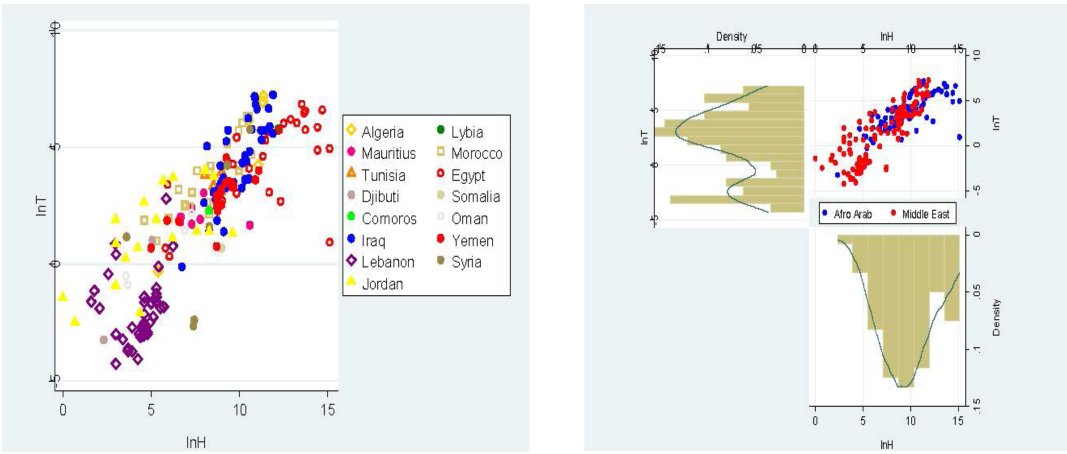
As mentioned, the outliers identification has been carried out using a linear regression of the log of total cost on the log of hectares covered and on the log of squared hectares estimated by MM rather than OLS. Then, the functional regression form used to identify outliers is:

$$ln\left(TC_{i,h,k}\right) = b_0 + b_1\ ln\left(H_{i,h,k}\right) + b_2\left[ln\left(H_{i,h,k}\right)\right]^2 + \varepsilon_{i,h,k} \quad forall \quad i = \{1,2,3,\ldots,225\}, \quad h = \{LS,SS,RM,ALL\}, \quad k = \{pooled, region, country\} \qquad (1)$$

where, $\ln(TC_{i,h,k})$ denotes the log of total irrigation investment cost for observation *i*, irrigation type *h* and territorial aggregation *k*, $\ln(H_{i,h,k})$ denotes the log of hectares covered by the irrigation investment project for observation *i*, irrigation investment type *h* and territorial aggregation *k*, $[\ln(H_{i,h,k})]^2$ denotes the squared of logs along the hectares covered by the irrigation investment for observation i, irrigation investment type h and territorial aggregation k, $E_{i,h,k}$ denotes the regression error term for observation *i*, irrigation investment type *h* and territorial aggregation *k* and finally b_0 is a constant term while b_1 and b_2 are the elasticities.

This is a log-log functional regression form with a quadratic regressor term. This functional form has been tested severally and confirmed to be optimal for the starting dataset at left of Figure (1) at different territorial levels for the following reasons. Regarding the log-log form, first, when logs of both dependent and independent variable are taken the distributions of variables are more near to a normal distribution as shown at right of Figure (1) and it is coherent with classic regression assumptions. Second, when logs are taken the R-adjusted increases considerably and it is usually desirable when a statistician have to choose between levels and logs. Third, the Box-Cox test rejects both the functional form in levels and the function form log-lin, then it is confirmed further on that both levels and log-lin forms are not appropriated. While regarding the inclusion of the quadratic term, this choice has been motivated by the necessity to capture no-constant elasticity between total costs and the hectares covered that allows increasing or decreasing marginal costs effects. Further, this term has been included only when, inside the regression estimated MM, it is significant according to the t-test. Furthermore, when it is t-significant this term is also capable of improving R-adjusted considerably.

Figure 1: *The starting log-transformed dataset [at left] and log-variables distributions [at right] for all countries (this figure, at left, points out the starting dataset variables by scattering the log of total irrigation cost versus the log of hectares covered by country, while at right, it shows the related depended and independent variables distributions with the same scatter now sorted out by region)*



As remarked, the regression shown in Equation (1) has been estimated MM rather than OLS to discriminate between potential outliers observation and no potential outliers observations. Then, once estimated, it has been drawn out a measure of vertical outlyingness given by the robust standardized residuals (denoted by $S_{stdresi,h,k}$) and flagged outliers as those observations that have a robust standardized residual larger than 2.25 in absolute value.

Once flagged the outliers, unit irrigation costs has been computed in the following three scenarios context. In scenario A, no vertical outliers are assumed then independently from the outlyingness statistics drawn, all observation are kept and the unit irrigation cost are computed as the ratio of total cost on the hectares covered, indeed:

$$UC^A_{i,h,k} = \frac{TC_{i,h,k}}{H_{i,h,k}} \quad | \quad abs\left(S_{stdres_{i,h,k}}\right) \leq 2.5 \quad or \quad abs\left(S_{stdres_{i,h,k}}\right) > 2.5 \qquad (2)$$

where $UC^A_{i,h,k}$ denotes the unit irrigation cost computed under scenario A for observation i, irrigation investment project type h and territorial aggregation k while $abs\left(S_{stdres_{i,h,k}}\right)$denotes the absolute value of our vertical outlyingness statistics measure.

Differently, in scenario B vertical outliers are cancelled out while no-vertical outliers observations are kept and the unit costs are computed as the previous scenario, indeed:

$$UC^B_{i,h,k} = \begin{cases} \frac{TC_{i,h,k}}{H_{i,h,k}} & | \quad abs\left(S_{stdres_{i,h,k}}\right) \leq 2.5 \\ the\ i_{th}\ observation\ is\ cancelled\ out & | \quad abs\left(S_{stdres_{i,h,k}}\right) > 2.5 \end{cases} \qquad (3)$$

Finally, in scenario C all observations are kept but vertical outliers are mean demanded once divided by their absolute value of the robust standardized residuals. Differently, for no-vertical outliers observations unit costs are computed as usual, indeed:

$$UC^{C}_{i,h,k} = \begin{cases} \dfrac{TC_{i,h,k}}{H_{i,h,k}} & | \quad abs\left(S_{stdres_{i,h,k}}\right) \leq 2.5 \\ \dfrac{abs\left(\frac{TC_{i,h,k}}{H_{i,h,k}} - E_{h,k}\left[\frac{TC_{i,h,k}}{H_{i,h,k}}\right]\right)}{abs\left(S_{stdres_{i,h,k}}\right)} & | \quad abs\left(S_{stdres_{i,h,k}}\right) > 2.5 \end{cases} \tag{4}$$

where, $E_{h,k}\,[.]$ denotes the averaging function that apply the mean operator to unit irrigation costs over observations i given irrigation type h and territorial aggregation k.

This outliers weighting scheme it is in line with the form of MM-estimators and it has been shown to produce very reliable summary statistics on unit irrigation costs as pointed out by the practical following application provided in the next section.

4. The cost analysis: the results and policy decisions

This section applies the methodology explained before proving reliable summary statistics on unit irrigation costs, such as, the mean of unit costs, their standard deviation, the maximum value and the minimum value at different territorial levels, namely, at pooled (Table (1)), regional (Table (2)) and country level (Table (3)) and by type of irrigation project, namely, small scale (SS), large scale (LS) and rehabilitation and modernization (RM).

Looking at pooled level, Table (1) shows the first and the most important result of this paper, it is not shown that LS irrigation investment projects are on average more expensive than SS irrigation investment projects but it depends on the scenario chosen. In fact, the mean of unit irrigation costs for LS irrigation investment projects is higher than the mean of unit irrigation costs for SS irrigation investment projects only in scenario B where vertical outliers are deleted.

Table 1: *Unit irrigation costs at pooled level: main summary statistics (this table, shows the number of observations, the mean, the standard deviation, the minimum and the maximum value of unit irrigation costs (UC) computed as in scenarios explained in Section(3) by irrigation investment type)*

	Scenario *A*		Scenario *B*		Scenario *C*	
	obs.	Mean (Std.Dev.) [min; max]	obs.	Mean (Std.Dev.) [min; max]	obs.	Mean (Std.Dev.) [min; max]
UC	225	11954.51 (33169.62) [.41 ;339750]	192	4274.89 (5333.02) [37.91 ; 27060]	225	5307.99 (6427.23) [37.91 ; 44606.92]
UCss	68	26787.76 (55980.29) [.13 ; 339750]	41	3810.17 (4186.94) [37.91 ; 27060]	68	6905.47 (7527.52) [200 ; 43812.24]
UCls	80	5193.91 (6205.70) [.14 ; 28040.57]	76	5095.75 (5704.64) [183.05 ; 27060]	80	5014.48 (5590.95) [183.05 ; 27060]
UCrm	107	4230.24 (9097.42) [.13 ; 78846.16]	100	2772.36 (3883.47) [37.91 ; 26647.3]	107	2936.20 (3999.48) [37.91 ; 26647.3]

Table 2: *Unit irrigation costs at regional level: main summary statistics (this table, shows the number of observations, the mean, the standard deviation, the minimum and the maximum value of unit irrigation costs (UC) computed as in scenarios explained in Section(3) by irrigation investment type)*

	Scenario *A*		Scenario *B*		Scenario *C*	
Afro-Arab region						
	obs.	Mean (Std.Dev.) [min; max]	obs.	Mean (Std.Dev.) [min; max]	obs.	Mean (Std.Dev.) [min; max]
UC	75	7275.88 (10072.16) [.41 ; 64000]	69	6972.65 (7695.34) [37.91 ; 38820]	75	6939.34 (7677.12) [37.91 ; 38820]
UCss	19	9019.92 (14439.58) [.13 ; 64000]	16	6698.65 (5685.41) [558.43 ; 19410]	19	7155.54 (5916.89) [558.43 ; 19410]
UCls	35	5161.12 (6026.75) [.14 ; 27060]	31	5814.87 (6107.34) [192.12 ; 27060]	35	5152.43 (6034.27) [9.81 ; 27060]
UCrm	40	4840.63 (6569.73) [.13 ; 34628.57]	39	4964.75 (6607.93) [37.91 ; 34628.57]	40	4840.63 (6569.73) [0 ; 34628.57]
Middle-East region						
UC	150	14293.83 (39838.63) [42.21 ; 339750]	121	3072.88 (4191.35) [242.85 ; 25222.91]	150	4638.69 (6134.29) [242.85 ; 39647.78]
UCss	49	33677.33 (64207.84) [42.21 ; 339750]	26	2895.61 (3833.23) [470 ; 18077.14]	49	6937.83 (7689.96) [470 ; 38600.26]
UCls	45	5219.41 (6409.05) [251.2 ; 28040.57]	42	4501.95 (5154.73) [355 ; 25222.91]	45	4423.91 (5013.56) [355 ; 25222.91]
UCrm	67	3865.83 (10346.86) [242.85 ; 78846.16]	61	1761.49 (2254.66) [242.85 ; 14089.38]	67	2021.69 (2583.51) [242.85 ; 14089.38]

Differently, when all observations are held or outliers weighting scheme is carried out the mean of unit costs referred to LS irrigation investment projects is lower than the mean of unit costs referred to SS projects[1]. This result imply that, larger is the scale of a given irrigation investment project and smaller could be on average the unit cost paid per hectare. It means that the investor, whether he has the option to choose the type of investment, could save on average money implementing a more efficient water policy by investing in LS projects rather than SS projects if he believes that his information has not atypical values or these values are present but he retains weighable.

Looking at the region level, Table (2) shows the second most important result of this paper. Once vertical outliers are handled, on average unit irrigation costs tend to be lower for Middle East countries rather than Afro-Arab countries[2].

[1] In fact, in scenario C the mean of unit irrigation costs for LS projects is around 1900 USD per hectare cheaper than the average of unit costs for SS projects (6905,14 USD paid on average per hectare versus 5014,48 USD paid on average per hectare). Further, this LS project mean convenience increases amply in scenario A (26787,76 USD versus 5139,91 USD per hectare). Differently, in scenario B the mean of LS projects becomes higher than the mean of SS projects (5095.75 USD versus 3810,71 USD per hectare).

2 In fact, in both scenario B and C the means of unit irrigation cots are lower for Middle-East country rather than in Afro-Arab countries. For example, in scenario B, the mean vary between 1761,49 USD per hectare and 4501,95

Looking at country level, Table (3) confirms, at this territorial level, that once vertical outliers are handled LS irrigation investment projects are not on average more expensive than SS irrigation investment projects but it depends on the chosen country. For example, LS projects are cheaper on average than SS projects in Lebanon, Egypt and Oman in both scenario B and C. This implies that higher is the scale of the irrigation project and lower is on average the cost paid per hectare. It follows that for an international investor are on average more convenient in these countries LS projects rather than SS projects because the cost per hectare for LS projects is smaller.

Table 3: *Unit irrigation costs at country level: main summary statistics (this table, shows the number of observations, the mean, the standard deviation, the minimum and the maximum value of unit irrigation costs (UC) computed as in scenarios explained in Section(3) by irrigation investment type*

	Scenario *A*		Scenario *B*		Scenario *C*	
Lebanon						
	obs.	Mean (Std.Dev.) [min; max]	obs.	Mean (Std.Dev.) [min; max]	obs.	Mean (Std.Dev.) [min; max]
UC	57	7672.74 (21626.04) [242.85 ; 124635.4]	46	2384.32 (8137.73) [416.66 ; 53333.33]	57	3218.77 (7643.65) [195.02 ; 53333.33]
UCss	16	23302.68 (36535.42) [470 ; 124635.4]	8	9486.11 (18817.3) [470 ; 53333.33]	16	8345.76 (13247.49) [470 ; 53333.33]
UCls	2	15655.54 (17515.09) [3270.498 ; 28040.57]	1	3270.49 (·) [3270.498 ; 3270.498]	2	1635.24 (2312.59) [0 ; 3270.498]
UCrm	39	851.09 (513.71) [242.85 ; 2450]	37	824.85 (445.34) [416.66 ; 2450]	39	851.09 (513.71) [242.85 ; 2450]
Iraq						
UC	40	7184.58 (9107.91) [437.73 ; 44228.57]	35	4799.84 (4434.95) [1011.35 ; 18077.14]	40	4671.53 (4380.21) [422.41 ; 18077.14]
UCss	12	7097.57 (12595.77) [1035 ; 44228.57]	11	3722.02 (4910.58) [1035 ; 18077.14]	12	3411.85 (4803.75) [0 ; 18077.14]
UCls	18	6588.21 (7159.93) [707.94 ; 25222.91]	16	4407.04 (3498.68) [707.94 ; 12900]	18	3970.43 (3523.55) [466.91 ; 12900]
UCrm	17	4919.09 (6500.72) [303.41 ; 26647.3]	15	3769.31 (3423.88) [303.41 ; 14089.38]	17	3962.94 (3249.07) [303.41 ; 14089.38]
Egypt						
UC	26	3822.36 (12349.21) [.41 ; 64000]	20	1751.26 (1358.45) [187.28 ; 4749.34]	26	2558.31 (3004.59) [187.28 ; 15601.41]
UCss	4	17266.11 (31184.74) [.13 ; 64000]	2	2532.14 (1055.61) [1785.71 ; 3278.571]	4	4590.44 (3310.83) [1785.71 ; 9371.253]
UCls	12	993.71 (1003.96) [.14 ; 3671.73]	9	1297.51 (984.09) [192.12 ; 3671.73]	12	977.96 (1019.09) [5.37 ; 3671.73]
UCrm	18	1019.13 (1239.52) [.13 ; 4749.34]	15	1215.69 (1271.65) [187.28 ; 4749.34]	18	1014.04 (1243.78) [.46 ; 4749.34]
Morocco						
UC	25	12041.02 (9747.34) [1116.87 ; 38820]	16	15058.23 (6871.64) [5176 ; 34628.57]	25	10369.99 (8528.41) [1073.01 ; 34628.57]
UCss	10	7656.79 (5514.61) [558.43 ; 19410]	7	7962.71 (2527.52) [6354 ; 13550]	10	6231.84 (3518.91) [1246.54 ; 13550]
UCls	14	8453.78 (6988.23) [558.43 ; 27060]	11	10434.92 (6572.81) [5176 ; 27060]	14	8231.05 (7239.63) [84.71 ; 27060]
UCrm	11	9645.87 (10150.43) [860.57 ; 34628.57]	4	17602.14 (11370.81) [11200 ; 34628.57]	11	7166.04 (10407.04) [480.15 ; 34628.57]
Yemen						
UC	24	3809.99 (4204.03) [355 ; 17759.56]	14	2475.48 (535.88) [1736.66 ; 3177]	24	1785.65 (952.74) [326.57 ; 3177]
UCss	3	12096.99 (2931.36) [8750 ; 14207.65]	0		3	1026.24 (693.44) [413.93 ; 1779.24]
UCls	20	2538.69 (1710.12) [355 ; 8952.381]	14	2475.48 (535.88) [1736.66 ; 3177]	20	1856.01 (1077.93) [176.08 ; 3177]
UCrm	2	2187.43 (1929.67) [822.94 ; 3551.91]	0		2	818.38 (347.74) [572.49 ; 1064.28]
Jordan						
UC	18	65733.87 (92577.48) [251.2 ; 339750]	11	79452.09 (97375.39) [922.5 ; 339750]	18	51232.3 (83149.87) [331.26 ; 339750]
UCss	11	94311.58 (107817.5) [922.5 ; 339750]	9	84103.04 (106995.5) [922.5 ; 339750]	11	8786.72 (9638.03) [92.25 ; 33975]
UCls	3	8046.55 (8743.12) [251.2 ; 17500]	0		3	1141.57 (900.02) [172.90 ; 1951.96]
UCrm	7	17377.53 (27908.79) [1000 ; 78846.16]	4	29261.4 (33440.42) [6000 ; 78846.16]	7	1693.23 (2820.69) [6.75 ; 7884.61]
Mauritania						
UC	8	5516.94 (2925.28) [131.32 ; 7800]	5	7506.27 (290.51) [7084.83 ; 7800]	8	4772.44 (3780.52) [108.41 ; 7800]
UCss	0		0		0	
UCls	2	1468.78 (1891.45) [131.32 ; 2806.25]	0		2	1050.06 (890.73) [420.22 ; 1679.91]
UCrm	6	6866.33 (1588.9) [3666.66 ; 7800]	5	7506.27 (290.51) [7084.83 ; 7800]	6	6255.22 (3075.42) [0 ; 800]
Tunisia						
UC	6	5546.18 (2334.21) [1622.25 ; 8818.45]	4	5709.11 (586.37) [4954.73 ; 6385.16]	6	4048.4 (2612.63) [685.81 ; 6385.16]
UCss	0		0		0	
UCls	4	4647.01 (3096.24) [1622.25 ; 8818.45]	2	4073.65 (1246.02) [3192.58 ; 4954.73]	4	2400.36 (2062.01) [685.81 ; 4954.73]
UCrm	3	4896.37 (1475.92) [3192.58 ; 5782.33]	3	4896.37 (1475.92) [3192.58 ; 5782.33]	3	4896.37 (1475.92) [3192.58 ; 5782.33]
Syria						
UC	6	16977.13 (34211.44) [42.21 ; 86486.48]	4	1881.56 (2930) [[42.21 ; 6195.45]	6	2600.47 (3054.25) [42.21 ; 6748.04]
UCss	6	16977.13 34211.44 [42.21 ; 86486.48]	4	1881.56 2930 [42.21 ; 6195.45]	6	2600.47 3054.25 [42.21 ; 6748.04]
UCls	0		0		0	
UCrm	0		0		0	
Oman						
UC	5	8566.35 (5027.95) [4226.82 ; 16594.45]	3	8885.27 (6724.55) [4226.82 ; 16594.45]	5	5499.5 (6642.84) [203.8 ; 16594.45]
UCss	1	16594.45 (·) [16594.45 ; 16594.45]	1	16594.45 (·) [16594.45 ; 16594.45]	1	16594.45 (·) [16594.45 ; 16594.45]
UCls	2	5030.69 1136.83 [4226.82 ; 5834.55]	2	5030.69 1136.83 [4226.82 ; 5834.55]	2	5030.69 1136.83 [4226.82 ; 5834.55]
UCrm	2	8087.97 (3149.49) [5860.945 ; 10315]	0		2	420.85 (306.94) [203.8 ; 637.89]
Algeria						
UC	5	8831.49 (6235.01) [1082.171 ; 15359.74]	3	10299.52 (6236.71) [3331.818 ; 15359.74]	5	6301.48 (7032.19) [47.49421 ; 15359.74]
UCss	1	3331.81 (·) [3331.81 ; 3331.81]	1	3331.81 (·) [3331.81 ; 3331.81]	1	3331.81 (·) [3331.81 ; 3331.81]
UCls	2	13768.24 220.73 [12176.73 ; 15359.74]	1	15359.74 (·) [15359.74 ; 15359.74]	2	7679.87 10860.98 [0 ; 15359.74]
UCrm	2	6644.58 7866.44 [1082.17 ; 12207]	1	12207 (·) [12207 ; 12207]	2	6103.5 8631.65 [0 ; 12207]

Differently, in Iraq. Morocco and Algeria LS projects remain on average more expensive than SS projects in both scenario B and C. This implies that higher is the scale of the irrigation project and higher is on

USD per hectare for Middle East countries while Afro-Arab countries have produced a mean between 4964,75 USD and 6698,65 USD per hectare. Then, means in Middle-East country are lower than means in Afro-Arab country for any type of irrigation investment. Further, in scenario C, the mean of SS irrigation investment project is 6937,83 USD per hectare for Middle-East countries while the mean for Afro-Arab countries is 7155,54 USD per hectare. Furthermore, the mean of RM irrigation investment project is 2021,69 USD per hectare for Middle-East countries while the mean for Afro-Arab countries is 4840,63 USD per hectare. Finally, also considering irrigation projects as whole, is has been confirmed that on average unit costs are lower for Middle East countries rather than Afro-Arab countries (4638,69 USD versus 6939,34 USD per hectare in scenario C and 3072 USD versus 6972,65 USD per hectare in scenario B).

average the cost paid per hectare. It follows that for an international investor are on average more convenient in these countries SS projects rather than LS projects because the cost per hectare for SS projects is smaller.

Finally, for other countries, such us, Mauritania, Tunisia and Syria since some type of irrigation investment projects are missing at total a comparison between SS projects and LS projects in not possible unless new observations or an enlarged dataset is created or provided. Then, for these countries is not possible to formulate investor policy recommendations.

5. Conclusions

The negative influences of outliers on datasets applications is known for a long time. This paper has proposed an advanced econometric method, applied to a real irrigation investment dataset, to handle this issue in a three scenarios context.

This methodology, that can be generalized to any other dataset, has produced reliable summary statistics on unit irrigation costs at different territorial levels and by type of irrigation investment that will help surely governments, international organizations and water management in implementing more efficient water investment decisions and water policies as well as knowing how much to pay on average or at maximum or at minimum for a given irrigation investment project type located in a given country.

Nowadays, the use of these robust statistical methods is becoming more and more important in many fields and applied sciences because outliers are virtually present in any dataset and they must be handled robustly in order to produce correct policy decisions and recommendations.

6. Further developments

These results raise several issues for future applied research. Four are mentioned here. First, it has been assumed that regressors have not outliers and they are properly measured. These two assumptions have implied first that, given the goodness of the estimated regression line, may be present as only vertical outliers and second that the hectare variable is well reported and measured without a measurement error. Then, vertical outliers has been identified under a linear log-log regression with or without a squared regression term, indeed the most suitable functional form case per case, as those observations that have a robust standardized residual larger than 2.25 in absolute value. Although this methodology has produced reliable, realistic and no distorted summary statistics on unit irrigation costs both regressors and the dependent variable might be poorly reported that means a measurement error in the regressors and or in the dependent. Further, measurement error might be correlated that means an additional challenge to handle. Under horizontal outliers and measurement errors the methodology here explained must be tuned and it represents the first future possible development. Second, outliers have been identified assuming no other variables affect the relationship between the total cost and the hectares. This assumption needed to be confirmed in order to avoid the omitted variable bias that can distort any regression consistently. Third, a Bayesian approach rather than traditional regression to identify potential outliers might be carried out taking advantage from the near normality of the log-data transformation. Further, once outliers have been Bayesian identified also a model based directly on the distributions is possible. Fourth, our results are based on 225 initial irrigation projects in two regions. Would there be additional improvements if we were to use more irrigation projects? Therefore, would there be additional improvements if we were use global data rather than two region country data instead? In other words, the issue of systematically selecting data observations from very many other data observations is a difficult challenge that requires further research. In general, having more information is a plus then it follows that enlarging the starting dataset, thought merging or appending also from different data sources should be needed and it represents the most important further development to carry out.

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D24

Water use in agriculture and in food products industry. A case study for Italy to evaluate pressure on water resources

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ABSTRACT

The increasing demand of water resources (wr) due to population growth, production and consumption activities of socio-economic systems, combined with Climate Change (CC) effects on hydrology and water use, are exerting a strong pressure on this natural resource. To face the risk of water scarcity, the challenge is to reduce the wr use intensity in agriculture, industry, energy production and civil use. A consistent and detailed knowledge on the amount of water used by each sector is essential to improve wr management, addressing appropriate policies to protect water availability and quality. In Italy the construction of a comprehensive and consolidate system of data collection on wr used by economic sectors is in place, to reach a higher degree of robustness and comparability of the estimations. To this aim, the role of official statistics need to be strengthened to fill data gaps and to enable more reliable analysis. Collecting data on water volumes used by sectors through statistical surveys and administrative archives can allow to highlight differences on wr requirements linked to various types of products, production processes, technologies used and specific features of the Italian productive structure. The aim of this paper is to present methodology and results of a study developed for Italy by Italian National Institute of Statistics (Istat) to estimate for the first time the volumes of wr used in the production of agricultural crops and vegetable food processed products. An estimation procedure based on the integration of data collected from various sources with official statistics provided by current surveys is implemented. The amount of irrigation water for agricultural crops and water used as input by industry to process vegetable food products is estimated. Results, carried out at the national level, provide an estimation of volumes of water used by the vegetable food chain segment to meet its own activities (reference year 2012). From these results, measures of pressure on wr by domestic production activities are provided.

Keywords: Water Resources, Agricultural Crops, Food Products Industry, Pressure Indicators

PAPER

1. Introduction

Interactions between Climate Change (CC), wr and socio-economic systems are complex and region-specific. CC can affects hydrology and wr through several dimensions: changes in the patterns of climatic variables (precipitation, temperatures, heat waves, extreme events), wr availability, impacts on water quality, changes in runoff, river flows, floods and droughts. Changes in the water cycle can deeply affect countries of many areas of the world, due to their negative impacts not only on agricultural production and food security but also on non-agricultural water uses such as industrial and urban uses. In this context, increasing competition for freshwater use in the sectors mentioned (including through population growth) has resulted in unprecedented pressures on wr, with many countries experiencing conditions of water scarcity as well as in ensuring the integrity of ecosystems. Moreover, water quality continues to worsen, further limiting the availability of fresh wr (IPCC 2014, OECD 2014). According to environmental sustainability and from a policy perspective, CC impacts on water cycle and consequences for agricultural, industrial and urban water uses, highlight prioritizing wr conservation and management in a sustainable way. To face the risk of water scarcity, the challenge is to reduce the water use intensity in agricultural and industrial sectors, in energy production processes and civil use. A consistent and detailed knowledge on the amount of water used in each sector is essential to improve wr management and to address an appropriate mix of policies to protect water availability and quality and to achieve a sustainable growth. Lack of integrated wr data is a systematic impediment to informed decision making about the sustainable use of such natural resource. Concerning Italy, data availability on the amount of wr abstracted, supplied, used, discharged and treated for different uses doesn't completely meet the information needs. Water statistics are produced by various agencies and institutions - often with administrative purposes - preventing data homogeneity, standardization and comparability at temporal and local scale. Istat has been working for several years to improve national knowledge on wr statistics, following EU guidelines relating to the Water Framework Directive 2000/60/EC and Eurostat initiatives on Water Statistics and Water Accounts (UNITED NATIONS 2012 - 2013). In this framework, the construction of a comprehensive

[1] Contribution to the ICAS VII: Rough draft on gender and rural women's empowerment in relation to DW/rural employment.

and consolidate system of data collection on wr used by different sectors is in place. Objective is to reach a higher degree of robustness and comparability of these environmental statistics to provide measures (in physical and monetary terms) of the phenomena taking place, also consistent with the system of monetary national accounting, to support policy decision making. Due to the aim complexity, the role of official statistics need to be strengthened to fill existing data gaps and to enable more reliable multidimensional analysis. To reach this objective collecting data on water volumes used by industry through an integration of sources is needed. By integrating current statistical surveys with administrative archives of public institutions and industry associations can allow to underline differences on water requirements linked to various types of products, production processes, technologies used and features of the Italian productive structure.

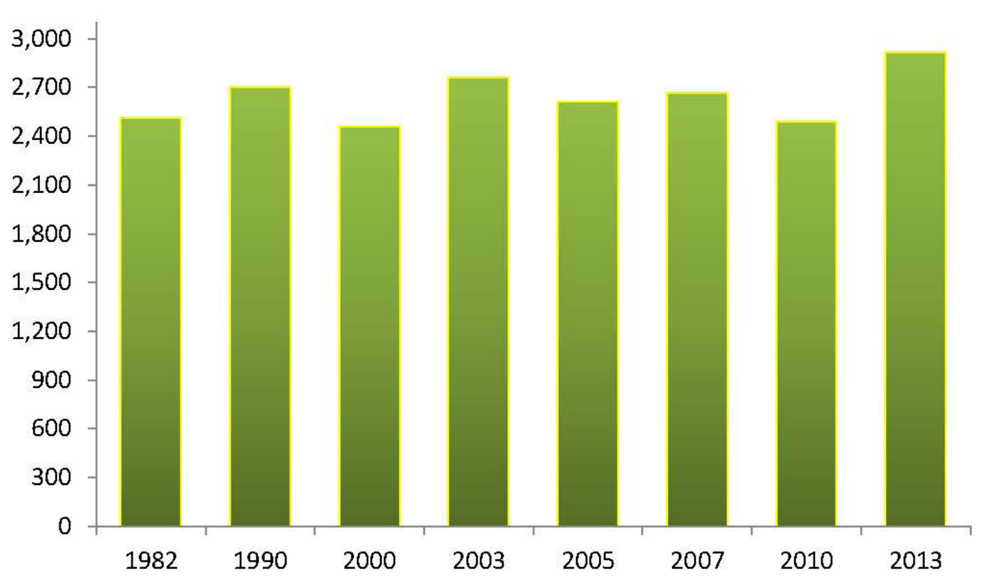
The aim of this work is to present methodology and results of a study developed for Italy to estimate for the first time overall volumes of wr used in agricultural crops production and in food products production whose origins are vegetable. Moreover measures of pressure on wr due to domestic production activities have been calculated. Istat have implemented an estimation procedure based on the integration of data collected from various sources: i) official statistics provided by current Istat surveys as Farm Structure Survey, Industrial Production PRODCOM Survey 2012, VI Italian General Agricultural Census 2010; ii) administrative archives of Italian public institutions; iii) a selection of representative Italian firms; iv) Industry Associations; v) EPD Environmental Product Declaration of firms ISO 14025; vi) international literature (Hosang and Bischof 1998, WS Atkins Ltd & Cranfield University 2002); vii) methodological guidelines for the OECD/Eurostat Joint Questionnaire on Inland Water (Eurostat 2012). The amount of irrigation water by type of crop and of water used as input by manufacturing industry for processing vegetable food products by groups of products have been estimated (Nace Rev. 2 and Ateco 2008 classifications). Produced at the national level, results of our study provide official estimates of the amount of water required by the food chain segment related to the production of fresh and processed vegetable products to meet its own activities. Results also highlight the more waterdemanding crops and the more water-intensive industrial food products. From these estimates, measures of pressure on wr exerted by domestic production activities due to the production of agricultural crops and vegetable food processed products (intended to satisfy final domestic and foreign demand) are provided. The paper is organized as follows. In section 2, data on irrigation water used by agricultural crops are analysed. In section 3, we present main results of the Istat study developed for year 2012 aiming to improve water statistics on industrial activities by producing, for the first time, official estimates on the volume of water used by manufacturing industry by sector.The findings of our research are summarized in the last section, providing measures of pressure on wr exerted by domestic production activities.

2. Water use for irrigation

Irrigation represents in Italy one of the most relevant pressures on natural environment in terms of wr use as in other Mediterranean countries, where increasing hot and dry seasons create conditions for additional water requirements to ensure the optimal growth for several crops (Istat 2016). Irrigable and irrigated areas represent two basic indicators to assess irrigation needs trend and their share in the total utilized agricultural area (UAA).

Irrigable and irrigated areas greatly vary among countries mainly because of regional climate and type of crop production. Based on official statistics provided by Istat Farm Structure Survey of agrarian year 2012-2013 (Istat 2015) the irrigable areas of Italian farms were equal to 4,074,750 hectares by 783,647 farms (Figure 1).

Figure 1 – Irrigated areas. Italy, agrarian years 1982-2013, thousands of hectares

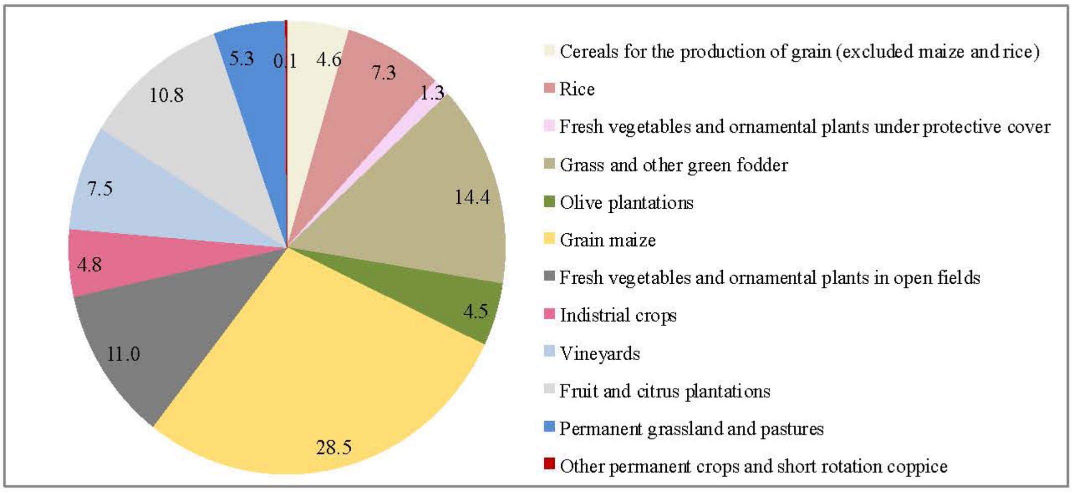


Source: Istat - Farm Structure Survey and General Agricultural Census

Compared to the agrarian year 1981-1982, irrigable areas have increased by about 3%. In agrarian year 2012-2013 irrigation was carried out by 720,335 farms (49% of farms) on 2,917,649 hectares of irrigated area + 16.2% with respect to 1982.

While for some types of crops full irrigation of the entire cultivated area is a distinctive feature, for other crops irrigation is supplementary and generally used to improve production especially in dry periods. Considering the overall irrigated areas by crops, 28.5% of the irrigated areas are planted with grain maize followed by grasslands and other green fodder reaching 14.4% (Figure 2). Fresh vegetables and ornamental plants in open fields represent 11.0% and fruit and citrus plantations almost 10.8%.

Figure 2 – Irrigated areas by crops typology. Italy, agrarian year 2012-2013, percentage values (%)



Source: Istat - Istat – Farm Structure Survey

Two indicators can be calculated to synthetize data on the irrigation needs. The first indicator is Propensity to Irrigation (PI), estimated by total irrigated areas on cultivated areas. The second is Tendency to the Use of Irrigation Potentiality (TUIP) measured by the percentage ratio between irrigated areas and irrigable areas. From official statistics on the agrarian year 2012-2013, PI is equal to 23.5% and TUIP to 71.6%.

Italian crop production system faces and will cope deep changes of weather conditions and wr availability, intensifying problems of water scarcity and irrigation requirements especially in the South, increasing drought risk and heat stress (Gismondi et al. 2016).

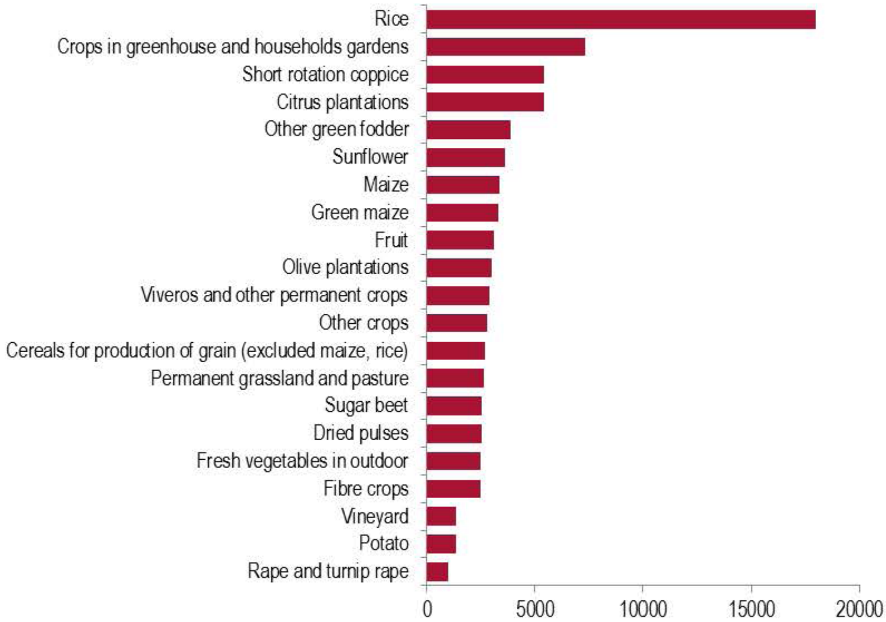
Data on irrigable and irrigated areas alone doesn't give a complete indication of water use intensity, which also depends on the type of equipment used (surface irrigation, sprinkler irrigation, drop irrigation). The type of irrigation system and the size of the agricultural holding may often be linked (Dono et al. 2011).

Being water the most critical resource for sustainable agricultural development, measures in physical units are needed. Volume of water used seems a meaningful indicator to evaluate the pressure on wr exerted by agricultural crops, taking into account several factors (such as CC, current weather conditions, crop type, harvested production, yields, soil characteristics, cultivation practices and irrigation techniques). Volume of water used for irrigation was provided for Italy once in 2010, in occasion of Istat VI General Agricultural Census and it's estimated about 11.6 billion of m3 of irrigation water 2,489,915 hectares of crops by 708,449 farms in agrarian year 2009-2010 (Istat 2014). The average volume of water used to irrigate one hectare of land was equal to 4.7 thousands of m3, with a certain degree of variability based on the type of crop (Figure 3). Rice, representing 10% of the irrigated area, required the highest water volume, almost equal to 18,000 m3 of water per one hectare of irrigated area. Greenhouse and households gardens - despite the low incidence of this crops on irrigated area (2.9%) - required 7,300 m3 per hectare. The less water-demanding crops are rape and turnip rape (beneath 1,000 m3 per hectare) and potatoes (1,300 m3 per hectare), overall represeningt only the 1% of the total irrigated areas.

To measure pressures on wr, the indicator volume of water used for irrigation calculated by area and typology of crop can give more detailed information suitable for analysis on the sensitivity of water demand by crops to CC phenomena and on efficiency in wr use if placed in relation to harvested production, irrigation systems as well as meteo-climatic conditions and soil characteristic.

Strengthening the production of official statistics on volumes of water used in agriculture on regularly basis is needed by integrating different data sources. Expanding temporal and spatial scale and disaggregation level at which data are provided allows to carry out medium and long-term reliable analyses.

Figure 3 – Volumes of irrigation water by crop typology. Agrarian year 2009-2010, thousands of m3 per hectare of irrigated area



Source: Istat – VI General Agriculture Census

3. Water used by food products industry

In Italy there is a lack of uniform estimates on the amount of water abstracted, supplied, used, discharged and treated for industrial uses. Available data are often difficult to be collected, as information is produced by various agencies and institutions with administrative and economic purposes, according to different levels of efficiency in archiving procedures.

For this reason, wr statistics on Italian industrial activities suffer from a large fragmentation of information, data heterogeneity and lack of standardization. Concerning statistics on water used by industry, an official survey useful to improve the knowledge on the matter doesn't exist in Italy (Tagliacozzo, Vignani et al. 2015).

Thus an Istat-Eurostat study was developed since 2013 to improve water statistics and accounts on industrial activities by producing for the first time official estimates at national level on the volume of wr used by manufacturing industry and mining and quarrying industry Nace Rev. 2, sectors 07-08 and 10-33 (Vignani, Tagliacozzo et al. 2016). As industrial water needs are strictly connected with the type of industry and product and largely dependent on technological features of the single plant, different types of industrial processes and technologies used have been taken into account.

An indirect estimation method has been developed and applied. The innovative element of the methodology is represented by:

i) using official statistics coming from the current Istat Survey on industrial production PRODCOM 2012, based on data by units of product of different typology and by value of output (instead of data by number of employees as applied in other studies);

ii) applying specific technical processing coefficients - calculated for unit of product in physical terms - to the amount of units of product, grouped by typology within each manufacturing sector.

The method allows to obtain estimates on overall volumes of water used as input in the production of manufacturing industry by unit of product and by sector. Additionally, an estimation of the water self-abstracted by industries have been developed, under the assumption that small firms (industries with 5 or less employees) are supplied by public water supply network. Published technical studies suggest methods to estimate wr use that are not directly suitable for analysis at a large scale, because they need to be calibrated to fit features of the country-specific industrial structure/ production.

Results show the total amount of water used as input in the production of manufacturing industry is equal to 5,509,128 thousands of m3 in 2012, while the volume of water self-abstracted by industries is 5,314,866 thousands of m3 (Table 1). The difference of 194,262 thousands of m3 represents the volume of water provided to small industries by public water network. This information is important to calculate a water balance of wr uses by all domains (civil, agricultural, energy production, industrial).

A sectorial breakdown allow to identify the volume of wr used by each sector and the share of wr used by the food products sector. Results represent the use of water as a whole in each sector, calculated from the volume of water used by unit and type of product.

The sectors with the higher demand of wr, together using one third of the total amount of water, are: "Chemicals and chemical products" (12.4%), "Rubber and plastic products" (11.7%), "Basic metals" (10.0%). Food products sector is placed in a group of sectors with a medium level of water required as input (6%) equal to 333,182 thousands of m^3.

The analysis have been deepened on the categories of vegetable food processed products to provide an overall estimation of volumes of water used by the food chain segment of vegetable products to meet its own activities. As Nace 10 classification food products includes also products whose origin isn't vegetable (i.e. production and manufacturing of meat, fish, dairy products, milk) a selection of food processed products (VFP) has been made. Wr required as input for their production represent almost 60.7% of the whole water used by food products sector and correspond almost to 184,564,828 thousands of m^3.

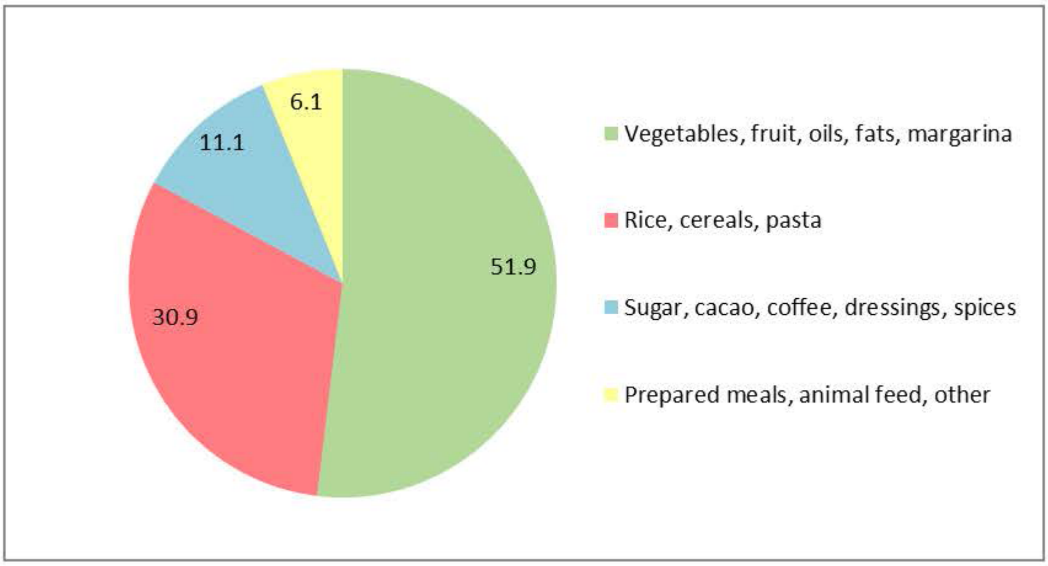
Table 1: *Water used by sector. Year 2012, thousands of m^3 and percentage values* (%)

Nace Division	Water use		Water use (>5 employees)	
	m^3	%	m^3	%
7-8 Mining and quarrying minerals	260,685	4.7	231,528	4.4
10 Food products	333,182	6.0	303,814	5.7
11 Beverages	92,525	1.7	90,883	1.7
12 Tobacco products	2,545	0.0	2,545	0.0
13 Textiles	348,496	6.3	326,351	6.1
14 Wearing apparel	147,585	2.7	129,163	2.4
15 Leather and related products	43,844	0.8	40,985	0.8
16 Wood and products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	120,420	2.2	113,233	2.1
17 Paper and paper products	354,686	6.4	350,408	6.6
18 Printing and reproduction of recorded media	12	0.0	11	0.0
19 Coke and refined petroleum products	2,386	0.0	2,386	0.0
20 Chemicals and chemical products	680,836	12.4	677,278	12.7
21 Basic pharmaceutical products and preparations	40,217	0.7	40,214	0.8
22 Rubber and plastic products	645,486	11.7	628,400	11.8
23 Other non-metallic mineral products	419,030	7.6	409,408	7.7
24 Basic metals	552,148	10.0	551,016	10.4
25 Fabricated metal products, except machinery/equipment	283,844	5.2	274,882	5.2
26 Computer, electronic and optical products	57,793	1.0	56,387	1.1
27 Electrical equipment	202,582	3.7	199,008	3.7
28 Machinery and equipment	224,288	4.1	220,123	4.1
29 Motor vehicles, trailers and semi-trailers	121,864	2.2	121,151	2.3
30 Other transport equipment	163,822	3.0	158,785	3.0
31 Furniture	116,154	2.1	113,241	2.1
32 Other manufacturing	115,625	2.1	113,552	2.1
33 Repair and installation of machinery and equipment	179,071	3.3	160,116	3.0
TOTAL	**5,509,128**	**100.0**	**5,314,866**	**100.0**

VFP products has been classified in four category of homogeneous products (Figure 4). The category including Vegetables, fruit, oils, fats, margarina uses 51.9%of the overall water used in the production of VFP, followed by Rice, cereals, pasta, that use about 30.9% of the total. The third group is represented by Sugar, cacao, coffee, dressings, spices (11.1 %) and the last one by Prepared meals, animal feed, other (6.1%).

To measure the pressure of water demand by products at net of production levels a Water Use Intensity

Figure 4 – Volumes of water used by categories of vegetable food products. Year 2012, percentage values (%)



(WUI) indicator have been calculated by the ratio between volumes of water used an sold production, by sector. Considering, in fact, unit of production vary within and between sectors among several type of measurement (weights, volumes, m2, number of pieces, monetary units), a normalization method into monetary terms allows to compare the demand of water, net to the sector's production levels and type.

The WUI indicator represents the volume of wr necessary to produce one euro of production sold. Calculated as average value among all sectors, it is equal almost to 8.8 litre/euro. The food products sector records a WUI equal to 3.9 litre/euro.

Our work represents a first attempt to estimate volume of wr used by industrial activities through and indirect methodology applying technical coefficients to unit of products. Although the method can be replicated for each year considered, the estimations - mainly due to PRODCOM sample features- have statistical significance at national level. Regional as well as sectorial breakdown decreases the estimation robustness. Goal to achieve is to strengthen the production on regularly basis of official statistics on volumes of water used by national manufacturing industry through collected data with the aim to expand temporal and spatial scale and disaggregation level at which data are provided.

4. Conclusions

In the context of CC, increasing competition for freshwater use in different sectors has resulted in high pressures on wr, with many countries facing the risk of water scarcity. To improve wr management and to address appropriate policies to protect water availability and quality, a consistent and detailed knowledge on the amount of water used by each sector is essential. In this context, the role of official statistics need to be strengthened to fill data gaps and to enable more reliable analysis on the pressure on wr. In Italy, Istat have been worked for the construction of a comprehensive and consolidate system of data collection on wr used by economic sectors and by population. Being water the most critical resource for a sustainable agricultural development, measures in physical units are needed. Volume of water used seems a meaningful indicator to evaluate wr pressure exerted by agricultural crops and food industry. This paper presents methodology and results of a study recently developed by Istat. For the first time volumes of wr used in national agricultural crops production and in vegetable food processed products production have been estimated. The amount of irrigation water by type of crop and of water used as input by manufacturing industry for processing vegetable food products by groups of products have been provided for one year, limited by data availability. The statistical procedure is based on the integration of data collected from various sources with official statistics provided by current surveys. Concerning national agricultural crops, water used for irrigation was estimated about 11.6 billion m3 in 2010, as provided once by VI Italian General Agricultural Census. Concerning vegetable food products industrial sector, the volume of water used as input corresponds almost to 184.564.828 thousands of m3 in 2012, as provided by the Istat study. The innovative element of the methodology applied is represented by: i) using official statistics coming from the current Istat Survey on industrial production PRODCOM, data by units of product of different typology and by value of output; ii) applying specific technical processing coefficients,- calculated for unit of product in physical terms, to the amount of units of product grouped by typology within each manufacturing sector. The indicator volume of water used calculated in physical units can give more detailed information suitable for conducting analysis on pressures on wr , sensitivity of water demand by crops/products to several factors (CC effects, irrigation systems, technology used) and efficiency in wr use. This work permits to fill some gaps on water pressure analysis so as to encourage strengthening the production of statistical information necessary for a comprehensive and multidimensional analysis. As underlined, several data sources can satisfy partially information demand on wr use and macro-aggregates at national scale only can be calculated in many cases. At date, in the Italian statistical system data on wr are collected with different purposes and integration is limited.

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THEMATIC SET

D25

MEASURING THE VALUE OF ECOSYSTEMS SERVICES, LAND DEGRADATION AND BIODIVERSITY LOSSES

Session Organizer
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ABSTRACT

The global effort to end poverty and improve food security faces a special challenge of doing so while ensuring that farms, forests and landscapes continue to produce food for generations to come. Integration of environmental goals in development programs, analytic tools, and in analyses to inform investments can contribute toward resiliency of production systems. Accordingly, the Sustainable Development Goals (SDGs) have committed to a number of targets which contribute to improved ecosystem services (ESS), land restoration and increased biodiversity. Similarly, the CGIAR strategy includes 'improved natural resources systems and ecosystem services' as one of its three System Level Objectives. The challenges facing efforts to sustainably increase agricultural productivity are many, including soil degradation, overdrawn and polluted waters, reduced pollination health, and diminishing genetic resources. Uncertainties associated with climate change pose further risks. Safeguarding agricultural biodiversity can provide sustainable solutions in tackling these challenges. Existing research indicates that agricultural biodiversity leads to production systems that are more resilient to biotic and abiotic stress, it improves ESS such as pollination health, water quality and use efficiency, and improves soil health. The commitment of the global community to integrate ESS and natural resources systems in its development goals provides an opportunity to create a framework for establishing baseline indicators and monitoring progress toward enhancing these goals. A challenge toward measuring the value of ESS and natural resources system lies in the fact that the services and systems studied are very site specific and development goals are measured at larger scales such as at national levels. Finally, most agricultural models to date have tended to analyse how yields or profits can be maximized or incomes increased. But these models have generally not examined what these scenarios mean for the natural environment and its ability to sustain future food productive capacity. Nor have the models explicitly linked agricultural biodiversity to ESS and in turn to sustainable productivity gains.

This session will include 4 papers devoted to the following areas,

1. A standard and practical approach to measure and monitor agricultural biodiversity across scales from the field to the national level. This discussion should focus on a few recommended indicators which can be used across different scales and are suitable for use in research across different disciplines, including in bioeconomic modelling.

2. A standard and practical approach to measure and monitor the outcomes of efforts to restore degraded land and forests. This discussion should focus on a few recommended indicators which can be used across different scales and are suitable for use in research across different disciplines, including in bioeconomic modelling.

3. A standard and practical approach to measure and monitor one or more of the ESS such as soil health or pollination health. This discussion should focus on a few recommended indicators which can be used across different scales and are suitable for use in research across different disciplines, including in bioeconomic modelling.

4. Approaches for analysing trade-offs between productivity, nutrition outcomes and environmental outcomes at multiple scales, such as households, agricultural sector and economy-wide.

LIST OF PAPERS

Introducing ecosystem service evaluation indicators in monitoring of irrigated agriculture in Uzbekistan (within the project ELD Central Asia)

U. Nazarkulov | Research Institute on Agricultural Economics | Tashkent | Uzbekistan
I. Rustamova | Tashkent State Agrarian University | Tashkent | Uzbekistan
N. Nishanov | ICARDA-Uzbekistan | Tashkent | Uzbekistan
DOI: 10.1481/icasVII.2016.d25

The MIMOSE approach to support large-scale statistics on forest ecosystem services

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F. Bottalico | Dipartimento di Gestione dei Sistemi Agrari, Alimentari e Forestali | University of Florence | Florence | Italy
L. Antonello | Dipartimento di Gestione dei Sistemi Agrari, Alimentari e Forestali | University of Florence | Florence | Italy
A. Barbati | Dipartimento per l'Innovazione nei Sistemi Biologici, Agroalimentari e Forestali | University of Tuscia | Viterbo | Italy
G. Chirici | Dipartimento di Gestione dei Sistemi Agrari, Alimentari e Forestali | University of Florence | Florence | Italy
P. Corona | Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria | Forestry Research Centre (CREA SEL) | Arezzo | Italy
S. Cullotta | Dipartimento di Scienze Agrarie e Forestali, University of Palermo | Palermo | Italy
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V. Giannico | Dipartimento di Scienze Agro-Ambientali e Territoriali | University of Bari | Bari | Italy
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D. S. La Mela Veca | Dipartimento di Scienze Agrarie e Forestali | University of Palermo | Palermo | Italy
F. Lombardi | Dipartimento di Agraria, Mediterranean University of Reggio Calabria | Reggio Calabria | Italy
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L. Pesola | Dipartimento di Scienze Agro-Ambientali e Territoriali | University of Bari | Bari | Italy
F. Riccioli | Dipartimento di Gestione dei Sistemi Agrari, Alimentari e Forestali | University of Florence | Florence | Italy
D. Travaglini | Dipartimento di Gestione dei Sistemi Agrari, Alimentari e Forestali | University of Florence | Florence | Italy
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DOI: 10.1481/icasVII.2016.d25b

Protection and enhancement of the coast of Mostaganem (Algeria): preliminary restoration study

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I. O. Elegbede | University of Cottbus-Senftenberg, Germany | Brandenburg | Germany
C. Corselli | Università degli Studi di Milano-Bicocca | Milano | Italy
DOI: 10.1481/icasVII.2016.d25c

D25

Measuring landscape diversity and fragmentation in EU agricultural areas from LUCAS Data

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DOI: 10.1481/icasVII.2016.d25d

Approaches for analysing trade-offs between productivity, nutrition and environmental outcomes at multiple scales

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D25

Introducing ecosystem service evaluation indicators in monitoring of irrigated agriculture in Uzbekistan (within the project ELD Central Asia)

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DOI: 10.1481/icasVII.2016.d25

ABSTRACT

For regular analysis and tracking of changes in the valuation of ecosystem services in irrigated agriculture, indicators and data sources included in a unified system of statistical services in rural areas are needed. In general, the development and introduction of such indicators and data will help to guide monitoring ecosystem services in areas such as cotton and grain farming, the main agricultural crops in irrigated agriculture of Uzbekistan.

Currently, almost all information is obtained through interviews, which is very labor intensive and covers a rather small radius of the population and areas involved in agricultural activities. Therefore, the development of new indicators for statistical reporting systems will improve the ability of ecosystem services' value estimates at the level of decision-making.

Keywords: Economic Assessment of Ecosystem Services, Bio-agriculture, Irrigated Agriculture, Agricultural Economics

PAPER

1. Introduction

Agriculture is one of the priority areas of national economy. Uzbekistan has favourable climatic conditions for production of various agricultural, including industrial crops. A significant portion of sown areas and almost all land under technical crops are irrigated lands served by a large public irrigation system.

Diminishing soil fertility in agriculture is one of the issues that need to be tackled. The content of humus in the soil decreases. Thus, in the study area, about 76 % of arable areas have content below 1 %, 22 % contain from 1 to 2% organic matter, and the remaining about 1% of irrigated arable land contains from 2 to 3% organic matter.

Improvement of soil structure can be achieved by rational combination (rotation) of crops. It is necessary to expand the area under crops and trees allowing the accumulation of nutrients in the soil. A rational choice of crops can reduce the amount of mineral fertilizers and various other chemicals, contaminating land and water.

Some international studies show, that average GHG emissions from traditional cotton cultivation can be 3,236kg CO e/ha and 1.5 kg CO e/kg of seed cotton produced. For a detailed analysis of carbon emissions from cotton cultivation, a further study is needed, because farmers and local authorities do not collect such data[1].

In accordance to some literature[2], the soil organic carbon stock (SOC) under irrigated cotton varied from 15 to 43 Mg C ha^{-1}. Perennial crops generally have the widest range of SOC stock as from 11 to 241 Mg C ha^{-1}, similar to a land use as pasture type. Currently the area under orchards and vineyards in the surveyed farms is only around 1.5 %. Absorption of carbon dioxide by tree planting in the surveyed farms approximately amounted to only 35 m3 per year. In the economic program of socio-economic development of the country in 2016, the President of Uzbekistan stressed the need to reduce by 2020 the volume of procurement of cotton to 350 thousand tons. The result, on released cotton plantations will be grown vegetables, potato, fodder, oilseeds and other crops, gardens and vineyards[3].

The traditional varieties of crops (cotton and wheat), subsequent reduction of productivity of

[1] Sumit Roy, Murli Dhar, P Vamshi Krishna, Rebecca May. Cutting cotton carbon emissions - Finding from Warangal, India.
[2] S.M.F. Rabbi and others. Climate and soil properties limit the positive effects of land use reversion on carbon storage in Eastern Australia.
[3] http://uza.uz/ru/business/agrarnaya-sfera-vesomye-tempy-rosta-25-01-2016?ELEMENT_CODE=agrarnaya-sfera-vesomye-tempy-rosta-25-01-2016&SECTION_CODE=business&print=Y.

irrigated areas, and the orientation of farmers to maximize harvest rather than economic benefits of the production function (not examined) require constant and increasing amounts of mineral fertilizers. This process leads to the subsidence of many harmful substances in soil and water, which directly affects the living organisms in the soil. Useful insects (entomophages, etc.) are spreading as a consequence of biological plant protection on irrigated fields. Despite this, use of the land under cotton has consequences such as the extinction of previous organisms and their habitat, staying birds, and various small animals.

Some traditional methods often harm land resources, at the same time causing damage to the environment. So, the burning of straw per hectare leads to emissions of 500 g of nitrogen oxide and 380 g of hydrocarbon, 3 kg of ash, 20 kg exhaust and carbon gases, which leads to the spread of various diseases. This process disrupts the structure of the soil, which leads to increased soil erosion and declining yields. In addition, entomophages and useful creeping animals die, local plants around the cereal fields are damaged and disappearing.

There are only few statistical materials indicating an influence of agricultural production systems on the environment. Statistical data almost correspond to the set of indicators that are applicable to centrally planned management of agriculture. There are indicators of production volumes, production costs of agricultural products. They tend to give information about the implementation of plans, but do not express the analytic capacity to maintain the conditions for sustainable economic and environmental sustainability of land and water use.

Maintaining the humus balance, the volume relations of plants with nutrient properties of the soil or organic matter, uptake and release of carbon, the prevention of various types of land degradation and others need to be considered as indicators of statistical information at the district level. The basis for the economic calculations is the fact that any economic effect from the use of land in agriculture must maintain the natural fertility of the soil. For this we use and propose indicators of crop rotations in the study area. Cotton cultivation is one of main form of agricultural production in the study area, as well as in Uzbekistan. The main question is how the farmers can conduct the proposed agricultural production in an economically advantageous way, will they change the structure of production taking into account conservation of natural resources?

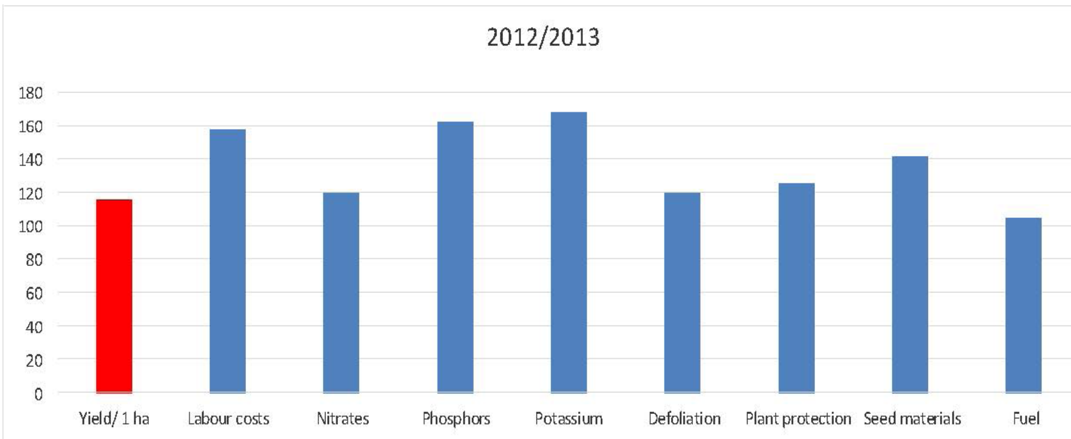
2. Cotton cultivation as a traditional form of land use

In the study of irrigated agriculture, the main products obtained from the interaction with ecosystem services include food, fuel and fibre, the nutrients for their growing. In addition, thematic area focuses on supporting ecosystem services - formation and soil conservation, supporting habitat, air purification, carbon sequestration, allocation of water resources, and cultural – i.e. creating areas for recreation and aesthetic values.

The analysis of the researched farms shows that yields tend to decrease. The yield increase is achieved due to the disproportionate increase of the costs of various production factors. So, when considering years with increasing yields (2013, Figure 1), it is clear that in comparison with 2012 the increase in yield of raw cotton per hectare was accompanied by a high increase in almost all factors of production except fuel.

This aspect clearly indicates a decline in the value of land, as part of the ecosystem, which is the

Figure 1 – Increase of production factors volume comparing to the cotton yield growth



Source: calculated by author based on survey data.

main economic factor in the context of irrigated agriculture. Considering ecosystem services, it directly reflects the provision of nutrients for the production of products from cotton cultivation tends to decrease. Therefore, the main objective of changing the situation, in our opinion, is the change or improvement of the crop rotation system adopted in local conditions.

It should be noted that the demand for by-products from cotton production increases. For example, cotton stalks can be used as raw material for production of furniture and other composite materials. On the other hand, the eventual liberalization of the domestic cotton market may increase the prices of raw cotton. Given the fact that changes also occur in the prices of production factors, it can be assumed that the optimization of production will lead to attractiveness of this type of irrigated agriculture. For a long period, this process will increase the load on land resources, requiring revision of land use from the point of view of crop rotation and reproduction of natural soil fertility.

Table 1 – Total volume of income generation from raw cotton growing, average per farm

	2012	2013	2014
Yield, t	198.4	222	151.2
Area, ha	62	60	56
Total revenue, thousand UZS	167466	206223	158609
Total expenditures, thousand UZS	158573	198519,2	149744
Income, loss (+,-), thousand UZS	8892	7703	8865
Profitability, %	5,6	3,9	5,9
Additional value, thousand UZS	9210	11343	8732
Real total revenue, thousand UZS	176676	217566	167341
Real Income, loss (+,-), thousand UZS	18103	19047	17597
Real profitability, %	11	10	12

Source: by author based on survey data

Since cotton is the raw material base for other industrial forms of production, it is necessary to consider what may occur by outflow of resources from these industries in cotton growing. For example, from raw cotton we can receive about 33 % of the weight in the form of fiber, about 54 % as oil and fodder, and the rest as lint. Changes in the demand for such related products directly affect the degree of attractiveness of cotton production. In addition, it is necessary to take into account the price of cotton fibre on international markets. Changes in these areas consequently can cause an increase of investments in the sector of crop production. Thus, it may lead to further overuse of soil, due to the application of a larger amount of mineral fertilizers, more intensive use of agricultural machinery, etc. As a result, the natural fertility in the long term will continue to decline. For a more detailed analysis, alternative uses in other forms of irrigated agriculture are necessary to be considered.

3. Economic and environmental sustainability of traditional cotton production

Although in the study area stubbing of cotton stalks is not as widespread as in the southern and western regions of Uzbekistan, the tendency of stalks cutting for fuel increases. This factor currently is constrained due to the sufficient gas supply. In many other areas remote from the capital, the gas supply is less. Consequently, all of the cotton stalks are removed. This contributes to a significant decrease in the proportion of organic matter, which naturally would be returned to the soil.

The value of cotton stalks can be also estimated in accordance to possibility of obtaining heat energy. According to some calculations[4], 1 kg dry weight of cotton stalks gives energy in about 15 mega joules. So 1 t dry mass of stalks can be equated to the energy obtained from approximately 0.3 t of diesel fuel. Thus, the value of production of raw cotton may be too attractive to refuse it as a production form leading to intense land degradation. Limiting factor is the increased supply of this raw material, especially in the seasonal section. Taking into account local conditions for the calculations, we choose cost rates that were obtained during surveys in the study area. Using data of fertilizers' cost obtained on the studied farms and comparing required amount of their additional contribution due to a withdrawal of organic mass, we can calculate the cost of losses from the collection of cotton stalks by the field after harvest (table 2).

The cotton production takes up to 3 t of organic mass from one ha under collection of cotton stalks for fuel and other needs. In order to cover the loss of nutrients that are not reproduced due to the withdrawal of this organic mass, farmer needs to apply about 14 t of organic fertilizer (table 2). Application of organic fertilizer restores the contents of nitrogen, phosphorus and potassium in the soil. Under normal conditions, 1 t of organic fertilizer covers 5 kg of nitrogen,

[4] T.A. Gemtosa, Th. Tsiricoglou. Harvesting of cotton residue for energy production.

Table 2 – Indicators of calculating cost of mineral fertilizers for reproduction of nutrients in the soil for the permanent cotton production[5]

Factors	Quantity	Value, UZSs		
The withdrawal of organic matter by cultivation of cotton (t)	3	2012	2013	2014
Reimbursement (organic fert., t)	14			
Nitrogen (kg)	68	76834	82602	109084
Phosphorus (kg)	20	23050	24781	32725
Potassium (kg)	55	61075	69404	76364
Total		160959	176787	218173

Source: by author based on survey data

4 kg of phosphorus and 1.5 kg of potassium. To resume the production of raw cotton, equivalent to the previous year, the farmer must purchase the necessary amount of mineral fertilizers with these nutrients.

Based on the table of profitability of growing cotton on the studied farms, the number of required types of fertilizers is multiplied by the price of their purchase. The result is the amount of money the farmer has to spend for the reproduction of substances that are lost due to the loss of humus in the soil. Comparing these values with the income received by the farmer from the sale (withdrawal) cotton stalks from the field, we can see economic loss from such kind of management (table 3). This example shows the economic feasibility of natural reproduction of the soil organic structure in studied conditions.

Table 3 – lEstimated loss from the sale of the cotton stalks for fuel, UZS/ha

Values	2012	2013	2014
Income from the sale of the cotton stalks	148,544	189,0515	155,925
Acquisition cost of NPP (expenses)	160,959	176,787	218,173
Win +/Loss -	-12,415	12,2645	-62,248

Source: by author based on survey data

4 Possibility of optimization in crop rotation

An alternative option for irrigation farming with preservation of the humus balance and economic utility of crop cultivation forms is the possibility of changing crop rotations. An expansion of the area under cultivation of alfalfa can be taken as an example to calculate an alternative scenario. Currently about 3 % of agricultural land on the studied farms is planted by alfalfa , and about 8 % in comparison with the area under the raw cotton cultivation. The proposed alternative aims at a combination within the rotation of alfalfa and cotton cultivations. For example, the calculation is based on maintaining a zero balance of humus as two years of alfalfa and three years of cotton cultivation.

For initial assessment of economic benefits from the preservation of humus balance in soil, initially we compared the cultivation of alfalfa and cotton from the point of view of their profitability in combination of crop rotation, which retains humus balance within a certain time. Calculations show that the production of alfalfa while maintaining the humus balance brings significant economic benefit compared with cotton (table 4). Its value for the study area is more than 80 %. The production of one crop - cotton in this situation brings in annual revenues of approximately 315 thousand UZSs per ha. On the other hand, lack of alfalfa in the crop rotation for the farm brings the loss of up to 255 thousand UZSs per ha annually. Thus, the farmer would be interested in the use of crop rotation including cotton and alfalfa.

The calculations were based on the revenue generated from the cultivation of cotton with the removal of residues from the field. If you eliminate this indicator, the results can change in favour of cotton. However, the income from growing alfalfa is more profitable form of agricultural production, because the livestock sector in the Metropolitan area is developing intensively and farmers can directly sell alfalfa to livestock producers. But cotton production traditionally will remain as a main form of irrigated agriculture in Uzbekistan. It seems it can be reduced to a certain scale, if it is justified from the point of view of maintaining sustainable land productivity. On the other hand, the government will go easier on the sown areas under cotton, if the productivity of land will increase (score of bonitet). The vacated land will be used for agricultural crops with great potential to sustain ecosystem services and biodiversity through soil improvement. For this purpose, it is expedient to further and more detailed study from the point of view of biological and ecological analysis.

[5] Nazarkulov U. (2003) Transformation of agriculture in Uzbekistan and restructuring issues of farm enterprises.

Table 4 – Economic benefit from growing alfalfa compared with cotton (2014)

Production form	Withdrawal/depositing of organic mass, t	Number of rotation years	Gross Margine, UZSs	Income value for 1 year, UZSs*
Cotton cultivation	-4,2	6	314225	314225
Alfalfa cultivation	6,7	4	854000	569333
Difference/benefits of crop rotation				-255108

** excluding the NPV and the discount rate.*

Source: by author based on survey data

At the moment, we mostly use economic interpretation, trying to assess the further course of the implementation possibilities of crop rotations. We are talking about the feasibility of maintaining the humus balance. The challenge is to determine whether the crop rotation is favourable from the point of view of factors as nutrients. On the one hand, it is important to determine how much alfalfa contributes as a supplier of organic mass. On the other hand, it is important to determine the cost of the withdrawal of nutrients by cotton cultivation. It is important to determine the ratio of economic benefits from the factors nutrients such as NPP (Nitrogen, Phosphorus, and Potassium) excluding the impact of the cost of other factors.

Table 5 – Assessment of the value of crop rotation (pictures 2014)

Organic matter, t/ha	6,7	-4,2
Organic fertilizer, t	30,5	-19,1
Nitrogen, kg	152	-95
Phosphorus, kg	46	-29
Potassium, kg	122	-76
The cost of organics in the rotation, UZSs	519230	-325488
The value of land from crop rotation of alfalfa, UZSs	193 743	

Source: by author based on survey data

Calculations show that a farmer will seek to increase the proportion of alfalfa in rotation with cotton. If we take the ratio of cotton to alfalfa as 6 to 4, we can assume that 12 years is the minimum period in which the whole land area may be used under alfalfa 4 years and under cotton 6 years. Calculations of total revenue from use of land under the cotton crop rotation with alfalfa in contrast to the use only under the cotton show that in the first embodiment, the farm receives economic benefit in almost 59 % higher (table 6). 32 % of this additional income in this case is obtained by changing the cost structure of nutrients in the soil.

Table 6 – The yield of farms from the change in crop rotation (the estimated area of 56 ha)

Form of crop rotation	Income**, thousand UZSs
Income from growing only cotton	99528
Income from combination of cotton and alfalfa *	167913
Income from the benefits of preserving the humus balance	53330

** in the ratio of 6 years cotton and 4 years of wheat for 12 years.*

*** for 12 years with a discount rate of 18% per annum.*

Source: by author based on survey data

5. Extension of tree plantations as an alternative scenario for the provision of ecosystem services

Following the alleged alternative option for creating a favourable environment from the point of view of ecosystem services proposes testing approaches to the development of agro forestry. One of the important directions is the creation or renewal of the forest belts around and on the territory of cotton fields. Surveys have revealed that in the past, this issue has received considerable attention at the state level, various programs were implemented to create windbreaks.

By combining these two forms of agricultural production, cotton yield would increase. This is an additional incentive to use this approach, because land allotment from cotton farming is a difficult process. Besides, it is necessary to take into account the risk of long-term investments, which farmers can accept only for a smaller area. Therefore, we can focus on the forestland approximately 3% of arable land currently used under cotton. The studied farms in 2014 used for cotton cultivation an average of 56 ha per farm. Thus, about 2 ha, the farmer can use under planting of trees. In this case, we focus on poplar (table 7). To calculate the net present value we use a discount factor of 1.18.

Table 7 – Calculation results of poplar growing on the cotton fields (the period of poplar maturity expected as 9 years). UZS

	2105	NPV, 2024
Income from 2 ha of planted poplar	-900000	8335862
Income from yield increase by 15%, 54 ha	22941630	116487635
The income from cotton cultivation, 56 ha	17596600	89347894
Income volume by poplar growing on the cotton fields		124823497
The benefit to the farmer, %		39,7

Source: by author based on survey data

The sequence of calculations from the farmer's point of view is carried out in accordance with the definition of benefit from the value of the timber that he can sell in 9 years (8.3 million UZSs), and the additional revenue from raw cotton production (116.5 million UZSs). This is obtained because of higher yields through the establishment of forest plantations. Thus, the net present value of revenue from this combination of both production forms is obtained in an amount of 124.8 million UZSs. If we take into account the production of only cotton, net present value of revenue over 10 years would have been approximately 89.3 million UZSs. Therefore, this alternative would bring the farmer an income that would exceed the traditional income at nearly 40 %. In addition, the risk is quite low due to minimum consumption of territory, severed from the main form of agricultural production.

6. Conclusions

- by retaining cotton residues on the field, the farmers have an opportunity to generate additional income from cotton cultivation. In practice, farmers are not aware of the usefulness of this approach, which requires research and awareness of farmers cultivating cotton;

- the remains of the cotton in the field also contribute to the living conditions for insects and microorganisms on the agricultural fields, contributing to the habitat of birds and small animals, such as hares and hedgehogs;

- reducing the amount of applied mineral fertilizers, and keeping residues of cotton on the field in the form of organic matter contribute to reducing emission of carbon dioxide into atmosphere;

- introducing indicators of crop rotation to indicate positive changes of the natural nitrogen amount in the soil. It would allow both to define levels of reducing mineral fertilizers to accumulate more carbon in combination with natural nitrogen in soil;

- indicating of using food base that is created due to the increase of areas under perennial grasses, farmers can get high economic returns through increased livestock production. Thereby reducing the burden on agricultural land, and obtaining organic matter by livestock develop conditions favourable for biodiversity conservation;

- indicating grow of poplar has utility from the standpoint of air purification, wind protection, recreation and aesthetic perception of agricultural landscapes;

- the main feature of growing poplar are main trunks as building material. Thus, there is carbon sequestration, since only part of wood is used as fuel.

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D25 The MIMOSE approach to support large-scale statistics on forest ecosystem services

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ABSTRACT

In the last decades, Mediterranean landscapes have been transformed by anthropogenic processes, such as changes in land use and climate. In particular, forest transition in mountain areas, and urban sprawl in lowlands could strongly undermine the ability of ecosystems to provide benefits over time. Under these changing conditions, forest ecosystems have reduced their functionality, resilience and stability. In this way, important forest ecosystem services, such as timber, non-wood products, climate regulation, biodiversity conservation, and cultural and spiritual values, will be eroded if forest resilience is not effectively maintained. Accordingly, forest planning is called to spatially allocate management alternatives and strategies in order to balance the final provision of forest goods and services demanded by local communities with the ecosystem functionality. In this study, we implement the "Multi-scale mapping of Ecosystem Services" (MIMOSE) approach in Sicily region to (i) assess the forest ecosystem services bundle over a 20- year time period; and (ii) evaluate how ecosystem services can be balanced to support sustainable forest management at the regional scale. Through the MIMOSE approach, at first we spatially assessed, in biophysical and monetary terms, timber provision and carbon sequestration, according to three forest management alternatives: business as usual conditions, maximizing economic incomes, and prioritizing conservation purposes.We then calculatedthe trade-offs among these ecosystem services and carried out a cross-case analysis. Finally, sustainable future-oriented strategies for forest landscape planning were identified, in agreement with the best balanced set of ecosystem services. The most important outcomes are the following: (i) timber provision is in general a conflicting service, especially when adaptation strategies are promoted; (ii) the best balanced set of forest ecosystem services is achieved by adopting a more conservative approach; and (iii) the bundle of ecosystem services is generally influenced by ecological and management conditions (e.g., differences among forest landscapes in the two regions), and is sensitive to harvest intensity and frequency, as well as to the length of the period used for the simulation. The MIMOSE approach demonstrated to be a spatially-explicit tool particularly suitable to support landscape planning towards balancing forest ecosystem potentialities with local communities' needs. Moreover, the approach can be considered an easy-to-use and replicable tool to cope with sustainable development goals in the Mediterranean area. In this light, the MIMOSE approach can improve the monitoring and assessment of ecosystem services demand and budget from local to national scale, thus contributing to the statistics and environmental accounting for the forestry sector.

Keywords: MIMOSE, forest ecosystem services, forest management and planning, regional scale.

PAPER

1. Introduction

Forest ecosystems are important sources of goods and services (hereinafter Forest Ecosystem Services;FES) for people worldwide, such as(i) timber and non-timber products provision,(ii) habitats and species conservation, (iii) regulation ofthe biogeochemical regimes, and (iv) enhancement of cultural and recreational aspects of a given landscape (for the Italian context, e.g., Vizzarri et al. 2015a). The FES availability depends upon the forest resilience, health and stability (e.g., Proença et al. 2010). Especially in Mediterranean landscapes, often degraded by human-driven interactions, the forest resilience is undermined, and the associated benefits for local communities reduced. Considering these challenging conditions, forest management and planning are called to balance the FES availability with the ecological and socio-economic aspects at local scale. In particular, the acquisition of more detailed information (e.g., chemicals, soil parameters),and the implementation of both advanced tools (e.g., LiDAR techniques) and innovative approaches (e.g., agent-based models) are increasingly requiredto support forest management inmonitoring the spatial and temporaldevelopments of forest landscapes, and in turn quantifyingtherelated changes in termsof FES provided, both in biophysical and economic terms. Theuse of tools such asthe "Integrated Valuation of Ecosystem Services and Trade-offs" (InVEST) or the "Artificial Intelligence for Ecosystem Services"(ARIES), has proven to beeffective in several cases (Posner et al. 2016; and Villa et al. 2014, respectively). Nevertheless, the lack of input data on forest structure, health and productivity, the weak integration between the current management and the socio-economic conditions, and the absence of economic statistics on ES availability strongly reduce the effectiveness of forest management and planning, especially in theItalian landscapes. Tofacethese situations, the "Multiscale Mapping of Ecosystem Services" (MIMOSE)approachwasdeveloped and implemented forforest ecosystems in the Molise region, Central Italy, to map timber provision and carbon sequestration, and assess the related trade-offs (Bottalico et al. 2016). In thiswork, we applied the MIMOSE approach to the forests ofthe Sicily region(Southern Italy),with the aim of highlightingconstraints and potentialities for large-scale FES assessment, and mappingandcomparing different Mediterranean contexts.

2. Material and methods

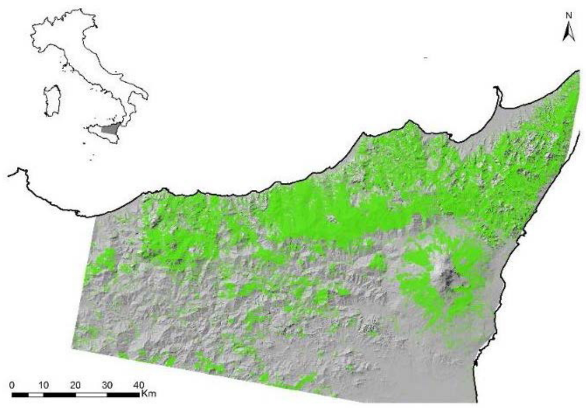
2.1 Study area

The study area is located in Southern Italy, in the north-eastern part of the Sicily region, and covers 962,300 ha (Figure 1). The elevation ranges between the sea level to 3,350 m a.s.l. (Etna volcano). The climate is Mediterranean along the costs, and temperate on the inland reliefs (Rivas- Martinez 2004). Forests and other wooded lands cover approximately 21% of the study area (Figure 1). Downy oak (Quercus pubescens Willd.) (35% of the total forest area), Turkey oak (Q. cerris L.) (13% of the total forest area), and European beech (Fagus sylvatica L.) (9% of the total forest area) are the most widespread Forest Categories (FCs). Plantations cover 17% of the total forest area (Cullotta and Marchetti 2006). The study area is characterized by the presence of protected areas (60% of the total forest area), such as e.g., the Madonie, Nebrodi, and Etna Regional Parks, and several sites belonging to the Natura2000 Network. Part of the forest area (47%) is not actively managed, because mostly covered by neoformation forests, degraded forest lands, often abandoned, and coppice forests exceeding the standard rotation age(mainly left to natural evolution). The remaining area is actively managed, and covered by high andcoppice forests(31% and 20% of the managed forest area, respectively), and forests under "special" management conditions (2% of the managed forest area; i.e. chestnut and cork oak forests).

2.2 The MIMOSE approach

MIMOSE is a spatially-explicit approach to assess, in both biophysical and economic terms, differentFES and related trade-offs in the Mediterranean region, according to alternative management strategies. In the present work, we implemented the MIMOSE approach through the following steps: (i) alternative management strategies (i.e. business-as-usual, BaU; nature conservation, NC; and wood production, WP)

Figure 1. - Map of Italy (left-top) and zoom on the study area. The forest area is reported in green



were applied at the Forest Management Unit (FMU) level in the study area;(ii) the modified InVEST modelwas implementedto quantify and map timber production and carbon sequestration over a 20-year period (from 2015 to 2035);and (iii) a qualitative trade-offs analysis was carried out. Finally, the results from this study were compared with those obtained from Bottalico et al. (2016), in the case of the Molise region. The trade-offs analysis concerns the comparison between the economic benefits derived by FES during the simulation periodby adopting different management strategies (BaU, NC and WP). As main economic benefits, the Total Net Present Value (TNPV; Euro), the Total Social Cost of Carbon (TSCC; Euro), and the Total Ecosystem Services Value (TESV; Euro) were calculated for timber production, carbon sequestration, and their sum, respectively. See Bottalico et al. (2016) for further details about the methodology adopted in this study.

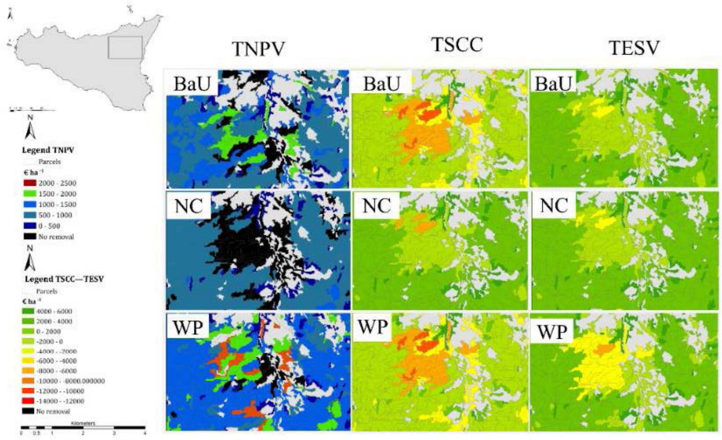
3. Results and discussion

3.1 Forest ecosystem services provision and trade-offs

In the case of timber production, the resultsshowthat the total amount of wood harvested in the area during the 2015-2035 period is 8.8 million m3, 4.7 million m^3, and 12.9 million m^3 for BaU, NC, and WP management strategy, respectively. The corresponding TNPV is 140.6 million Euro, 70.4 million Euro, and 236 million Euro for BaU, NC, and WP management strategy, respectively. In particular, the average amount of timber removals corresponds to 44.2 m^3 ha^{-1}, 23.7 m3 ha^{-1}, and 64.7 m^3 ha^{-1} for BaU, NC, and WP management strategy, respectively. The corresponding average NPV is 707.6 Euro ha-1, 354.4 Euro ha^{-1}, and 1187.3 Euro ha^{-1} for BaU, NC, and WP management strategy, respectively. In the case of carbon sequestration, the resultsshowthat the total amount of carbon stocked in the area during the 2015-2035 period is approximately 1.4 million Mg C, 5 million Mg C, and -2.7 million Mg C for BaU, NC, and WP management strategy, respectively. For carbon sequestration, the negative values correspond to the carbon removed exceeding the current increment during the simulation period. The corresponding TSCC is 83.8 million Euro, 306.1 million Euro, and -167.2 million Euro for BaU, NC, and WP management strategy, respectively. In particular, the average amount of carbon stock increasesof 6.8 Mg C ha^{-1}, 24.9 Mg C ha^{-1}, and decreases of-13.6 Mg C ha^{-1} for BaU, NC, and WP management strategy, respectively. The corresponding average SCC is 421.6 Euro ha^{-1}, 1539.9 Euro ha^{-1}, and -841.4 Euro ha^{-1} for BaU, NC, and WP management strategy, respectively. TESV is 224.4 million Euro, 376.5 million Euro, and 68.8 million Euro for BaU, NC, and WP management strategy, respectively. In particular, the average TESV is 1129.2 Euro ha^{-1}, 1894.3 Euro ha^{-1}, and 345.9 Euro ha^{-1} for BaU, NC, and WP management strategy, respectively.Figure 2 shows some details related to TNPV, TSCC, and TESV in a specific locationof the study area.

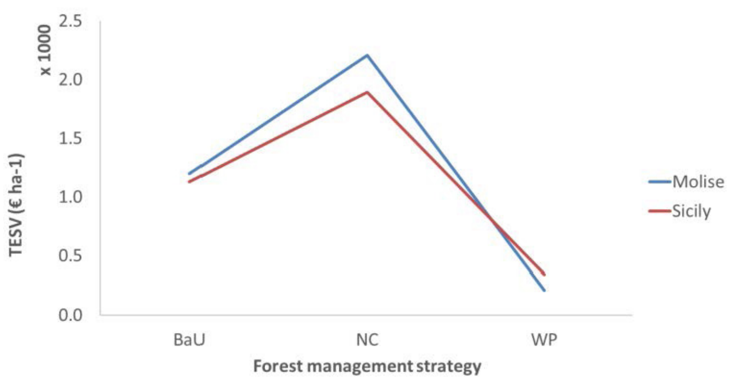
In general, TESV increases of approximately 67.8% when passing from the baseline (BaU) to the more conservative forest management strategy (NC), and decreases of approximately 69.4% towards a more productive strategy (WP). This dichotomous trend is explained by the combination of the forest management strategies (in terms of forest management system applied, harvesting intensity and frequency) and the characteristics of forest stands,such as, e.g., the averagestand age, which is 22 years (in the investigated stands),very close tothe theoretical end of the rotation period in coppice forests, depending on FC (e.g., 15-20 years;Rey et al. 2002). This aspect implies that certain simulated forest practices(e.g., the final cut in coppice with standards forests vs.no forestry intervention in coppice forests) may create a borderline between an increased TESV when adopting a more conservative approach, and a reduced TESV whenimplementing a more productive strategy,ofthe same magnitude. For example, in the case of downy oak forests (covering more than 35% of the total forest area), the reduction of the area subjected to the final cut in coppice forests with standards release (-40.4%) results in an increased TESV (+15.9 million Euro) when passing from BaU to NCmanagement strategy. On the contrary, for the same FC, increasing the area of coppice forestswith standards release (+8.1%) results

Figure 2 - Maps showing the spatial distribution of total Net Present Value (TNPV; Euro ha^{-1}), Total Social Cost of Carbon (TSCC; Euro ha^{-1}), and Total Ecosystem Services Value (TESV; Euro ha^{-1}) for the simulated forest management strategies (BaU=Business as Usual conditions; NC=Nature Conservation; WP=Wood Production) in the Etna volcano surrounding area



in a strong reduction of TESV (-56.2 million Euro),when passing from BaU to WP management strategy. This discrepancy is due to the allocation of a large portion of the downy oak forest areaconverted from coppice to high forest, and left to natural evolution, in the caseof the NC management strategy over the considered period (approximately 40%). In this way, thecarbon accumulation in above-ground biomass in the future is facilitated (cf.Luyssaert et al. 2008). Concerningthe European beech forests (8.5% of the total forest area), thesimulated forestry interventions result in a decreased TESV (-25.7 million uro), when passing from BaU to WP management strategy.This may be due to the fact that e.g., although most of the European coppice with standards forests are actively managed (i.e. harvested), the increasing of TNPV still remains lower in comparison with the decreasing in TSCC, when passing from BaU to WP management strategy. Accordingly, the period chosen for simulations (i.e. 20 years) seems to be short in order to effectively understand the future development of forest stands, and in turn to assess the implications of some forestry interventions on TESV, such as e.g., natural evolution, conversion of coppice forests to high forests. The results show the same trend as synthesized in Bottalico et al. (2016) for Molise region.Figure 3 reports a cross-case comparison of average TESV per hectare between Molise region and Sicily case study.

Figure 3 - Box plot showing the main differences in terms of TESV (ha-1) between both the forest management strategies (BaU=Business as Usual; NC=Nature Conservation; WP=Wood Production), and the two Mediterranean case studies in Italy (i.e. Molise region and Sicily case study)



The average TESV per hectare is higher in the Molise region for the NC management strategy than inthe Sicilian case study,while it is lower for the WP one. This mainly derives from the presence of younger stands, and the implementation of current less intensive forestry interventions in the Sicilycase study, in comparison with the conditions found in the Molise region. In addition, the harvesting rates during the simulation period for the NC management strategy are lower for Sicilian forests, if compared with the Molise ones (55% vs. 62%). On the other hand, the harvesting rates simulated for the WP management strategy are higher for Sicilian forests, if compared with the Molise ones (88% vs. 83%).This is due to the fact that e.g., the European beech forests in the Sicilian case study are mostly located at high elevations, and withinprotected areas. As a consequence, less intensive forestry interventions for these stands were hypothesized when simulating the stand development in the NC management strategy.

The results mainly show that timber provision and carbon sequestration (i.e. climate change mitigation) are in general conflicting services. The biomass removal originateshigh timber revenues (TNPV) and low carbon stock (TSCC), at least in the short run. This indicates that the 20-year simulation period should be extended in order to further understand the development of forest landscapes over time, and find a more balanced TESV. The forestry interventions have to be tailored on the interaction betweenforest management,the biophysical characteristics of the forest stands, and the objectives to be reached (e.g., maximization of timber provision, adaptation strategies). In particular, the combination of the harvesting frequency and intensity with the ecological status of forest stands strongly influences the future FES provision. This is particularly amplified in young stands, whereincreasingharvesting intensity may lead to a strong reduction of biomass, and subsequently of carbon stock in the short period. Especially in Mediterranean forest landscapes, which are often abandoned or degraded (e.g., Scarascia-Mugnozza et al. 2000), forest management and planning must balancetheeconomic incomes with increasedresilience and stability of forest ecosystems (e.g., Vizzarri et al. 2015b). This implies that forest management and planning strategies in these peculiar contexts should be aimed at (i) effectively implementing productive- oriented forest management strategies in healthy and stable forest stands; (ii) reducingharvesting intensity and frequency in less productive forest stands (i.e. conversion to high forests; natural evolution); and (iii) continuously monitoring themanagement outcomes, also with the aid of simulation tools to evaluate future FES provision at different spatial scales.At broader scale, the ecological footprint (China; e.g., Zhao et al. 2009), and the CICES classification (EU; Maes et al. 2016), were proposed as key approaches (i.e. indicators' frameworks) to further understand the human impact on natural capital, and improve the ES flow monitoring.

4. Conclusions

This study demonstrates that MIMOSE is an integrated approach for assessing the influence of alternative management strategies on the FES provision, as well as for understandingthe forest ecosystem dynamics,from the landscape to the regional scale, thus contributing to the statistics and environmental accounting for the forestry sector. In MIMOSE, the integration of spatially-explicit information (biophysical characteristics) with an expert-based approach (management strategies) plays a key role in supporting forest management and planning (Bottalico et al. 2016), at least in the following three ways: (i) current and future-oriented statisticson the development of forest stands are provided; (ii) a spatial distribution (location) of FES is given; and (iii) the effects of forest management alternatives on forest resources is assessed over space and time. Accordingly, the MIMOSE approach can be replicated in other Mediterranean contexts, with relatively low costs, since it is an effective tool for supporting decisionsaimed at implementing more adaptive strategies in changing landscapes, and balancing environmental constraints with socio-economic needs.Finally, the MIMOSE approach is consistent with the need to assess and map ES at multiple scales, in order to detect and monitor the relationships between local communities and natural resources, in terms of e.g., ecosystem structure, processes and final benefits provided (stocks and flows). This is crucial to promote and implement the sustainable development goals, especially in the Mediterranean region (e.g., www.planbleu.org).

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D25

Protection and enhancement of the coast of Mostaganem (Algeria): preliminary restoration study

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ABSTRACT

The project aims to identify the quantifiable and permanent variables to assess the overall development of the marine ecosystem of Mostaganem. This identification is based on a methodological approach of dialogue, which is between the social sciences responsible for the identification and characterization of sustainable development in the particular context of Mostaganem marine ecosystem and marine scientists responsible for the representation and quantification of such knowledge. This question is to obtain operational elements for managers in charge of the sector. It therefore underpins the thinking and detailed position on the nature and operation of the system of sustainable management of the marine ecosystem in Mostaganem. The study area is a marine ecosystem known for its biodiversity and its sites of biological and ecological interest. This study provides results on the characterization of Mostaganem coast, diagnosis and analysis of environmentally sites bioecologique, tourism, and socio-economic challenges. This is due to human activities and tourism development alternatives for sustainable development with regard to physical balance and landscape quality of the site. This research used a baseline study and proposes solutions to development problems facing initiatives Mostaganem Marine ecosystem development.

Keywords: Marine ecosystem, Algeria, coast restoration, sustainable development, Cheliff Estuary

PAPER

1. Introduction

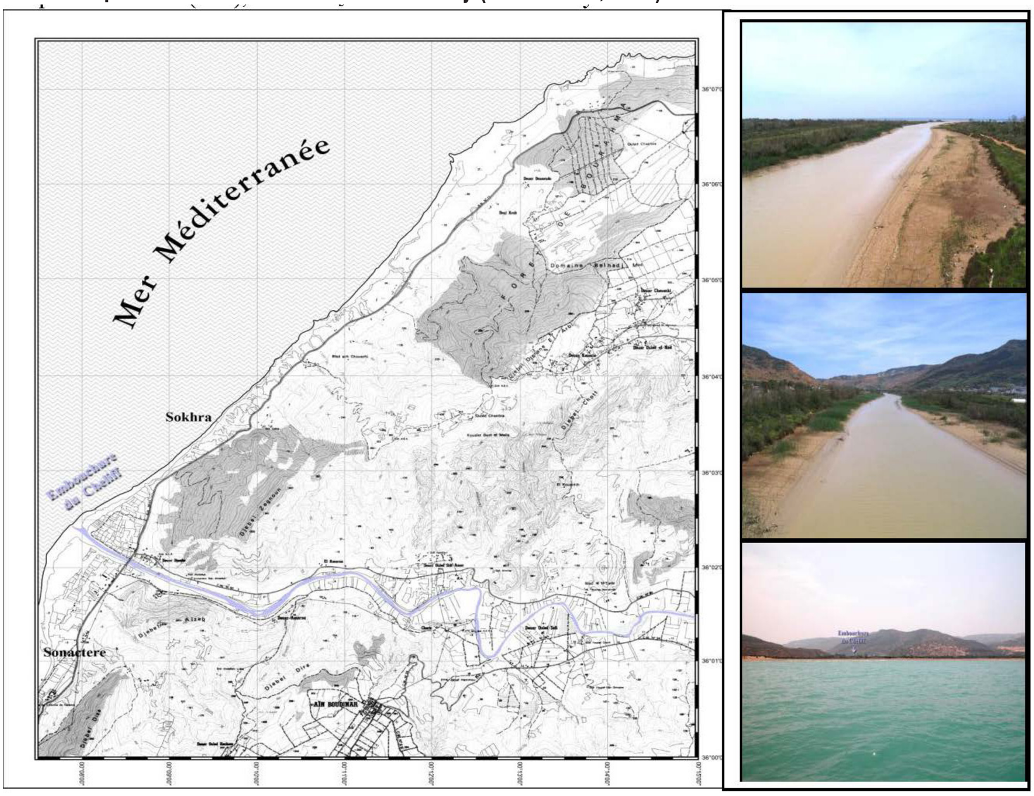
The Cheliff River (Fig. 01) is the largest River in Algeria; it's 700 km long with a flow rate of about 2700 m3/s (Bouzelboudjen & Mania, 1989; Gagneur & Kara, 2001; Al-Asadi et al., 2005, Kies et al., 2012; Kies & Kerfouf, 2014a). It passes through different wilayas like as Mostaganem, Relizan, Ain-Defla and Cheliff. The River of Cheliff is dynamic, extremely variable and plays crucial roles within the structure, the function and also the evolution of the marine coastal of water ecosystems of the bay of Mostaganem (Kies, 2015). Nutrient availability at Cheliff River controls the abundance and structure of phytoplanktonic populations at the bay of Mostaganem. Eutrophication problems are clearly identified in this body of water with micro invasive algae covering its surface at certain times of the year (Kies et al., 2012; Kies & Kerfouf, 2014a; Kies, 2015). Some work on the Cheliff River have indeed established direct links between pollution of the sea state and domestic and industrial wastewater discharges directly discharged into the Cheliff River without any treatment (Bouzelboudjen & Mania, 1989; Kies & Taibi, 2011; Kies et al., 2012; Kies & Kerfouf, 2014a,b; Kies, 2015).

Bay Mostaganem is located in the Algerian west coast. This bay receives urban and industrial discharges via the hydrodynamics of water, swells brewing phenomena and water circulation. Because of the intensification of effluent discharges and many leisure complex construction, the Bay of Mostaganem which was in the past a little disturbed natural environment, is about to turn into a real dump of urban waste. The objective of this study is to assess the physico-chemical quality of surface waters of this bay. Thus, a temporal and spatial study has tracked the seasonal changes in temperature, salinity, pH, dissolved oxygen, ammonium, nitrite, ortho phosphates, Suspended Mater (SM), of BOD5 and COD from January 2014 till December 2015.

2. Materials and methods

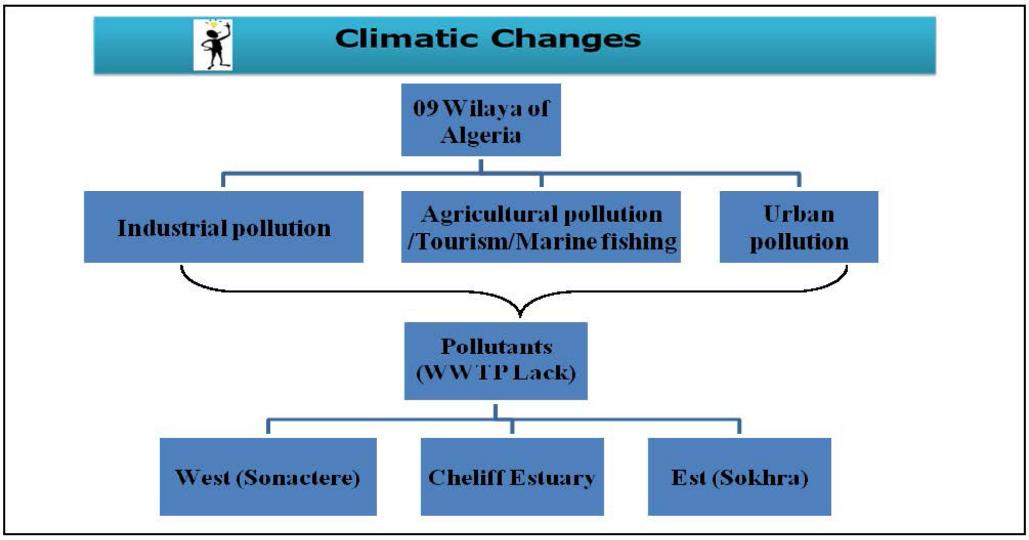
We selected two different stations. The first one "Station 1" located in the River of Cheliff (Sour and Sidi Belattar). The second "Station 2" was fixed on the bay of Mostaganem, which is divided in two regions, the Sokhra bay at the Est of Estuary of Cheliff River and Sonactere bay at the West of the same Estuary (Fig.01 & Fig. 02). Twenty four (24) samples were collected at each station during the studied period (from January 2014 until December 2015).

Figure 1. - Mostaganem map with Cheliff River (colored in blue) and beaches of Sonactere and Sokhra, with the photos of Cheliff River and its estuary (Kies & Taibi, 2011)



We used identification key for species determination (Bougis, 1974) and fomol solution (70%) for fixation of phytoplankton specimens. Algal taxa were identified using an inverted microscope at magnifications of x 400 (Vollenweider, 1971; Rodier, 1996).

Figure 2. - General diagram of the behavior of pollutants in the Cheliff River, the Cheliff estuary and the Mediterranean Sea) (Kies et al. Present research)



3. Results and discussion

3.1. Phytoplankton abundance

A total of 70 phytoplankton species were identified during our survey in the two stations. The dominant cluster is Chlorophyta (along the period of study particularly in summer time) followed by Chrysophyta cluster that proliferates in autumn season 2014. At Station 1 (Tab. 01), the maximum of Cyanophyta (blue-green algae) was recorded in May 2014, and the minimum in January 2015. At Station 2 (Tab. 01), the maximum of blue-green algae was recorded in November 2014, and the minimum in February 2015.

Euglenophyta species were found at Station 1 (River of Cheliff), during the sampling period. A maximum was recorded in August 2014 and the minimum in January 2015. Euglena species were found too during the sampling period at Station 2 (Bay of Mostaganem) with value ranged between a maximum at July 2014 and a minimum at December 2015. The Green algae (Chlorophyta) were dominant at Station 1 than at Station 2 (with 42 and 38 species respectively). In May 2014, the maximum number of green algae was recorded at both stations. The minimum was recorded in January 2015 at Station 1 and in March 2015 at Station 2. The maximum number of diatoms (Bacillariophyta) was recorded in June 2015 at both stations. Low numbers of diatoms were found in November 2014 at Station 1 and in March 2014 at Station 2 during the sampling period. This phylum was found in five of ten occasions at Station 2. The Cheliff River was powerfully dominated by chlorophyll (Gagneur & Kara, 2001; Al-Asadi et al., 2005), whereas the bay of Mostaganem had equal proportions of diatoms (i.e.: *Nitzschia acicularis, Cyclotelle meneghiana*) and chlorophyte (i.e.: *Oocystis, Scenedesmus*).

Table 1. - Seasonal distribution of microalgae in the two stations studied

Phyla	Station 1		Station 2		Genera dominated at 1 & 2	Rare Algae At Sation 1 (Cheliff River)
	Max	Min	Max	Min		
Chrysophyta	06.2015	11.2014	06.2015	03.2014	Nitzschia Navicula Cyclotelle Gyrosigma	Melosira granulata
Chlorophyta	05.2014	01.2015	05.2014	03.2015	Strombomonas Scenedesmus Oocystis Dictyococcus Tetraedron Coelastrum	Pediastrum Tetraedron Staurastrum Cosmarium Monoraphidium Chlamidomonas
Cyanophyta	05.2014	01.2015	06.2015	01.2015	Oscillatoria subsalsa Nostocopsis Microcystis	Oscillatoria tenuis
Euglenophyta	08.2014	01.2015	07.2014	12.2015	Euglena	Trachelomonas

3.2. Connectivity between river and the sea

A follow-up in 2014-2015 of pollution indicators (temperature, pH, dissolved oxygen, ammonium, nitrite, ortho phosphates, BOD5, COD, and SM) in surface waters was carried out in order to estimate the quality physicochemical of the Bay of Mostaganem. The results revealed the existence of a water contamination by domestic and industrial wastewater from the urban area of the nine provinces of the country carried by the Cheliff River marked by significant spatial and temporal variation. By analyzing the graphs of the variables obtained from January 2014 till December 2015 (Fig.03), we have a tendency to notice for this era "of contact" that nutrients [NO2 (nitrites), NO3 (nitrates), NH4 (ammonia), Ptot (total phosphorus), SiO2 (silicates)] area unit terribly dependent parameters with Chlorophyll. a, that support a rise of OM (organic matter) described by the DBO5 (biological demand for oxygen), whereas parameters [OD (dissolved oxygen) and T° (temperature)] area unit associated with the supply of the suspended matter (SM) and to the turbidity (Turb). Since there is a consumption of the varied nutrients (N, P, Si) by the microflora species with nearly identical concentration. Therefore, there is a phytoplanktonic diversity for the period of connectivity between the watercourse and the ocean.

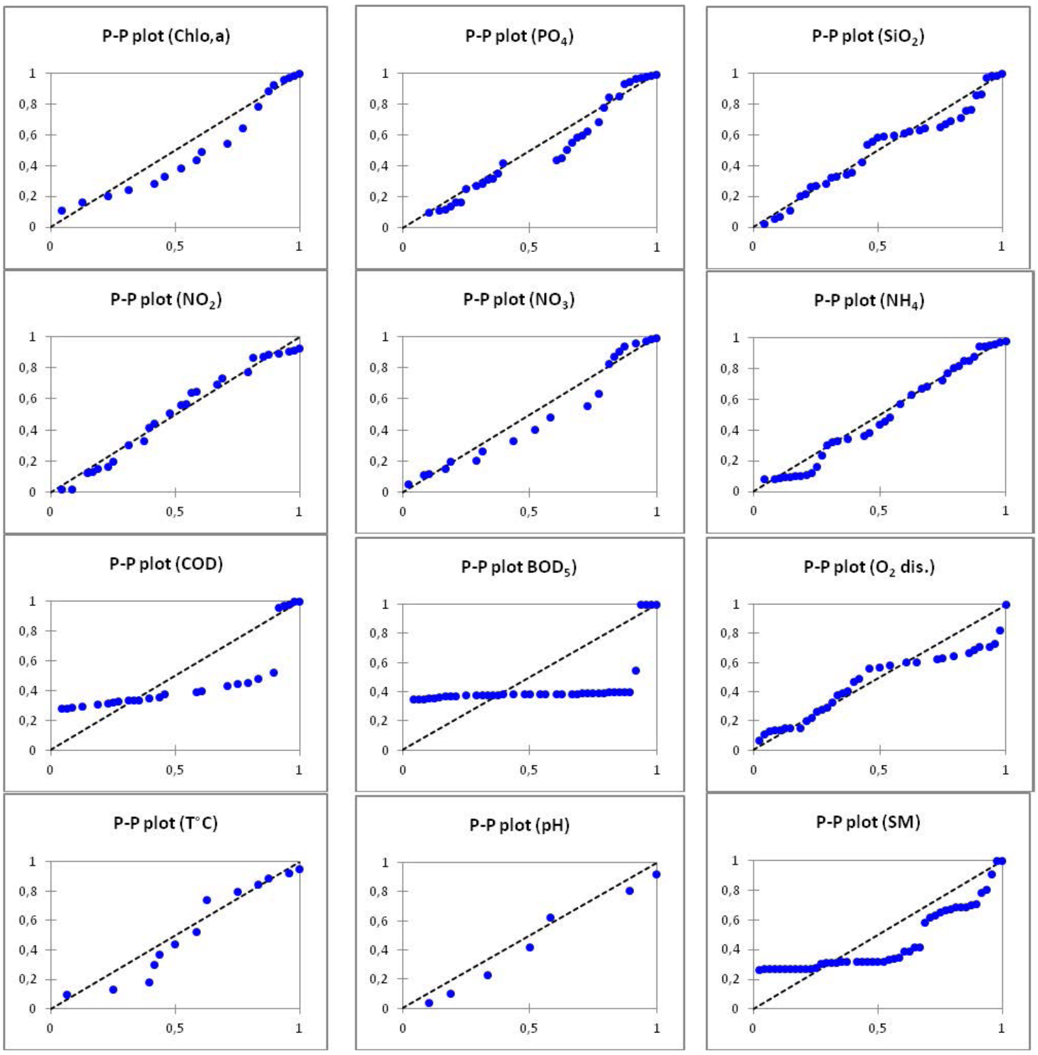
The discharge of wastewater into the environment may cause a rise in temperature. The temperature variations curves of the companies studied have the same evolution, with different amplitudes. The most significant differences are observed in February and April, and the lowest was in rainy season (Bouzelboudjen & Mania, 1989). This relative stability reflects thermal homogeneity of the waters of the bay (Kies et al., 2012; Kies, 2015; Elegbede et al., 2015). Most vital reactions are slowed or even stopped by a significant lowering of the temperature. In contrast, temperature increases can have effects to kill certain species, but also to promote the development of other species resulting ecological imbalance (Kies & Taibi, 2011; Kies et al., 2012; Kies & Kerfouf, 2014b; Bu et al., 2014; Kies, 2015). The pH of the

Table 2 - Variations of Physical and Chemical Parameters

Descriptive Statistics	Obs.	Min	Max	Mean	SD	CV
T	48	8	27	14,13	6,36	2,22
pH	48	7.4	7.9	7,70	0,18	43,43
Dissolved oxygen	48	3.9	9.1	7,54	1,71	4,40
Suspended Matter (SM)	48	34	26294	5 330,50	8 883,58	0,60
SiO2	48	1.2	21.4	10,69	6,10	1,75
COD	48	10	170	67,38	61,00	1,10
BOD_5	48	2.1	38.2	14,41	12,86	1,12
COD/ BOD_5	/	3,22	4,45	4,26	4,51	0,98
NO_3	48	4	21	10,63	5,07	2,10
NO_2	48	0.13	4.8	1,14	1,53	0,74
NH_4	48	0.22	11.1	4,41	4,89	0,90
PO_4	48	0.03	2.06	0,88	0,75	1,17

water of Mostaganem bay is relatively alkaline. The seasonal average values are between 7.1 and 8.3 (Fig. 03).

Figure 3 - Monthly changes of the physicochemical parameters during the periods of contact between the River (Chellif) and the sea (Mostaganem shallow water area) during 2013 and 2014



This slight alkalinity shows the influence of sea water generally basic compared to those of continental origin. The highest pH values were observed in April, during the period of strong marine influence and the lowest in June and October, during the rains and floods. For dissolved oxygen, the average values of the dissolved oxygen content of the surface water of the Mostaganem bay fluctuate between 3.9 mg/l and 9.1 mg/l (Fig. 03 & Tab. 02). The lowest levels are obtained in February (Great dry season), related to the consumption of oxygen by the organic matter from wastewater traces. As for ammonium, nitrites and orthophosphates, the high levels of these nutrients observed in the Bay of Mostaganem result of several phenomena whose discharges of domestic and industrial wastewater; ocean and River inputs; the "wash out" by chemical fertilizers rainwater spread on industrial plantations.According to (Kies & Taibi, 2011; Kies et al., 2012; Kies & Kerfouf, 2014b; Bu et al., 2014; Kies, 2015; Elegbede et al., 2015) the concentrations of nutrients in surface waters vary regularly under the influence of border areas (watershed, streams, ocean ...). The discharge of the Cheliff River that is rich in nutrients to the sea of Mostaganem, could explain the high values of the NH4 +, observed in long dry season. The contents of NH_4^+, NO_2^- and PO_4^{3-} high, observed in the rainy season and floods, is explained by the massive arrival in the Bay of wastewater settlements, rainfall runoff, combined with water floods of the Cheliff River (Fig. 02-03 & Tab. 02), rich in nutrients (Kies et al., 2012; Kies, 2015). The pollution level in nutrients determined in this study is relatively high compared to the east side of Mostaganem rating compared to the estuary Cheliff; this classifies the Bay of Mostaganem and Cheliff River among eutrophic (Kies & Taibi, 2011; Kies et al., 2012; Kies & Kerfouf, 2014b; Kies, 2015).For parameters BOD_5, COD and SM in general, the water of the bay are heavily loaded with solid particles and matter in suspension. The highest values were obtained in February and April, during the long dry season and those in the lowest period of rains and floods. This could be explained by the fact that in rainy season, the water circulation becomes weak and suspended particles tend to settle. COD and BOD5 record the greatest values in February and April, during the long dry season, indicating organic contamination of the waters of the bay. The smallest values are obtained in periods of rains and floods.

To characterize the nature of the pollution and degradation of performance, the COD/BOD5 ratios were calculated (Tab. 02). According to (Kies et al., 2012) if the ratio COD/BOD5 is greater than 3, the effluent will be predominantly chemically biodegradable. This study shows that the reports COD/BOD5 are between 3.22 and 4.45; which corresponds to industrial wastewater characteristics with difficult degradation. The descriptive statistics that include all biological and physico-chemical data are presented in Table 02. Between the different stations (Cheliff River, Cheliff Estuary and the Bay of Mostaganem) and different months, the density difference was such that it was necessary to use a logarithmic ordinate for the graph. Graphics univariate quantitative data composed of 48 rows and 16 columns which were rescale from 0 to 100.

4. Conclusions

The results of this study show that the realm close to the Cheliff watercourse would be representative of reference conditions of the Cheliff estuary and also the bay of Mostaganem for its restoration. The class Diatomophyceae and Conjugatophyceae are indicators of pollution with ammonia, but the Dinophyceae are indicator of intense mineralization of the medium. The physicochemical and hydrobiological analysis of samples from the watercourse, the ocean and also the estuary in periods of flooding showed that Cheliff watercourse pours important quantity of pollutants within the watercourse mouth area. Contaminated waters issued by nine wilayas of the country are fed by the Cheliff River to empty into the Bay of Mostaganem. The pollutants are urban, agricultural and industrial.

The study discovered the presence of nitrogenous substances, phosphorus and sulfur; suspended matter (organic and inorganic) is significant. Consistent with the scientific observation conducted between January 2014 and December 2015, detected pollutants have adverse effects on wildlife and on the marine life of the bay of Mostaganem, notably within the area of the mouth of Cheliff. Owing to the winds of the East and coastal ocean currents that result, polluted waters are moving in times of floods to the west coast and might sometimes reach the beach of Sablettes (December 2015 wherever precipitation reached 156.5 mm). The large quantities of solid particles found in the water prevent the penetration of daylight, for this, the development of the flora is reduced to a minimum in the area of the mouth as is confirmed by the observation during marine's immersion. Additionally, it is probable that the flora like Posidonia oceanica meadows cannot be established within the space of the study due to the robust horizontal currents and the nature of the substrate (sandy bottom mixed with clay). This vegetable poorness so involves a really low diversity of fauna.

Companies Wilayas upstream of the Cheliff River minimize production charges by rejecting waste that can makes damage in the Wilaya of Mostaganem (downstream). So the problem of pollution from Cheliff watercourse isn't a matter of "all or nothing" however rather a case of "more or less". This can be explained by the fact that the results of the pollution increase with the degree of contamination and also the price of non-pollution decreases with it. This work showed the influence of Cheliff watercourse on the marine ecosystem, as well as negative effects on the phytoplankton and plants life, that has a real disturbance on abundance.

5. Recommendations

The intervention of the authorities is essential to reduce pollution at the optimum level. To reach acceptable levels, they should be equipped with policy instruments such as the imposition of a solution on polluters and victims of pollution which minimize costs that they bear together. Each Wilaya upstream to increase its interest cost of abatement and the Wilaya downstream to increase the cost of the damage; the introduction of compulsory treatment of wastewater from urban and industrial activities before they are released into the environment; promotion of scientific knowledge through research and information; dissemination of scientific knowledge and environmental education; revision of standards relating to water pollution, taking into account the concentration of the pollutant because the polluter can increase the amount of water that contains a polluting effluent that meets the standard, so they have consider the damage generated by the concentration of the pollutant per unit of time, not only the amount of the pollutant; establish a land use plan (and coastal) or physical planning; this instrument would, in relation to the possible establishment of new heavy and polluting industries, to prevent pollution of the coast of Mostaganem. It takes thorough foundation for economic demand and ecological data studies, namely climate change, the susceptibility of the soil and plant pollution, hydro-chemical, bio-chemical and hydro-biological. The economic argument should be directly related to the importance of the environment.

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D25

Measuring landscape diversity and fragmentation in EU agricultural areas from LUCAS Data

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ABSTRACT

Landscape is characterised by interaction of natural processes and cultural feature. Human activities affect landscape and landscape linear elements such as hedges, dry stone walls, ditches, roads and railways influence biodiversity; landscape analysis requires an appropriate set of information able to describe land cover diversity and fragmentation. Since 2006, Eurostat carries out an area frame statistical survey on the state and the dynamics of land use and cover in the European Union called the LUCAS survey (Land Use/ Cover Area Frame Survey). The LUCAS surveys are completed in-situ every three years. LUCAS provides information for monitoring a range of socio-environmental challenges, such as land take, soil degradation, and the environmental impact of agriculture or the degree of landscape fragmentation. The latest LUCAS survey, carried out in spring - summer 2015, covers all the 28 EU countries and observations on more than 270 000 points. To this extent, we consider the latest available data collected by the LUCAS surveys in the years 2009 and 2012. The analysis can be generalised to LUCAS data 2015 when available.

The aim of the paper is to attempt of using the data collected by LUCAS survey for landscape analysis in an evolving system such as the EU countries, providing an appropriate set of information able to describe the landscape diversity and its fragmentation in agricultural land, jointly with the changes in land cover and in land use. In particular the paper shows an example of use of the informative capacity of LUCAS survey in describing and monitoring the variation of the territorial structural elements.

Keywords: landscape fragmentation, transect, data analysis

PAPER

1. Introduction

The impact of human activities on the land cover has grown enormously, being able to alter entire landscapes with important ecological consequences. A landscape refers to an area of land whose character and functions are defined by the complex interaction between natural processes (relief, soil type, water availability, climate, biological diversity) and cultural features (human intervention through agriculture, forestry, rural policies, construction and economic structures). European countryside is also characterized by structural linear elements that portray the joint role of nature and humankind on environment. The presence of grass verges, hedges, dry stone walls, ditches and other semi-natural linear elements is considered as an important factor to biodiversity, in some cases helping to promote ecosystem services (such as pollination or pest control), in others constituting negative barriers that could limit the movement of species. In this sense can be intended, for example, all those linear elements which have a dissecting nature (such as roads, railways and aerial cables), that are closely linked to population and infrastructure developments, and impact on biodiversity.

The analysis of these topics, in an evolving system such as the EU countries, requires exploiting an appropriate set of information able to describe the landscape diversity and its fragmentation in agricultural land, jointly with the changes in land cover and in land use. To this extent, we consider the data collected by the LUCAS (Land Use and Cover Area frame Survey) surveys in the years 2009 and 2012. The analysis will include LUCAS data 2015 when available.

LUCAS survey is carried out at EU level every three years; it is based on a sample of about 270 thousands geo-referenced points, selected from a frame of more than 1 million of points that belong to the intersections of a 2 square km grid built all over the EU territory. LUCAS is carried out by direct observations of surveyors in a small area centred on the selected point (with a width of 20 square meters). For each of them information on land cover (i.e. the bio-physical coverage of land, like natural areas, forests, buildings and roads or lakes) and of land use (i.e. the socioeconomic use that is made of land, like agriculture, commerce, residential use or recreation) is collected; it is allowed to get a main and a secondary land cover and land use codes. Moreover, the surveyors take a series of photographs of the point itself, and of what in all four cardinal directions (north,

[1] Contribution to the ICAS VII: Rough draft on gender and rural women's empowerment in relation to DW/rural employment.

south, east and west); some specific information are also collected as "ad hoc modules" added in each survey (top soil sample in 2009 and the transects in surveys 2009 and 2012).

The aim of the paper is to attempt of using the data collected by LUCAS survey for landscape analysis and to check the performances of the survey in describing and monitoring the territorial structural elements. The analysis is carried out considering the level “Country” because of the simplicity in presentation, even if the same methodology can be easily extended to regional level. The richness of the LUCAS classifications allows defining agricultural areas in different ways; in this context we referred to an extensive definition that considers the points belonging to Cropland and Grassland or characterized by a land use of agriculture (including fallow land, kitchen gardens) or forestry. The selections were made over the main or secondary land covers and land uses values. Moreover, in order to facilitate the comparison, only the countries that participated to the survey in both 2009 and 2012 are considered. These conditions led us to consider 23 countries and about 75% of their total area. In the following analysis, a set of indicators derived from the transects and concerning the richness and fragmentation of landscape are defined, calculated and synthetized with multivariate techniques on weighted data.

2. The Transect in LUCAS survey

Transect in LUCAS survey consists of a straight line walk of 250 meters in an eastwards direction from the point, where surveyors record the transition of the different land covers and of the linear elements, according to a specific classification in the sequence of their appearance (figure 1). Land covers are collected by means of the first digit of the standard LUCAS definitions (table 1).

Figure 1 -Transect information collected by LUCAS

Table 1 - Land cover classification, LUCAS 2009 - 2012

A	*Artificial land*	*E*	*Grassland*
B	*Cropland*	*F*	*Bare land*
C	*Woodland*	*G*	*Water*
D	*Shrub land*	*H*	*Wetland*

The linear features include 19 elements such as walls, hedges, roads, railway lines, irrigation channels or electric power lines; these features are taken into account if their width is larger than 1 meter (with the exception of walls ditches electric lines and fences) and at least 20 meters long. These elements could be grouped into five main subclasses, with a further distinction by considering a positive or negative impact on the biodiversity (as identified by experts in the topic) or classified according to their capacity to structure the countryside or to cause dissection of landscape (table 2). It has to be noted that the evaluation of the impact depends on the environmental context. Single bushes or single tree

Table 2 - Linear element classification, LUCAS 2009 – 2012

Linear element	Macro classification	type	Impact
Grass margins <3m	Green linear feature	structure	++
Heath/Shrub, tall herb fringes <3m	Green linear feature	structure	++
Single tree, single bushes	Green linear feature	structure	+
Avenue trees	Green linear feature	structure	+
Conifer hedges <3m	Green linear feature	structure	+
Bush/tree hedges/coppices, visibly managed	Green linear feature	structure	+++
Bush/tree hedges, not managed, with single trees	Green linear feature	structure	+++
Grove/Woodland margins (if no hedgerow) <3m	Green linear feature	structure	+++
Dry stone walls	Rock/stone linear elements	structure	++
Artificial constructions (other than dry stone walls)	Infrastructure linear elements	dissection	--
Fences	Infrastructure linear elements	dissection	--
Electric lines	Infrastructure linear elements	dissection	---
Ditches, channels <3m	Water linear feature	structure	++
Rivers, stream <3m	Water linear feature	structure	+++
Ponds, wetland <3m	Water linear feature	structure	+++
Rocks, outcrops with some natural vegetation	Green linear feature	structure	++
Tracks	Transport linear feature	dissection	--
Roads	Transport linear feature	dissection	--
Railways	Transport linear feature	dissection	--
Other linear elements	Other	dissection	0

could be positive (e.g. solitary trees in grassland) or part of a degradation process if remnants of tree lines. Avenue trees are positive for biodiversity, but completeness has to be taken into account. Conifer hedges are positive for biodiversity in boreal or alpine regions, where they are part of natural forest, and negative in Atlantic regions where they are part of gardens in residential areas. Visibly managed bush and tree hedges (pollarded) indicate a cultural landscape, that's well managed, probably rich on birds. Not managed vegetation deriving from abandonment can show plant species decline, but they can be good for larger mammals. Groves are mostly important for birds, butterflies and plant species.

Dry stone walls are relevant for plants, reptiles, insects and mosses, while other artificial constructions are barrier for natural species. Fences potentially constitute a bar and together with electric lines disturb landscape aesthetics. Water linear elements are in general positive for biodiversity, depending on the quality of the water or the vegetation along, or whether permanent or temporary water; ditches can be negative for the landscape (drainage of wetlands) and temporary ponds can be important habitat. Transport linear features (tracks, roads and railways) can be absolute barriers for invertebrates.

Land covers that characterize the transect are used to represent the richness of the landscape in terms of diversity, while the linear elements were considered as indicators of fragmentation. They can be calculated at elementary level or grouped according to the definitions reported in table 2 or by aggregations based on statistical analysis (see the next paragraph).

3. Dissection elements analysis

Generally synthetic indicators are previously identified and then applied to data to be analysed; they can be based, for example, on one or more classifications reported in table 2 as already done (Palmieri A, Dominici P, Kasanko M., Martino L., 2011). In this paper we propose a different approach: in the first place to analyse the data in order to identify relationships between variables and, on this base, to build up the indicators.

An analysis of the fragmentation (the variables in the first column of table 2) was made to verify the existence of a relation within the linear elements and between them and the countries, or, in other words, whether and how the fragmentation elements are able to shape groups useful to calculate synthetic indicators and to discriminate the countries; the analysis was carried out both on 2009 and 2012 survey data. To this purpose, the correspondence analysis (CA) (Benzécrì, 1973) was used. Starting from the table of cross frequencies of the linear elements by countries, CA allows to graphical identify the correspondence between the row categories (in our case the countries) with the column ones (the different kinds of linear elements). Such correspondence is obtained by projecting all the categories in a ĉcompromise spaceč(usually of dimension 2, i.e. a place). The coordinates of such projections are obtained by taking into account the row and the column profiles; this permits to take into account a metric that is not influenced by the different marginal totals.

To verify the effects of the years (2009 and 2012), we conducted a CA by considering the projections of the variables as estimated for the 2012 and, in the resulting space, we projected the countries according to the distribution of transects as observed in 2009.

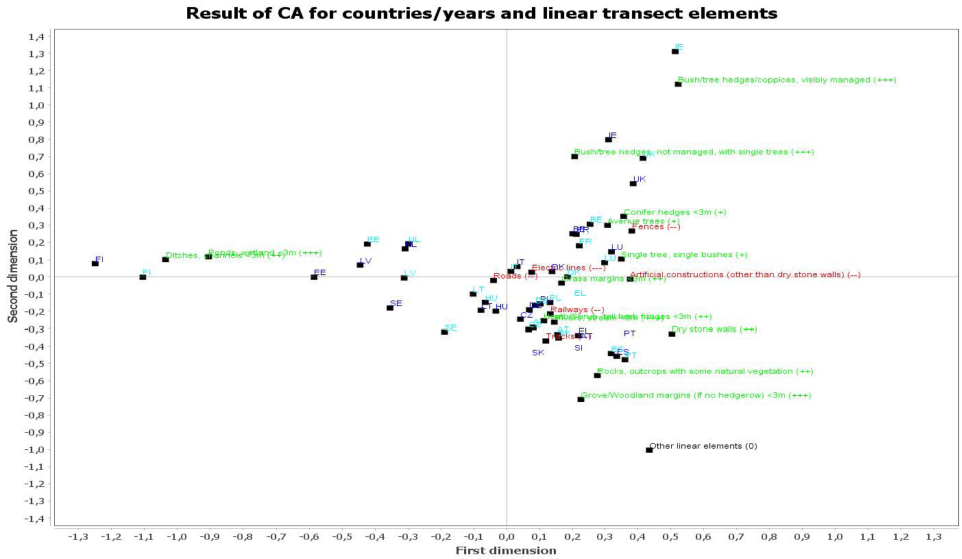
The first result obtained by the CA analysis allows identifying groups of linear elements that can summarise the fragmentation of the landscapes. In particular it is possible to create six groups, each of these defined by considering the projections as in figure 2. In particular:

- Ditches, channels ←3m, Ponds, wetland ←3m;
- Single tree, single bushes, Avenue trees, Conifer hedges ←3m, Bush/tree hedges/coppices, visibly managed, Bush/tree hedges, not managed, with single trees;
- Grass margins ←3m, Heath/Shrub, tall herb fringes ←3m, Rivers, stream ←3m, Dry stone walls, Rocks, outcrops with some natural vegetation, Grove/Woodland margins (if no hedgerow) ←3m;
- Tracks, Roads, Railways;
- Artificial constructions (other than dry stone walls), Fences;
- Electric lines.

For each group it was calculated an indicator that represents the relative frequencies of its linear elements on their totals; the indicators have been calculated on each point surveyed in the LUCAS framework.

Moreover, as second result, the CA allows us to describe the relations between the linear elements and the countries. In particular Finland, Estonia, Netherland and Latvia are grouped and characterised by ditches and ponds (it has to be noted that the rivers, initially classified in the same water linear feature are, instead, positioned in the opposite quadrant). Bush/tree, conifer hedges and avenues trees are features that seem typical of Ireland, UK, France Belgium and Luxembourg. Heath/Shrub, rivers,

Figure 2 – Projections of countries by year (2012 in blue and 2009 in cyan) and of the linear transect elements (in red those with a negative impact and in green those with positive impact) as resulting from the Correspondence Analysis



grove/woodland margins, rocks and fry stone walls characterize Spain, Portugal, Greece, Austria, Slovakia and Slovenia. The remaining countries/linear features are, instead, not well interpretable because projected near the barycenter of the axes, that represents the area in which the relations are not discriminant. Another interesting result of the CA relies on the fact that the countries maintain their relative position between the two years, showing a stability in their characterization.

4. The landscape diversity indicators

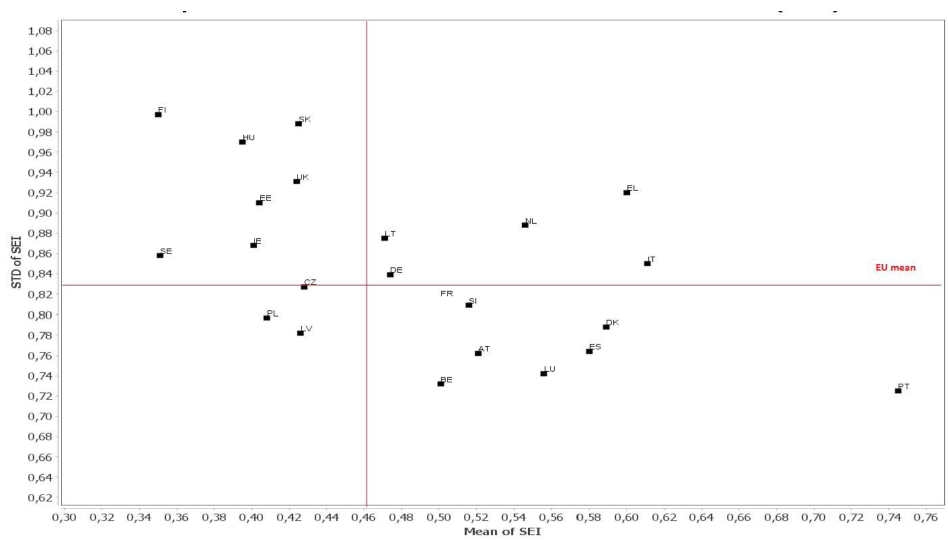
A direct measure of the degree of homogeneity or heterogeneity in terms of the physical coverage of the land can be drawn by the number of different land cover types (see table 1) observed in each of the transects surveyed.

The information on different types of land cover and their relative abundance (i.e. whether the same type of land cover recurs in a transect) can be summarised by means of two Shannon indices (Palmieri et al., 2011): the Shannon Diversity Index (SDI) and the Shannon Evenness Index (SEI).

The latter, obtained by dividing the SDI by its maximum value, is easier to read, as it varies between 0 (no diversity, i.e. a single land cover type) and 1 (maximum observed diversity combined with complete evenness).

To verify the discriminating capacity of SEI, further indexes are computed: 1) mean values at country level of SEIs, calculated for each point; their distribution is reported, for the year 2012, in the scatterplot in figure 3; 2) SEI standard deviations, taken as indicators of the heterogeneity of the index within the countries are also shown in vertical axis.

Figure 3 – Scatterplot of means and standard deviations of the SEI indexes for each country, as observed in LUCAS 2012 (the red lines identify the values for EU)



Analysing the SEI distributions for 2009 and 2012 it is possible to characterize the countries in four main typologies, considering those with a higher, or lower, value of the diversity index and, respectively, its variability. In particular Czech Republic, Poland and Latvia seems to have a higher homogeneity in the land cover with a less variability in respect to Finland, Hungary, Slovakia, UK, Estonia and Belgium, also characterized with a less diversity in land cover. Latvia, Netherland and Greece, instead, have a higher diversity index, but also more changing in their territories than the remaining countries. Because of its potentiality in discriminating the countries, SEI index is taken into consideration in analysing landscape together with dissection indexes.

5. The landscape analysis

As shown above, dissection as well as diversity indexes can be used separately to analyse the countries landscape but a different approach can be adopted. A further analysis has been carried out by considering together two sets of indicators; on one hand the six synthetic indexes, built up according to the grouping of linear elements identified in paragraph 3, and the SDI diversity index of land cover. On these seven indicators, a principal component analysis was carried out in order to obtain the latent variables (factors) representing the optimal combination of the indicators not affected by multicollinearity. The groups where identified by means of a disjoint cluster analysis (based on the K-means algorithm) applied on the resulting factors and the optimal clustering of the countries landscapes per year was obtained.

The analysis identified four clusters; they are characterized in terms of the original seven indicators by considering their mean value per cluster that more discriminate the groups; figure 4 reports the means for EU and for each cluster in the years 2009 and 2012.

Figure 4 – Mean values of the indicators for the dissection linear elements and for the SEI index as observed in EU and as obtained by the cluster analysis on the countries/years

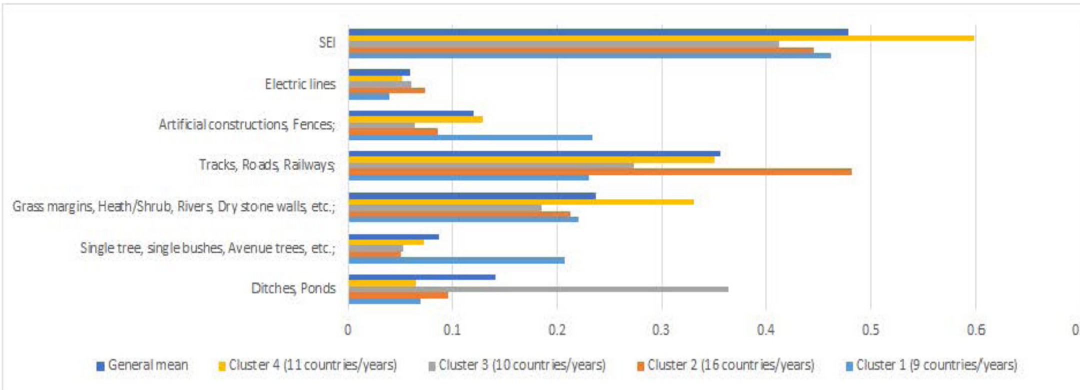
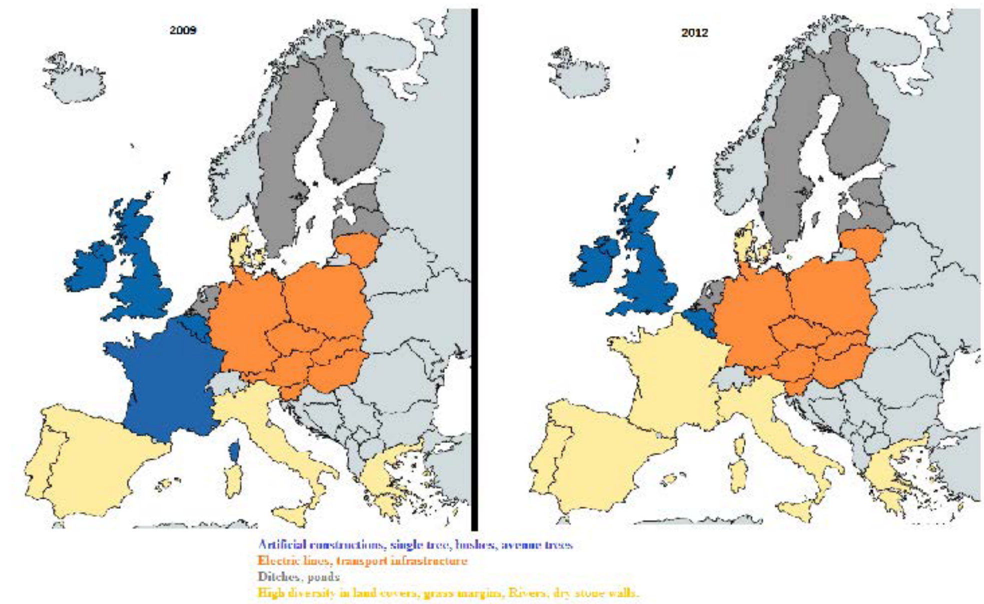


Figure 5 – EU countries according to the cluster to which they were attributed



The analysis allows us to label the clusters in the following way:

- Cluster 1: Artificial constructions, single tree, bushes, avenue trees, medium diversity in land covers
- Cluster 2: Electric lines, transport infrastructure, medium diversity in land covers;
- Cluster 3: Ditches, ponds, lower diversity in land covers;
- Cluster 4: Higher diversity in land covers, grass margins, Rivers, dry stone walls.

Maps in figure 5 report, for the years 2009 and 2012, the different countries coloured according to the cluster in which they are classified. The maps show a stable classification among the two survey years except for France that passes from an ǍAtlanticčcluster to a ǍMediterraneančone. The country indicators in 2009 were close to the new group and so the change it is probably due to sample variations that in 2012 privileged the south points with regards to the north ones. Denmark, in both years, is classified in the “Mediterraneančcluster mainly because of its value of the Shannon index, which shows the diversity of land covers in comparison with the other countries/groups.

5. Conclusion

The paper shows how data collected by LUCAS survey, allow landscape analysis in an evolving system such as the European Union countries, and provide an appropriate set of information able to describe the landscape diversity and its fragmentation in agricultural land, jointly with the changes in land cover and in land use. In particular the paper describes how the application of multivariate statistical techniques is able not only to describe and discriminate different landscapes typologies in different countries but also to identify a set of indicators to support and complete the ones derived from the dissection elements classifications. The stable results obtained in correspondence and in cluster analysis could indicate that variations in point's selection and in data collection do not affect substantially the capacity of LUCAS in monitoring the EU landscape, even though a pure panel approach is to be preferred for a periodical monitoring.

The above analysis is a first attempt to exploit the potentiality of LUCAS using multivariate analysis on specific indicators derived from LUCAS primary data. The methodology can be fine-tuned using other indicators derived from auxiliary information collected by the survey; moreover the heterogeneity within countries, at level of regions and/or elevation classes, can be further studied in order to obtain a more analytical description of the EU agricultural area and probably a new picture of the variations over the time. We are including in the analysis the data from 2015 survey and results will be compared for different land cover classes; this will allow us to improve the system of indicators and to verify their dynamic. As far as regional context is concerned the efficiency of sample with panel structure has to be studied too.

LUCAS transects allow to study the richness of the land cover and of its dynamic though the years. The information could be used in estimating proper models to analyse agricultural systems when enriched with other information.

Other approaches for landscape observation, based on remote sensing or administrative sources are not included in this paper but the integration of such information could offer new opportunities in ameliorating the analysis. Both predefined and derived indicators, combined with suitable auxiliary information can be used for monitoring territory at macro level.

LUCAS micro-data are freely available to the user by direct download from Eurostat web site

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Approaches for analysing trade-offs between productivity, nutrition and environmental outcomes at multiple scales

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ABSTRACT

Biodiversity affects the stability of ecosystem services, which in turn affects agricultural productivity and therefore global food security. The nature of the linkages between biodiversity and food security vary across temporal and spatial scales and are influenced by socio-economic drivers of agricultural systems. Based on existing literature, this paper outlines the relationships between biodiversity, ecosystem services and food security. It additionally reviews tools which can be used to integrate biodiversity and ecosystem services into analytic frameworks to allow a better understanding of the trade-offs between different agricultural systems and their ecosystem services provisioning, as well as the resulting impact on productivity and human well-being.

Keywords: *trade-off*, Agricultural systems, Ecosystem services, Model integration

PAPER

1. Introduction

There is increasing evidence that plant biodiversity increases ecosystem services (ESS) stability (Hautier et al. 2015), and that selection of appropriate land-use patterns and agriculture management practices not only increase productivity but also mitigate and enhance adaptation to climate change (Powers 2010; MA 2005). Conversely, poor production and management choices lower agricultural productivity and food security as a result of degraded land, scarcity and reduced quality of water, increased pest and disease risks, and loss of natural pollinators. Given this relationship between the health of ecosystems and economic development, including food and nutritional security, the global community adopted a sustainable development agenda at the 2015 UN General Assembly (UN 2015). This agenda includes the goals of sustainable agricultural production (under Goal 2); management of water (Goal 6); management and efficient use of natural resources (Goal 12); and protection, restoration and promotion of sustainable use of terrestrial ecosystems (Goal 15). The CGIAR similarly identifies improving natural resources and ecosystem services (ESS) as one of its high-level outcomes in its Strategy and Results Framework (CGIAR 2015) and has adopted a systems approach for its 2016-2022 research agenda. The establishment of these global development goals and frameworks for actions provide an opportunity to fully integrate biodiversity and ESS in the global agriculture research and development agenda, to not only improve food and nutritional security but also to achieve healthier agricultural ecosystems.

Understanding the multiple interactions between land use, management, environmental pressures and ESS is complex with interdependencies, trade-offs and tipping points. Understanding environmental, social and economic drivers requires transdisciplinary approaches. This paper explores some of the emerging approaches to integrate biodiversity and ESS into economic analysis of agricultural systems, particularly into those models designed to forecast the impact of potential investments and innovations on future productivity. Much of the discussions in this paper are based on a workshop convened at Bioversity International May 2015 (Rojas et al. 2015). In the following section, challenges faced in integrating biodiversity and ESS in economic models are discussed. The conceptual framework is then presented, highlighting the link between cropping patterns, practices and environmental outcomes. The next section discusses bio-economic models at different scales (from local to economy-wide). The paper closes with some discussions and conclusions for further work.

2. Challenge in integrating biodiversity and ESS in economic models

The productivity of agricultural ecosystems depends on ESS provided by natural ecosystems (Power 2010). According to the global initiative ďThe Economics of Ecosystems and Biodiversityč(TEEB), ESS are ďthe flows of value to human societies as a result of the state and quantity of natural capitalč(TEEB 2010). The Millennium Ecosystem Assessment (MA 2005) describes four categories of ESS: supporting services (e.g. soil formation, photosynthesis and nutrient cycling), provisioning services (e.g. fresh water, food, fuel and timber), regulating services (e.g. climate regulation through carbon storage and water cycling) and cultural services (e.g. recreation, spiritual, educational and aesthetic). Some examples of ESS related to agricultural ecosystems which affect productivity pertain to supporting services and include pollination, biological pest and disease control, maintenance of soil structure and fertility, nutrient cycling and hydrological services (Power 2010).

Biodiversity, among other factors, plays an important role in the provision of these services (MA 2005). Hautier et al. (2015) demonstrate a positive correlation between plant species biodiversity and ecosystem stability. Plant biodiversity affects soil nutrient content and therefore soil quality (Hajar et al. 2008; Ponisio et al. 2014; Mulumba et al. 2012). Selecting the right mix of crops rather than using one or a few dominant crops can dramatically increase crop water-use efficiency (West et al. 2014; Brauman et al. 2013). Biodiversity on farms and on landscapes provides broad genetic variations in plants and animals that is essential for adaptation and for resilience against future threats from pests and diseases (Heal et al. 2004; Hajar et al. 2008; Garrett and Mundt 1999). Increased crop diversity is shown to enhance pollinator health (Garibaldi et al. 2014; Isaacs and Kirk 2010). These ESS are also influenced by factors other than biodiversity and can be difficult to measure. Nevertheless there are ongoing efforts to identify metrics which can be used as indicators of these services (Biodiversity Indicators Partnerships 2015).

Biodiversity can be considered in two different contexts, intraspecies biodiversity and interspecies biodiversity. Intraspecies biodiversity is diversity within a single species while interspecies diversity is diversity of different types of organisms in a given ecological system. Both types of biodiversity are essential for stability in ESS and thereby for sustainable food production systems. The relevance of each biodiversity type, when used in analysis or in policy discussion, depends upon the scale at which the issue is being discussed or analyzed. The added complexity for analysis therefore involves consideration of context-specific types of diversity and the appropriate scale for the analysis.

Another important consideration from an economic and political point of view is the public goods nature of biodiversity and ESS. This means that they exhibit neither rivalry nor excludability. Rivalry refers to whether one agent´s consumption is at the expense of another agent´s consumption. Excludability indicates if some agents can be prevented from consuming a good by other agents (Perman et al. 2003). While some aspects of ESS such as pertaining to specific fields may be enjoyed privately by its owners, improved ESS resulting from preserving biodiversity can generally be enjoyed by all. Moreover, the costs of maintaining or enhancing agricultural biodiversity and ESS are usually incurred by individual landholders or operators and these are costs which occur in real time. The returns from these activities, which are enjoyed by all, however, may occur over a long period and may not cover the costs of the operator in the short term. Thus, inclusion of biodiversity and ESS into bioeconomic models requires addressing temporal and spatial challenges of private costs incurred in the short run for generating public goods in the long run.

Finally, the analysis of possible impacts of innovation, changes in biodiversity, and other interventions on ESS and, consequently, on agricultural productivity necessitates a systems framework and requires consideration across multiple scales. Interventions at the field and farm-level, including changes in biodiversity, affect the future flow of relevant ESS and, in turn, the agricultural productivity at any given site. Changes in policy or farm practices affecting the longer-term income potential of affected households, can cause a multiplier effect on future rural economy and even, in special cases, affect future national economy. Moreover, economically driven short-term land management decisions made by farmers at small scales can add up to drive ecological changes across whole landscapes across longer timeframes. Therefore, agroecosystems are intrinsically associated with natural ecosystems (Nicholls and Altieri 2004) and changes to agricultural landscapes affect the health of forests, wildlife, rivers, seas and other natural habitats. These changes in turn affect human activities and economic benefits associated with these habitats.

ESS depend on the interaction of multiple ecosystem types at different temporal and spatial scales, characterized by dynamic and non-linear relationships (Balbi et al. 2015; Bateman et al. 2012; Bennett et al. 2009), and the production of ESS in agricultural systems depends on the services provided by neighboring ecosystems (Power 2010). In recent years, significant strides have been made in analytic tools and computing capacity for work in this area (Rojas et al. 2015; Antle et al. 2015). These efforts have generally emerged from within different disciplines or, as in the case of integrated assessment models, have occurred in multidisciplinary teams. However, a concerted effort has not been made to model and study the trade-offs associated with agricultural production between productivity and environmental sustainability at multiple scales, taking into consideration agricultural biodiversity and ESS.

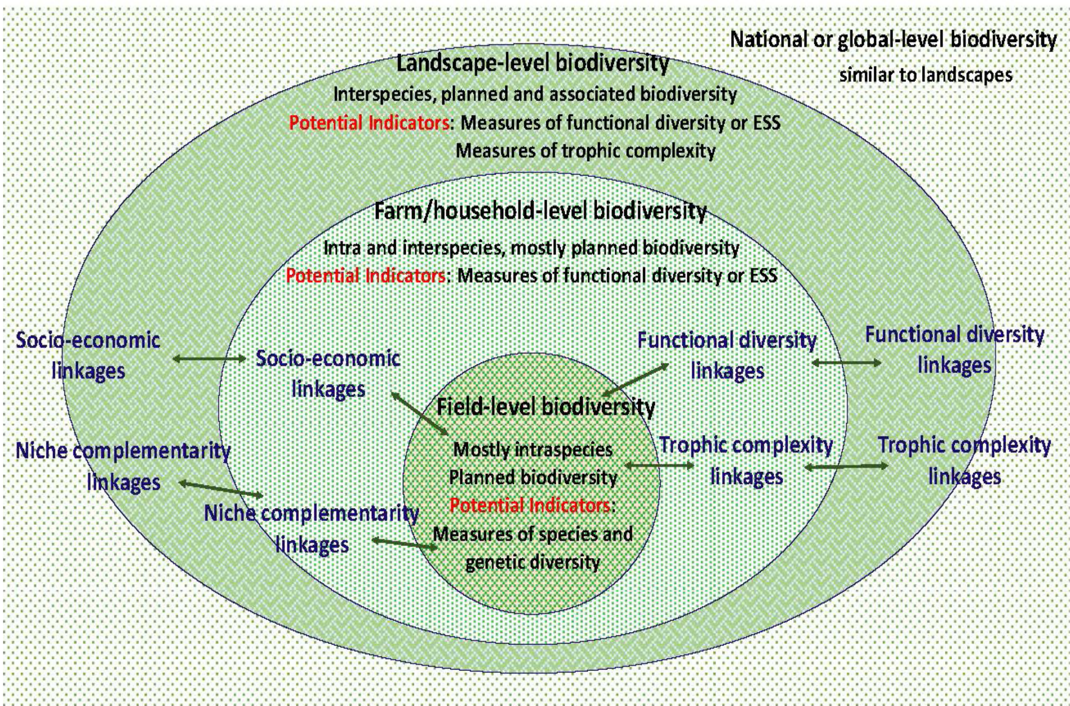
3. Conceptual framework for analysis

Nicholls and Altieri (2004) separated biodiversity in agroecosystems as *planned biodiversity* and *associated biodiversity*. Planned biodiversity is all life intentionally put in the ecosystem and varies with space, time, and other ecological conditions while associated biodiversity is all life that is attracted to, benefits from, and in turn contributes to planned biodiversity. The linkages between these are often established through *functional diversity*, the range of activities that organisms within an ecosystem perform. These include a variety of biological processes, functions or characteristics of a particular ecosystem, which connect a given agroecosystem to the health of the broader planned or associated ecosystems such as through ESS, for example soil quality, pollination or biotic and abiotic resilience. Another important linkage between planned and associated biodiversity is niche complimentarity which refers to the condition when different organisms use the same resource in different ways without directly competing with each other. Finally a third relevant aspect of connection between the two sets of biodiversity is *trophic complexity*, which indicates interactions between organisms at different levels of predation. These linkages between planned and associated biodiversity illustrate how the two systems, which could further extrapolate to socio-economic systems, are inter-connected. The precise relationships linking the two systems provide means of identifying measures for monitoring biodiversity and the possibility of using these measures as input in modeling exercises. For example, under certain conditions, information on soil quality, pollination, or a measure of trophic complexity can be used as either a reflection or an outcome of the existing status of biodiversity. The use of such measures would first need to be validated by studies which indicate their appropriateness for a given context.

Much of the past agriculture literature has tended to focus on planned biodiversity. Studies have mostly dealt with biodiversity within the context of 1 or 2 components of functional diversity, such as productivity (Li et al. 2009) or tolerance to biotic and abiotic stress (Costanzo and Bàrberi 2013). Yet it is known that practices on fields or a farm affect many components of biodiversity such as functional diversity, shift niche complementarity, and may consequently result in significant permanent changes to trophic complexity. Therefore models designed for the analysis of long-term agricultural productivity should consider analysis across multiple scales, taking into consideration the vertical linkages across scales as well as the horizontal linkages across sectors.

First at the field level, the effect of a choice of planned biodiversity on ESS and consequently its impact on productivity must be understood. At this level, activities and studies may focus on intra-species analysis, although inter-species is an important consideration in developing countries. Analyses additionally need to consider the connectivity between farm practices and non-cultivated areas within the farm and the impact of all practices on ESS (Fig 1). Second, how biophysical outcomes (including yield) of farming choices and practices affect social and economic dimensions are important aspects for consideration. These aspects may need to be examined at the farm or at the household level, with due consideration or incorporation of biophysical relationships. Third, the implications of choices made at the field and farm-level need to be fully examined at the agricultural sector level. This analysis needs to take into consideration how changes in planned biodiversity affect: the crop mix; implications for nutritional outcomes; the rural economy; and, as desired, the broader agro-economy and trade at the national and global level. Finally, agricultural sector level decisions and changes affect decisions, choices and outcomes in other sectors, including back on biodiversity and ESS. Also as earlier discussed, biodiversity status in planned agroecosystems affect biodiversity in associated non-agricultural ecosystems. Therefore the analysis of potential interventions at the field level need to be viewed within the broader economy-wide context.

Figure 1 – Conceptual framework for biodiversity assessment at different scales



As a basic conceptual framework any model designed for analysis of sustainable agricultural systems needs to incorporate the chain of linkages between changes in planned biodiversity and associated biodiversity, regardless of the scale of analysis. It is also useful to note that there can be multiple objectives along these chains, such as achieving food security, healthy diets, higher incomes, better livelihoods, resilient soils, sustainable use of water resources, and biodiversity in its own right as well as from a functional perspective. These outcomes occur at different scales. There are also multiple points at which interventions can be made, ranging from national-level interventions to field-specific interventions in agro-ecological systems.

Sustainable systems analysis needs to consider the choice of agricultural and land use activities and the resulting changes in linkage components such as functional diversity, niche complementarity and trophic complexity, and the trade-offs between these and the long-term productivity potential.

Using the concepts discussed by McGranaham (2014), such an analysis requires indicators of biodiversity measures at the field-level which can be related to functional diversity, and can be used as variables in most of the bioeconomic models. Measures of functional diversity associated with field-level changes in biodiversity are particularly well-suited in the analysis of field or agricultural sector models (Fig. 2). Among other indicators, functional diversity together with trophic complexity measures can be used as convenient indicators at the farm, household and economywide models. Given the current advances and efforts in data collection systems and data sharing platforms (Rojas et al. 2015; Antle et al. 2015), incorporation of appropriate indicators in modeling tools should be feasible.

Rojas et al. (2015) reviewed the literature to identify possibilities to harness existing capabilities to better incorporate biodiversity and ESS into economic analysis of agriculture systems. They developed a framework for assessing how well an existing model integrates these elements and whether there are scopes for improving it. Based on their approach, figure 2 summarizes key considerations in integrating biodiversity and ESS into analytic frameworks, with particular emphasis on linkages across scales and sectors.

Figure 2 – Conceptual framework for the model based assessment of the value of biodiversity

Vertical Linkages	Horizontal Linkages				
	Diversity-type		Assessment factors		Socio-economic consideration
Local-scale Field Farm Household Landscape	Mostly intra-species Intra and inter-species Intra and inter-species Intra and inter-species	↔	Crop yield, ESS Crop and livestock yield, ESS Food availability and demand, ESS Yield, ESS, community-level demand	↔	Benefits>costs at field level Joint benefits > joint costs at farm level Joint benefits > joint costs at household level Joint benefits > joint costs at community level
↕			↕		
Agricultural-sector	Mostly intra-species	↔	Relative demand, supply, prices nutrient, ESS	↔	Relative benefits/cost across commodities
↕			↕		
Economy-Wide	Intra and inter-species	↔	Relative demand, supply, and prices of food, and other consumer good; nutrition impact, ESS	↔	Impacts along value-chain, across commodities, across industry sectors, and across political boundaries

The conceptual framework, firstly, helps articulating linkages across scales and sectors. The effects of investments and interventions at the local scale, whether field, farm, household or local landscape, bubble up to higher scales and ripple across to other sectors. These linkages are not unidirectional. Changes made at the economy-wide level or at the agricultural sector level, for example a policy change, can in turn affect changes at the field, farm and household-level. The linkages in the analytic tool do not need to be hardwired into one single super-model. Rather, there can be soft linkages across models designed for different sectors and scales. Second, the framework helps to consider the requirements of modeling approaches designed for integrating biodiversity and ESS. This allows planning for necessary data collection during project design and implementation. Finally, given the existing linkages across scales, a key question in performing such analysis is whether the chosen approach allows for linking analysis across scales. It is likely that a modular configuration provides the versatility needed for adapting to different research objectives rather than one complex model with built-in linkages.

Assuming that a given modeling framework captures well the biophysical and socio-economic aspects, results from a given analysis must be examined within the context of other ongoing related work. Most models will rarely be able to integrate intra-household dynamics, particularly with respect to gender roles and decision making. Therefore the results from bioeconomic models must be examined with other ongoing analyses to explore gender and cultural aspects. Similarly models are simulated for certain selected scenarios and may not capture all complexities of all possible scenarios. Nevertheless, bioeconomic models are powerful tools for examining ex-ante and ex-post trade-off analyses between the impacts of a given innovation on productivity, nutritional outcome and ESS. The following sections briefly discuss the necessary steps in linking biodiversity to ESS, and integrating ESS into bioeconomic models at three scales of analysis as presented in figure 2.

4. Modeling the linkages between cropping patterns and practices to environmental outcomes

Agricultural economics profession has a long history of using different models which relate cropping patterns and practices to environmental outcomes. For example, Groundwater Loading Effects of Agricultural Management Systems (GLEAMS) model has been used in many earlier studies to examine the effect of agricultural practices and policies on groundwater (Boisvert et al. 1996). Models such as Soil and Water Assessment Tool (SWAT), which predict water availability and water quality have also been used in many studies (Douglas-Mankin et al. 2010). In recent years, there has been considerable effort within the biophysical science community to better understand the environmental impacts of cropping patterns and practices. Specific plot-level (Kumar and Nair 2007) and landscape-level (Swift et al. 2004) work has been undertaken to study the impact of agricultural biodiversity on environmental outcomes. In addition, there have been several concerted efforts to assess and value ESS. For example, TEEB has adopted a structured way to value biodiversity and ESS (TEEB 2010). ARIES, Artificial Intelligence for Ecosystem Services, provides a flexible suite of applications for mapping benefits, beneficiaries, and ESS flows (Villa et al. 2014). InVEST similarly estimates the biophysical provision of different ESS across a given landscape (InVEST 2015).

Bioeconomic models which are linked exogenously or endogenously (Janssen et al. 2010) to crop models can translate changes in ESS, crop-choices and management practices to crop yield. Many of these models use the DSSAT (Decision Support System for Agrotechnology Transfer) modeling system that comprises crop simulation models for over 28 crops (DSSAT 2015). Another common crop model is the Agricultural Production Systems Simulator (APSIM) software, a modular modeling framework which was designed to provide predictions of crop production in relation to climate, genotype, soil and management factors (Keating et al. 2003). Crop yields generated from such models can in turn be used as inputs to other bioeconomic models.

While efforts to estimate ESS from changes in biodiversity and land-use patterns are well-documented, these studies have not been systematically linked to economic analysis or always linked to specific field-level agricultural practices. Currently few analytical models capture complex behavior of (agricultural) ecosystems, and evaluate them at different scales (Balbi et al. 2015). Even simulation models, which take a more systems oriented approach, have focused on isolated processes and rarely examine effects of agricultural practices in multiple ecosystems (Balbi et al. 2015). Shepherd et al. (2013) conducted a review of data, from monitoring initiatives in sustainable intensification of agriculture, to examine past and ongoing efforts designed to inform decision-makers regarding trade-offs between food security, environment, and socio-economic goals. The authors identify weaknesses in many of the ongoing efforts but also point out that these weaknesses can be addressed. Among other solutions, they indicate the importance of data-sharing platforms to facilitate dissemination, reuse and learning. Similarly Antle et al. (2015) note that as growing demands are placed on agricultural ecosystems and landscapes, infrastructures are needed for supporting a comprehensive approach to data, knowledge, and its use for sustainable landscape management. The challenge therefore remains to leverage data, tools and skills present in the biophysical sciences to better link changes in crop choices and management practices to changes in the flow of ESS, which in turn affects productivity in subsequent years.

4.1 Bioeconomic models at local scale

Bioeconomic analysis at a local scale should include analyses of both productivity and environmental responses to varietal improvement or to other improved technologies. The impacts of a technology at a given locality can be analyzed at the field level, farm-level or at the household level, depending on the research purpose (Fig. 2). At the field level, the essential consideration in the past has tended to be whether, for a given crop, a given new technology is more profitable than the existing one. Farm-level analyses, similarly have tended to examine the profitability of a new technology taking into consideration all the enterprises on a given farm. While profitability and yield responses are important and essential considerations for wider adoption of a given technology, it is also important to analyze impacts on ESS to examine implications for long-term economic growth, environmental outcomes and sustainable food security.

Farm household models are a popular analytic tool for integrating household demand into the analysis of farm-level decision making (Louhichi et al. 2010; Kaimowitz and Angelsen 1998). These models are appropriate for analyzing the empirical relationship between farmer´s land use pattern, household preferences, and resource availability. They are capable of incorporating details regarding different crop and livestock systems and examining a number of technologies and potential impacts of a range of policy interventions (Louhichi et al. 2010). The models are particularly well-suited in applications regarding subsistence agriculture where production, labor allocation and consumption decisions are linked (de Janvry et al. 1991). These models can be applied to a single time period or over multiple years.

Figure 3 – Bio-economic models at local scale: strengths and weaknesses

	Strength	Weakness
Framework	Most operate using a 'bottom-up process' with the model based on detailed geophysical site-specific information.	Data requirement can be demanding.
Scope	It allows for site-specific trade-off analysis of productivity and environmental outcomes. Impact on human diets can also be incorporated.	Relating farm practices and crop choices to environmental outcomes can be difficult. Intra-household dynamics such as gender issues will need to be considered outside the model.
Domain	It is a good scale at which to analyze field-level activities in connection with farm or household level activities and try to link them to the immediate landscape.	Making these connections involves data issues. Some studies attempt to work with a few farms in a given landscape. Others start with large number of farms and reduce these to a few 'typical farms.'

Research has expanded to consider farm-level decision making within a landscape context. Given the scope for analyzing multiple benefits and costs, spatially explicit ESS provision modeling tools have increasingly become available. These tools describe multiple services or goals which a household or a farm can seek to optimize, such as agronomic, profit and environmental goals. These models are able to assess the impact of human activities on the provision and value of multiple services across space and time (Müller et al. 2010). At the moment however, the larger economic processes of market forces are often not incorporated in such models. Spatial models have high data requirements and limited spatial coverage, with infrequent capture of higher aggregation processes (Smeets et al. 2014).

Rojas et al. (2015) examined a number of farm and household-level models that are used for analyzing biodiversity and ESS. Based on this review, figure 3 presents their key strengths and weaknesses. While these models are useful to relate household-level decision making to its impacts, it is difficult to incorporate intra-household dynamics into the analysis. Factors such as gender-roles and nutritional impact on women and children, may need to be analyzed outside the models. Moreover, model scenarios must be selected and results interpreted taking into consideration these dynamics.

Given that the models are based on site-specific information, data needs can become cumbersome. There is also a challenge in deciding whether to make the model be true to a specific site or make the model more general and applicable across different sites. A possible solution is to adapt model prototypes, designed for specific farm or household typologies based on survey data, for use across different geographic sites covered by the same survey. Similarly, whether each component of the model, such as models for different crops considered, are endogenous to the model or exogenous can greatly change the level of complexity. It may be useful to design the model in a modular framework and enable linking different components as needed, rather than making a very complex single model which requires considerable investments for adaptation with each new use. However, a shared platform for data and for sharing analytic modules will significantly facilitate moving forward the research to allow integrating biodiversity and ESS into economic analysis.

4.2 Bioeconomic models at the agricultural sector level

Agricultural sector models belong to a set of models known as the partial equilibrium (PE) models which take into consideration only a part of the economy assuming the rest of the economy remains unchanged (ceteris-paribus condition). PE models incorporate both supply and demand of an industry or a sector of interest hence being able to capture market equilibrium processes. PE models are widely used for agricultural sector modeling because they offer the possibility of a comparatively detailed depiction of the sector while being comprehensive in spatial and commodity coverage and maintaining the capability of capturing market feedbacks taking place at relatively aggregate spatial scales. These models are powerful tools for assessing national/regional level policies, and also the impact of innovation within a commodity on the market price, demand and supply of other commodities.

Currently the agriculture economics profession has a wealth of information based on which model improvements can be undertaken to better integrate biodiversity and ESS into agriculture systems analysis. A commonly used tool IMPACT (International Model for Policy Analysis of Agricultural Commodities and Trade) is a global multi-market, dynamic model that provides long-term projections (up to 2050) of global food supply, demand, trade, prices and food security (Flachsbarth et al. 2015; Robinson 2014). The model covers 58 agricultural commodities including livestock, fisheries, crop processing for sugar, oil seeds and cassava, and biofuels production. Globally, agricultural production is depicted at the level of 320 spatial units or ďood producing unitsč(FPUs) based on 154 major river basins and 159 political regions or country boundaries. GLOBIOM is a global recursive dynamic model that integrates the agricultural, bioenergy and forestry sectors following a bottom-up approach based on detailed grid cell information on biophysical conditions, for agricultural production (including altitude, slope, soil characteristics, and the agro-ecological zone) and land use suitability, at a spatial resolution of 10 Km grid. Agricultural production is represented at a level of →200,000 spatial units (Havlík et al. 2014) for 18 globally most important crops, a range of livestock production activities, and forestry commodities as well as different bio-energy transformation pathways. Similarly MAgPIE (Model of Agricultural Production and its Impact on the Environment) a global, spatially explicit, recursive dynamic model uses a bottom-up approach and has a spatial resolution of 0.5°x0.5° which results in around 60,000 grid cells. This model covers 20 crops, 3 livestock, and 10 regions in the world (Lotze-Campen et al. 2010).

Figure 4 – Bio-economic models at the agricultural sector level: strengths and weaknesses

	Strength	Weakness
Framework	Most models are based on readily available national, global or regional data on production, trade and consumption and other uses. A few newer models are adopting the 'bottom up' approach of basing the model on site-specific information.	Integrating biodiversity and multiple ecosystem services to these models is relatively a new concept, and to date limited applications exist beyond some climate change analysis.
Scope	These models are well suited to examine inter-commodity market dynamics, both in local and global markets, including along value chains when included in the model, with changes in innovation or policy changes.	Relating farm practices and crop choices to profitability and environmental outcomes can be difficult. Intra-household dynamics such as gender issues will need to be considered outside the models. As the scope is limited to the agriculture sector, these models cannot directly consider impact on or from changes in other sectors of the economy.
Domain	These are relatively easy to use tools to compare the impacts of innovations across a number of countries and commodities, with simple disaggregation of bulk farm-gate product, semi-processed and processed products.	Relating environmental externalities can be incorporated in the models but currently the profession has limited applications. The models can be externally linked to household and economy-wide analysis, but this work is also currently under-developed.

While the above discussed models do not capture economic feedbacks between the agricultural sector and the rest of the economy (Fig. 4), agriculture sector models are an important tool and a necessary step for a comprehensive analysis of a given new innovation or a policy change within the agriculture sector. The model's aggregate spatial scale has limited representation and linkage with externalities and ESS, but model enhancements are being undertaken for greater consideration of site-specific biophysical information (Valdivia et al. 2012). For more comprehensive analyses, results from agriculture sector model can be linked to economy-wide models. In addition, results from analyses at other scales can be used to customize the model for specific scenarios.

4.3 Bioeconomic models at the economy-wide scale

The most common framework for analyzing innovation or policy changes using an economy-wide approach is the computable general equilibrium (CGE) model. These models cover production, consumption, input, and trade of all economic sectors for a given country, region or even for all countries worldwide. CGE models represent the optimizing behavior of all agents within the economy as producers, consumers, factor suppliers, exporters, importers, taxpayers, savers, investors, or government. This comprehensive coverage of economic processes allows assessing the full economic value to society of a public good such as biodiversity and ESS.

Important uncertainties and limitations to CGE modeling analyses are that the high level of aggregation conceals variations in and economic interactions between the underlying elements, and limits the degree to which bottom-up information and data can be effectively integrated within the larger model. Often the representation of specific commodities or agricultural technology and technological change can be limited. However, advances on bioenergy analyses have been made in some Global Trade Analysis Project (GTAP) model versions (Smeets et al. 2014), as well as assessments of ESS and biodiversity using CGE ICES (Intertemporal Computable Equilibrium System) model (Bosello et al. 2011).

Figure 5 – Bio-economic models at the economy-wide level: strengths and weaknesses

	Strength	Weakness
Framework	Model is based on aggregate national accounts data which is readily available.	High-level of data aggregation in the model only allows impact analysis at a very aggregate level.
Scope	It allows for analysis across all sectors of the economy, producers, consumers, suppliers of factors of productions, exporters, importers, taxpayers, investors, government. As such, it will also allow taking into consideration the impacts of biodiversity and ESS outside the agriculture sector.	As a complete consideration of biodiversity and ESS into such a model has not been attempted before, it will be a big challenge to develop the necessary data to include them into the model.
Domain	Given the public good nature of biodiversity and ESS, these models will capture comprehensively their economic value to society.	The model will not be able to capture the 'intrinsic value' individuals may place on biodiversity and ESS to just conserve them for future generations. As such it is likely that the estimated value will be an under-assessment of the true value.

Similar to the advances in agricultural sector models, significant advances have been made in CGE models. The recent version 8 of the GTAP database contains 57 commodities and 129 regions, including up to 12 agricultural commodities on the supply side and seven on the demand side. The forestry sector is included through a forest products commodity (GTAP 2015). Similarly, Modeling International Relationships in Applied General Equilibrium (MIRAGE) covers 113 regions of the world and up to 57 sectors (IFPRI 2015). MIRAGE was used to analyze climate change impacts in South-Asia (Laborde et al. 2011). A version of MIRAGE called MIRAGE-BioF was used to analyze biofuel policies, as well as to assess the impacts of trade and agricultural policies on income and poverty in developing countries (Valin et al. 2013). While these represent global models, there are ongoing efforts to improve economy-wide models at individual country-levels. For example, under the Nexus Project, which is a loose consortium of organizations engaged in building and using CGE models for African countries, an effort is underway to improve and expand the scope of analysis. Data coverage is currently being expanded to cover energy and water sectors and the inclusion of biodiversity and ESS is under consideration.

Economy-wide models allow calculating the costs and benefits accrued to society in general from investments in conservation of agricultural biodiversity and ESS. These models can take into consideration the indirect impacts, such as loss to tourism, recreation, hunting and fishing, from agricultural run-off and leaching from fields many miles away. The models can also be used to examine potential impacts under various policy options to conserve or enhance biodiversity and ESS, on different sectors of the economy. As indicated in figure 5, given the scale at which these models operate, it is difficult to precisely link the estimated impact to specific crops, fields or local markets. But, if linked to analyses in other sectors and to analyses at lower scales, a given policy can be fully examined to consider the impacts on productivity, biodiversity and ESS with linkages to specific crops, fields, landscapes and markets.

5. Concluding remarks

This paper has presented a conceptual framework for integrating biodiversity and ESS into economic analysis of agricultural systems. As global food security is intrinsically linked with biodiversity and ESS, it is critical that any analysis of the productivity impact of a given agricultural technology also includes its environmental footprints. The impacts of how biodiversity is manipulated at the field level can ripple horizontally across landscapes and vertically across economic scales, requiring linkage in analyses across these scales. While the paper does not devote significant time to this issue, the paper also points out the need for temporal consideration in analysis since the cost of preserving biodiversity and ESS are privately borne in the short-run, but its gains are publicly accrued over a longer timeframe.

The paper also points out the need to examine ESS impacts of crop choice and agricultural practices and link these impacts back to yield impacts in the long-run. Yield predictions can then be incorporated into economic models at multiple scales to examine future implications for food security, through the impact on productivity, biodiversity and ESS. It is important to consider the analysis at multiple scales in order to more comprehensively capture intervention impacts. At the local scale, the profitability of a given innovation can be considered in the context of a farm enterprise or at the household level, with linkages constructed to ESS flows. At the agriculture sector level, the given innovation can be examined in the context of a range of agricultural commodities and their domestic and international markets. At the economy-wide level, the impact of a given innovation on ESS can take into consideration the effects beyond the agricultural sector. Therefore the analysis at each scale complements the analysis at another scale, indicating the need to have analyses linked across scales.

Given the current state of science regarding geospatial data, computing and modeling capabilities, it is feasible to regularly integrate biodiversity and ESS into analyses which are designed to assess the food and nutritional security impacts of a given agricultural innovation. However translating this idea into practice is more complex. As discussed by Antle et al. (2015) linking the relationships between land management decisions and multiple outcomes is complex and requires coordination across a number of different stakeholders. The authors point to the need for infrastructure to support the management of agricultural landscapes. While efforts have been made to establish platforms for sharing data and tools, more can be done in this area. As shared platforms for data, analytic modules, tools and models are essential for integrating biodiversity and ESS into economic analysis of agriculture systems, a question arises regarding who funds it. Funding agencies and the research community need to explore different options for incentivizing the sharing of data and computer models. Antle et al. (2015) present some suggestions, including the role for private-public partnerships, within the context of the United States. Food security of any given country is linked to actions and well-being of other countries. In the context of challenges presented by climate change and degradation of ESS globally, any infrastructure for data sharing and facilitating analysis in the United States should also be linked to global data and research efforts. To confront the global challenge of food security and climate change we need a global effort to perform analyses that allows identifying the best options to increase agricultural productivity, while also maximizing the global availability of macro and micro-nutrients and minimizing the environmental footprint of agriculture production systems.

While underscoring the need to perform the trade-off analyses discussed in this paper, it has to be noted that these models are merely approximating very complex systems. In some areas we have a good understanding of the relationships and in others only an emerging understanding. The type of analysis advocated here will have inherent weaknesses and will need to act in parallel with other types of evidence – some of which will be qualitative. However, developing these analytical approaches will likely help facilitate transdisciplinary working and systems thinking. It will expose some of the areas where we currently lack understanding – identifying new research priorities, which in turn will lead to improvements in analysis.

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THEMATIC SET

E26

MEASURING ENERGY EFFICIENCY IN AGRICULTURE AND BIO FUEL PRODUCTION

Session Organizer

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ABSTRACT

Energy efficiency can enhance sustainability, support strategic objectives for economic and social development, promote environmental goals and increase prosperity. Measuring energy efficiency of agriculture and biofuel production is crucial when planning energy policies aimed to partially replace fossil fuels and to lower green house gas emissions. Reducing the dependency on non-renewable energy sources relies both on the use of renewable energy and on the improvement of energy efficiency in productive processes. However absence of solid data, lack of standard methods, presence of multiple objectives – among other factors – complicate the evaluation of energy efficiency of agriculture and biofuel production. Moreover the rapid expansion of biofuel production has generated considerable interest and a variety of approaches to understand the impact of biofuel growth on the global food economy. The session will discuss criteria and methods related to energy efficiency assessment in agriculture and biofuel production. Specifically, the session will focus on the following areas: 1. Assessment methods of energy efficiency in agriculture and biofuel production; 2. Evaluation of the energy and environmental efficiency of the primary sector at country/regional level and for different farming systems; 3. Analysis of the impact of biofuel growth on the global food economy. The session will welcome thematic papers focusing on these three areas. Methodological studies concerning constraints and difficulties for energy efficiency measurement such as data gaps/needs and implications for Institutions involved in agriculture statistics will be welcome as well.

LIST OF PAPERS

European territorial cooperation and local benefits, increasing energy efficiency in the Mediterranean agro-food sector

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M. S. Scarpinella | Sapienza University of Rome | Rome | Italy

DOI: 10.1481/icasVII.2016.e26

Energy impact matrix: using Italian FADN to estimate energy costs impact at farm level

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Evaluating revenues and economic growth for farms producing renewable energies: an investigation based on integration of FSS and EOAH 2013 Survey Data

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DOI: 10.1481/icasVII.2016.e26c

THEMATIC SET

E26

Assessing bioenergy sustainability through the use of the Global Bioenergy Partnership (GBEP) sustainability indicators for bioenergy

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European Territorial Cooperation and local benefits, increasing energy efficiency in the Mediterranean agro-food sector

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Abstract

The agro-food sector is characterized for demanding a significant amount of energy in its industrial processes. According to the Joint Research Centre of the European Commission, the amount of energy necessary to cultivate, process, pack and bring the food to European citizens' tables accounts for 26 % of the EU's final energy consumption in the same year (Monforti-Ferrario et all 2015). In the Mediterranean area, the agro-food sector is highly represented by Small and Medium Enterprises (SMEs) which demand innovation and practical solutions to greening the supply chains. In contrast, SMEs are often reluctant to change production behaviours due to limited financing alternatives, lack of information on the most fitting technologies or gaps in knowing benefits without affecting the quality of the final products.

Aiming at assisting agro-food SMEs of the Mediterranean area, the project Sinergia[2] has contributed to identify innovative processes, address energy efficiency patterns in the productive chains and guarantee a wide replication of the technological solutions for energy saving and CO2 reduction. Sinergia pools the experience of 10 Mediterranean partners who jointly developed an Energy Self-Assessment Tool (ESAT) to help SMEs to better know their own energy consumption features and to identify energy saving potentials. The project is financed in the framework of the EU Cohesion Policy through its European Territorial Cooperation (ETC) objective. The aim of this paper is to analyse the effects and contributions of ETC to the increase of energy efficiency levels in agro-food sector. The paper analyses Key Performance Indicators (KPI) of reference and highlights how ETC exercises can address data availability challenges.

Keywords: Energy efficiency, Agro-food sector, SMEs, Mediterranean

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[1] The scientific output expressed does not imply a policy position of the European Commission. Neither the European Commission nor any person acting on behalf of the Commission is responsible for the use which might be made of this publication.

[2] The project website is: http://www.sinergia-med.eu/

1. Introduction

Over the recent years, market trends and environmental pressures make clear that an essential requisite for future growth and competitiveness of the European agro-food industry are not only the investments in the global network of commodities and distribution channels but also to extend the paradigm of sustainability in the food processing from the big corporations to the SMEs. This aspect is particularly important if we observe it from the energy side. Although agro-food industry is considered as a low-energy intensity sector, some steps in the value chain are characterised by consuming high levels of energy to transform, process, cook, warm, dry, cool and store the final food products.

In the Mediterranean region, agro-food industry is one of the largest and more productive sector, mostly composed by small and medium enterprises with limited resources and unqualified personnel for addressing greening practices in the supply chain innovation. Furthermore, SMEs typically consider additional investments not as a way to improve their energy efficiency but as a loss or major change in their product market characteristics and quality already assimilated by target consumers.

The purpose of Sinergia is to help the Mediterranean agro-food industry to spark green energy practices. One of the most innovative aspects of the project is the proactive method offered to the agro-food SMEs to make them feel closer to the knowledge poles in the field of energy and to stimulate investments to improve the environmental footprint of food processing. Sinergia tackles the energy challenges by designing friendly instruments to increase the SMEs' awareness and introduce innovation in the energy efficiency processes. These instruments are designed to cover monitoring and selection of the most fitting technologies to the energy managers' across the whole investment life cycle.

This paper focuses on Sinergia project as an example of European Territorial Cooperation where several partners of different Mediterranean countries have addressed a common challenge by giving a unified response through collective action. To this respect, the added value of ETC is of significant importance for the agro-food sector as it allows sharing knowledge, good practices and motivating exchanges between experts and entrepreneurs of several Mediterranean countries.

2. European Territorial Cooperation, joining efforts to support the Mediterranean agro-food sector.

In the European Union, the Cohesion Policy finances initiatives to reduce disparities among member states and regions who evidence different growth progression as a result of heterogeneous market dynamics and trends. European Territorial Cooperation is part of the EU Cohesion Policy and promotes collaborative actions in response to common challenges. In the Mediterranean area, ETC addresses some of the common challenges normally by following a three-phase approach consisting of: (1) diagnosis and strategies to be addressed commonly by partners of different territories, (2) testing activities and demonstrative actions to validate future and higher interventions and (3) transferability and capitalization actions based on the amplification of previous test and results towards concrete policy changes (Gómez and Stephanedes, 2015).

Results of European Territorial Cooperation are not normally seen as infrastructure-oriented achievements. Instead, ETC contributes to the delivery of reports and analysis based on state of the art, legislation tendencies and changes, roadmaps, guidance materials for several public targets, communication and awareness raising campaigns, establishment of local working groups, international conferences, events to facilitate exchanges between public and private sector, political Memorandums of Understanding and provision of evidence for improving local, regional and national policies (Gomez Prieto, 2015).

Concerning the agro-food sector in the Mediterranean area, over the period 2007-2013 the European Territorial Cooperation instrument contributed to the support of several stakeholders through different initiatives in areas such as innovation and transnational collaborative platforms (Agro-environmed, 2013), promotion of sustainable diets and agriculture traditions (Fooding, 2011), simplification of technical and administrative procedures and operation for Horticultural Perishable Products (E.H.P.P.C, 2011), exchange for technology transfer in the agro-biotechnologies (Agrobiotech exchange, 2005) and energy efficiency advice to SMEs (Sinergia, 2015)

According to the nature of ETC, achieved results should be considered as interface of new interventions in same or similar thematic and targeted territories. Although project outputs are of varied nature they could be used individually or collectively to define starting points, references or baselines of future projects and initiatives. This approach is part of the so-called capitalisation strategies promoted at programme and project level.

3. The Sinergia project, increasing energy performance by transfer innovation.

Sinergia is an ETC project implemented by the transnational programme Interreg MED. The project is coordinated by the Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA) and engages the participation of eight partners representing research centres, federations, clusters and agencies of Spain, Italy, France, Greece, Slovenia, Croatia and Turkey committed to the development of agro-food sector in the Mediterranean area.

The main mission of Sinergia is to promote the technology transfer to the SMEs of the agro-food industry in order to (1) identify innovative processes and address energy efficiency patterns in the productive chain (2) guarantee a wide replication of the technological solutions for energy saving and CO_2 reduction undertaken by the different agro-food divisions and productive clusters in the involved MED regions and (3) strengthen the competitiveness of the agro-food industry in the Euro-Mediterranean and global markets.

To achieve the objective, the project developed 50 pilot cases addressing concrete technological options to boost better energy performances in SMEs, with high potential of replication to strengthen competitiveness and sustainable resource management of agro-food industry in the Mediterranean area. The following case addresses for instance energy efficiency practices in a winery of Greece.

Case study on Energy efficiency practices in a Greek winery

Company description and products. Brintzikis is a Greek winery and produces 500 tons of wine annually wine from locally grown grape varieties. It is the first winery in Greece with zero carbon footprint, thanks to its two ground source heat pumps systems coupled to photovoltaic panels. Production process includes grape collection from the vine trees, transport to the winery, production of must, cold static decantation, separation, alcoholic fermentation, aging, storing and bottling.

Energy use. Heating needs are limited to 5 days in winter in order to maintain wine storing temperature at 12 °C. Cooling is needed during the wine production season in September for treatment of must after pressing and removal of grape solids, static decantation and alcoholic fermentation of the must. Additional cooling is needed in order to maintain the wine aging as well as a storing room temperature at 18 °C during from May to October. Electricity is also needed for lighting, driving motors at the pressing system and filtering units, as well as for pumps and fans.

Renewable Energy technology installed. Heat, cool and chill are provided by a pair of ground source heat pumps (57 kWth heating and 53 kWc cooling each). One of them provides base load and the second provides peak load. At times when both heating and cooling are needed in the plant, one GSHP provides heating and the other cooling, operating in maximum efficiency due to the favourable temperature prevailing at the bore hole heat exchangers (BHE). The GSHP units are connected to a ground heat exchanger which delivers 16 °C water to the GSHPs in heating mode during winter and 20 °C water in cooling mode during summer.

Electricity is provided by photovoltaic panels placed at the roof, which sell all generated electricity to the grid at a guaranteed feed-in tariff according to national regulations. The PV panels generate 150 MWh of electricity annually exceeding plant needs of 100 MWhe.

Annual energy savings. Useful energy delivered by the GSHPs is estimated at 152 MWhc for cooling plus 17 MWhth for heating. The corresponding electricity consumption is estimated at 32 MWhe, resulting in energy savings of 137 MWh annually. In addition, the PVs provide another 150 MWhe of renewable energy every year. It must be noted that correction of the power factor does not result in energy savings, but only in cost savings.

These pilots demonstrated in one hand the variety of industrial processes and energy consumption patterns in the Mediterranean agro-food sector. Even if we talk about similar food items, feta cheese production in Greece entails a particular process that cannot be compared to the elaboration of Mozzarella in Italy or Banon in France. On the other hand, small and medium entrepreneurs are normally more sensible towards the preservation of traditional industrial processes rather than modernising the practices by introducing energy efficiency measures that could bring both economic and environmental benefits.

Sinergia project also implemented a set of tools to promote technology transfer in agro-food industries of the Mediterranean. Concretely, an energy efficiency simulator, a food energy tech database, help desks and an energy self-assessment tool were designed to stimulate energy efficiency practices in SMEs and demonstrate that final products can be elaborated with the same quality and less energy consumption. In this paper, analysis is concentrated in the Energy Self-Assessment Tool[3].

4. The Energy Self-Assessment Tool and key performance indicators

The Energy Self-Assessment Tool (ESAT) was designed to stimulate energy efficiency patterns in the productive chain of SMEs' industrial processes. The tool is based on an free-accessible software[4] which was developed to process a set of information about SMEs' energy cost/consumption and production data. Users can enter data about energy performance associated to food production into a software that provides a diagnosis regarding the energy efficiency of the site by comparison with appropriate benchmarks. ESAT allows to evaluate higher margins of energy performance improvements and supports enterprises in their choices.

As for the functioning, ESAT was designed to work on two operative levels: the first one is a preliminary check-up consisting on a simple and quick process to calculate SME performance indicators and compare them with reference values for the same sector. Here, the tool requests for basic information in order to deliver indicators related to working hours per day, energy bill and averages. In the second level, a comprehensive energy check-up, based also on preliminary information, allows the system to properly identify when and where the higher energy consumptions occur along production process. This second level assists SMEs to identify specific energy consumption by analysing all energy vectors consumed and energy techs installed.

The Energy Self-Assessment tool not only allowed to determine quantitative values of energy consumption in targeted SMEs of Mediterranean agro-food sector. The obtained results were also visible through the increase of awareness about SMEs energy consumption not only by entrepreneurs but also by policy makers and other relevant stakeholders. Comparison on SMEs energy performance, energy consumptions assessment for each segment of the production chain and simulation of major energy efficiency scenarios were also part of the associated results.

The key performance indicators addressed by Sinergia were linked to the needs and demands of the agro-food industry as one of the largest and most important manufacturing sector in the Mediterranean area. Although mostly composed by SMEs with limited resources and qualified personnel for investing in research and innovation, the Mediterranean agro-food sector counts on great innovation potentialities leading to improve energy efficiency levels of industrial processes.

After diagnosis analysis and surveys addressed to representatives of SMEs, these KPI were jointly defined by project partners as a way to identify common solutions. Concretely, the defined KPI were: energy consumption per square meter, energy cost per square meter, energy consumption per volume produced and energy cost per volume produced.

[3] Details of these tools are available at: http://www.sinergia-med.eu/index.php/my-energy-efficiency-simulator

[4] Managed by the Italian National Agency for new technologies, energy and sustainable economic development ENEA. Available at : www.esat.casaccia.enea.it

5. Discussion and key messages to stakeholders and policy makers

In previous sessions, it was demonstrated how European Territorial Cooperation contributed to improve energy efficiency levels in the Mediterranean agro-food sector. Sinergia project in particular addressed key interventions towards the support of SMEs in order to modify energy consumption practices. However, some observations and results obtained through project operation are valid for policy dimension at local, regional and national level. The following messages are addressed to policy makers and stakeholders committed to the improvement of the Mediterranean agro-food sector:

Moving companies towards sounding energy efficiency diagnosis. Making the agro-food companies, in particular the SMEs, aware about their potential energy efficiency upgrade is definitely the first step to achieve reasonable energy efficiency levels. Assisting SMEs to run an initial self-diagnosis of their energy consumption patterns is the way to convince them to investigate market alternatives as well as to identify suitable low carbon technologies fitting with specific industrial processes. Decision support systems such as ESAT represent a concrete support to any SMEs as it offers a set of energy performance reference values for the selected agro-food divisions and technologies, helps enterprises to pre-evaluate the potential benefits, maps out the innovation hubs and the available local RES and E-services. Tools like ESAT encourage the agro-food companies to wisely approach their own energy performance problems and deal with the EU directive on energy efficiency which promotes the energy diagnosis in the EU SMEs.

Improving the industrial associations' innovative services for the greening of the supply chain. Most of the agro-food companies are not fully aware of the transformation of the EU market towards the single market for green products. In the meantime, large agro-food corporations have started requiring green standards to their supply chain, selecting mainly sub-providers able to meet clear environmental criteria. In this perspective, the green innovation challenges not only the enterprise at individual level but the whole agro-food local productive system (clusters of companies located in the same territorial background). The agro-food associations should be widely supported in order to enhance the efforts to provide their members with a vision over the future market trends and new services, with the goal of promoting the large scale introduction of eco-innovation model analysis in the agro-food sector and stimulating targeted investments.

Assisting agro-food companies to get oriented across the numerous sources of information. The access to good quality and scientific-based innovative ideas to improve the environmental performances of the agro-food industry is one of the main challenges to stimulate the green innovation of this sector. However, the enterprises, especially small and medium sized ones, must be supported in order to fully exploit the advantages offered by heterogeneous, numerous and complex information sources. SMEs often do not have a sufficient capacity to understand what technology options could better fit with their own production patterns and to calculate the cost/benefits of the investment in the full life cycle. Key elements to meet new SMEs' requests of information are the various tools available online to enable two-way information flows, starting from the simplest to the more evolved, that attract the companies making it possible to obtain useful information about the opportunity of new energy technologies. Therefore, the use of organized and structured tools allows SMEs to achieve an high level of innovation, but this process should be guided by technology intermediates and skilled specialists to better fulfil the companies' expectations.

Introducing innovation within the traditional food processing systems. Food and Drink sector shows relative slowness to pursue innovation, including the integration of new clean technologies into the industrial processes. Among the main challenges for stimulating innovation in agro-food, the following ones are the more recurrent: risks of investment towards innovation, failure rate of innovation projects (technical management, business support) during the process, legal and administrative barriers, insufficient protection of confidential information/knowledge related to the food processing, inflexible legislative framework for research and innovation and bureaucratic system of public funding schemes. Furthermore, SMEs typically see financing possibilities as a way to improve their traditional longstanding manufacturing processes rather than introducing innovative elements in the production chains.

Smart specialisation as a driver of innovation and interregional cooperation. Agro-food is one of the main economic pillar in the Mediterranean area and it is recognized as priority of smart specialisation in most of the concerned Regions. The introduction of eco-innovation model analysis in the agro-food sector, both to reduce the environmental stress factors in the value chain and to support the competitiveness of the agro-food SMEs requires synergies between regional strategies. To this regard, the European Commission has recently[5] launched a Smart Specialisation Thematic Platform on Agro-food. The platform promotes innovation-driven investments and cooperation around new agro-food growth opportunities.

Training and skills are fundamental! On one hand, the specialization of the educational systems, from the technical colleges to the universities, to meet the demand of new green skills and green jobs shall be pursued by encouraging new forms of public and private collaboration on the labour market. On the other, the enrichment of the vocational training with topics for the development of skills on eco-innovation, the innovation management and the sustainability issues are necessary to assure a correct implementation of priorities. Initiatives among agro-food federations, high education, R&D and specialized market/skills organizations should be promoted to increase the professional capacities in energy diagnosis and green energy projects in agro-food enterprises.

Creating alliances and inter-disciplinary networks. Agro-food sector in the Mediterranean area needs reorientation towards eco-innovation driven businesses in order to face the world-wide competition and effectively contribute to reach international post-Kyoto goals. Opening up to strategic intervention from technical, political and financial perspective strongly depends on the participation in European and international networks, economic forums, technology platforms and project partnerships. New and traditional cooperation on technology tendencies and novelties as well as in low environmental footprint patterns shall be conveyed within specific agro-food supply chains and be implemented by enterprises. National and European Agro-food cluster's vision in favour of sustainability has to be deeply promoted also across the small and medium agro-food stakeholders. In this perspective, the mechanisms for bottom-up participation and transnational think-tank in profiling the "vision to sustainability and competitiveness" should be enhanced.

Transposing new energy and clean technologies to the market. Developing close-to-market research projects focused on energy efficiency, renewables and clean technologies is necessary as a supplementary way of transposing research into market by introducing new high-tech applications for the agro-food enterprises. The elaboration of new projects under targeted financing programmes should be inspired by the advances and results derived from EU Technology Platforms. Concept and approach should be characterized by innovation (research-driven innovation and innovation in business models, design, branding and services that add value for users especially for SMEs) and engagement of all actors (R&D performers, final beneficiaries, intermediates) in the innovation

[5] Official launching of the Agro-food platform took place on 1st June 2016, Brussels as a joint initiative between DGs Agricultural and Rural Development, Regional and Urban Policy, Research and Innovation and Joint Research Centre.

cycle. A special attention should be devoted to the implementation of demonstrative pilots, being the key-factor to accelerate the propagation of successful case studies to the market.

6. Conclusions

European Territorial Cooperation has contributed to greening the Mediterranean agro-food sector through several initiatives. Sinergia project in particular has demonstrated that although the variety of industrial processes, techniques and traditions, Mediterranean stakeholders and policy makers might converge on joint action to provide collective answer to the energy efficiency challenge of related industries. Additionally, the public-domain character of achieved results and outputs, allow to prepare, design and implement further related interventions by integrating what has been already analysed, elaborated and concluded.

Decreasing energy consumption is one of the main options to make agro-food companies green and competitive. Reliable, scientific-based and independent tools of public use like ESAT might motivate the interest of agro-food SMEs to get a first screen of the possible company-based energy efficiency interventions. This tool, along with other Sinergia outputs, allowed to clarify SMEs' concerns related to: What are the best available technologies in the fields of energy efficiency for specific agro-food SMEs in specific food processing area? Are there any other example, best practices or successful case studies to get inspiration in the Mediterranean Region? Is my personal energy consultant aware about the newest applications?

Many of the problems faced by the EU agro-food sector cut across the territories of the MED areas characterized by similar climates and geo-morphologies for the land use in agriculture as well as socio-economic conditions and effective solutions. require an integrated approach and cooperation between the various authorities and stakeholders involved in order to ensure a cohesive and sustainable development of the sector. The know-how of Mediterranean SMEs is usually based on a specific and traditional products. Small entrepreneurs typically consider potential investments to improve their energy efficiency as a loss in the low price approach or as a major change in their product market characteristics already assimilated by consumers. Therefore, more focused intervention to assist Mediterranean SMEs on greening their daily processes is necessary.

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Energy Impact Matrix: using Italian FADN to estimate energy costs impact at farm level

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ABSTRACT

Agriculture accountsbetween 2 and 3 percentof national energy consumption even if direct and indirect energy usesconstitutean important part of farmer's costs. Furthermore, the considerable increase of energy prices in the past years, affected significantly farmers, generating disturbing effects on production costs.

This paper present a novel approach to estimate energy impact on operating costs at farm level.To point out the impact of global energy costs of Italian farms, "Energy Impact Matrices" (EIMs) were defined through an analysis of national Farm Accountancy Data Network (FADN), collecting data concerning the costs of direct (electricity, fuel, gas) and indirect (seeds and plants, fertilizers,pesticides and herbicides,) energy uses for each Type of Farming (TF) and Economic Size Class (ESC) of farms.

The EIMs obtained, show the differences for each intersection TF/ESC referred to the percentage weight of energy expenditures on operating costs of farms, highlighting those cases with values above national average.

The results of the analysis are useful to identify specific agricultural sectors where adopt measures at regulatory level - addressing public funding and investments - as well as at private level, promoting actions forreducing energy coststhrough management approaches such as energy audits.

Keywords: Farm Accountancy Data Network,energy costs,energy impact,energy audit.

1. Introduction

The Italian national Authority for electricity gas and water services (AEEGSI) highlighted,in its 2015annual report,a total agricultural consumptions of 2,69%, the 0,47% from electricity, the 0,12% from gas, the 2,09% from oil and the0,01% from renewable sources.Although it can be considered a small percentage of national consumptions, for farmers it represents a topic issue, as direct and indirect energy uses, have an high incidence on total farm inputs.

Furthermore, in the stream of consumption of 500-2.000 MWh/Year (most representative in Italy) prices are over EU average for 20% (except, taxes and charges) and of 26% considering the gross price (AEEGSI, 2015).

Energy consumption in agriculture can be direct – as with gasoline, diesel, petroleum, natural gas, electricity - or indirect as with fertilizers (Sands R. et al. 2011). The impact of costs related,on farms activity, depends strictly from type of farming and economic size.

In the past years Italian agriculture has been affected by an increasing of production costs, that, in 2011, reached about 5%, with peaks of 19% for feed and agricultural fuels.

Coldiretti, one of the most representative Italian farmers organization, estimated 200 million euros of additional costs for the whole agricultural sector.

This high level of costs concernedespecially energy intensive activities such as livestock companies, those ones needing energy to heatgreenhouses (such as flowers, vegetables and mushrooms) and for drying forages for animals, in addition to all those with energy demanding processes with high level of mechanization.

Such increasing of energy price was due by a combination of external dynamics, mainly the constant growth of oil prices from 2009 to 2012 and the charges in energy bills due to incentives for renewable energy production,near to 10 billion euros in 2012.Those factors entailed energy price variability, hampered farmers to make reliable predictions on their own energy costs andgenerated unexpected additional expenditures,whose incidence can vary between different type and size of farms and between farm to farm belonging to the same category.

For this reasons,energy efficiency-basedmanagement approaches can led to farm’s competitiveness, considering also that, with the future climate change and population growth,pathway for improving energy efficiency and reducing environmental footprint need to be identified (Khan et al., 2009).

This paper analysesthe impact of energy costs of Italian farms, using “Energy Impact Matrices” built through an analysis of national FADN. The FADN methodology - often used to estimate sustainability indicators at farm level like “Sustainability Farm Index” (SuFI) (Longhitano et al. 2012) or energy use and energy use efficiency of specific set of specialized dairy farms (Meul et al. 2007) - classifies farms in Type of Farming and Economic Size Class.

By referring to the concept that we can’t manage what we don’t know, this kind of analysis is an useful tool to identify specific targets in the agricultural sector to use energy efficiency as driver for farm’s performance improvements, both under economic and environmental perspective(Fabiani, 2014).

In addition, this kind of assessment can provide the building blocks for a national energy efficiency plan, where, one of the focus is better approach to energy management farms. Similar approaches have already been undertaken by some European countries (i.e. see the

Plan de Performance Energetique- PPE, in France. http://agriculture.gouv.fr/ministere/le-plan-de-performance-energetique-2009-2013-des-exploitations-agricoles).

2. Materials and methods

2.1 Farm Accountancy Data Network

The Farm Accountancy Data Networkwas launched in 1965 and established by the Council Regulation number 79/65/EEC.It is an yearly survey carried out by the Member States of the European Union and represents an important tool for the evaluation farms' income and the assessment of the Common Agricultural Policy (CAP) impacts. The FADN is a unique source of microeconomic data harmonized at European level, i.e. the bookkeeping principles are the same in all countries, as well as established by Council Regulation 79/65 (the legal basis for the organization of the network).

The scope of the FADN survey covers only farms whose size exceeds a minimum threshold[1] so as to represent the largest possible proportion of agricultural output, agricultural area and farm labour, only for market orientated farms. For Italy the threshold that farms must meet to join the FADN sample was set equal to 4000 euro ofStandard Output – SO[2].

The services responsible for the operation of the FADN, collect every year accountancy data from a sample of farms in the European Union. Farms are selected to take part in the survey on the basis of sampling plans established at nationallevel in the Union. The methodology applied aims to provide representative data along three dimensions: regional, economic size and type of farming.

The main purpose of the survey is to gather accountancy data for the determination of incomes and business analysis at farm level. The information collected concerns approximately 1000 variables and is transmitted by Liaison Agencies to the EU. The FADN database, widely recognized as an efficient tool to estimate environmental performance and footprints (Westbury, 2011 and Dalgaard, 2006),contains, among other, data on energy costs related to direct uses (divided inelectricity, fuel, gas) and to indirect consumptions (seeds and plants, fertilizers, pesticides and herbicides) for each Type of Farming and Economic Size Class.

Data collected at farm level are aggregated in a set of standard groupings and, for each accounting year, the standard results are computed at the level of the European Union and for each Member State.

In this work FADN data were aggregated as follow (Table 1):

- Types of Farming (TF), 8 classes:a farm is classified as specialist if the Standard Output (SO) of one of the farms productive activities (or more than one if the activities are related) represents over two thirds of the total SO of the farm, otherwise it's classified as Mixed.

[1]Thresholds of economic size establishing the minimum size of agricultural holdings included into FADN field of observation differs between Member States.

[2]The Standard Output (SO)is the average monetary value of the agricultural output at farm-gate price of each agricultural product (crop or livestock) in a given Region. The SO is calculated by Member States per hectare or per head of livestock, by using basic data for a reference period of 5 successive years; for example, SO 2007 covers the calendar years 2005 to 2009. The SO coefficients are calculated for more than 90 separate crop and livestock items. This large number of items not only reflects the diversity of agriculture within the European Union, but also indicates the level of detail that is required to ensure that the results of the FADN and of other surveys are comprehensive and reliable. (FADN website).

- Economic Size Classes (ESC), 8 classes:the economic size of an agricultural holding is measured as the total SO of the holding expressed in euro[3].

Table 1:*Types of farming (TF) left, and Economic Size Classes (ESC- €) right*

Classes	Type of Farming
1	Fieldcrops
2	Horticulture
3	Wine
4	Other permanent crops
5	Milk
6	Other grazing livestock
7	Granivores
8	Mixed

Economic Size Class	Description
I	< 4.000 euro
II	from 4.000 to 8.000 euro
III	from 8.000 to 25.000 euro
IV	from 25.000 to 50.000 euro
V	from 50.000 to 100.000 euro
VI	from 100.000 to 500.000 euro
VII	from 500.000 to1.000.000 euro
VIII	> 1.000.000 euro

2.2 Methodology of analysis and Energy Impact Matrix (EIM)

The analysis of this work is based on theFADN2013 database, the last update available. For eachtype of farming and economic size class,“Direct energy”, “Indirect energy” and “Globalenergy”(direct + indirect) costswere considered andcorrelated with the farm economic index“Operating costs”.Operating costs represent those costs linked to the agricultural activity of the holder and covers the categories “Off farms consumption factor” (seeds, plants, fertilizers, pesticides and herbicides, water, electricity, fuel, feed and forage), “Other costs”(such as commercialization and transformation expenditures, overheads and land related costs), and “Third party services” (rental expenses, health costs, insurance, etc.).

The first part of the analysis allowed us to define the national average value of direct, indirect andglobal energy costs and their impact (%) on operating costs for each intersection of TF and ESC. The followingTable 2presents an example for ESC I.

Table 2: *Example ofDirect, Indirect and Global energy costs and impact of ESC class I.*

Type of Farming (TF)	EconomicSizeClass (ESC)							
	I							
	Farms	A-Operating Costs	B-Direct Energy	Impact % (B/A)	C - Indirectenergy	Impact % (C/A)	Global Energy (D=B+C)	Impact % (D/A)
Field Crops	12	2.506,00	754,72	30%	657,42	26%	1.412,14	56%
Horticulture	0	-	-	NA	-	NA	-	NA
PermanentCrops	4	1.462,25	568,26	39%	503,75	**34%**	1.072,01	**73%**
Grazing livestock	4	1.711,25	717,68	**42%**	82,50	5%	800,18	47%
Granivore	0	-	-	NA	-	NA	-	NA
Mixed Cropping	2	3.156,50	1.890,75	**60%**	330,50	10%	2.221,25	**70%**
Mixed Livestock	0	-	-	NA	-	NA	-	NA
Mixed Crops-Livestock	0	-	-	NA	-	NA	-	NA
Italy	***22***	***2.230,86***	***817,36***	***37%***	***495,23***	***22%***	***1.312,59***	***59%***

In the definition of the EIMs only values consistently higher then national average were considered using the statistical criteria of "Average Coefficient of Variation" to highlightthose intersection TF/ESC with an high incidence (red values). The Coefficient of Variation (CV) represents a standardized measure of dispersion of a probability distribution. It is often expressed as a percentage and defined as the ratio of a group of data's standard deviation σ to its mean μ:

$$CV = \frac{\sigma}{\mu} \text{ with } \mu \neq 0$$

The CV shows the extent of variability in relation to the average of the population. When its value is high, it means that the data has high variability and less stability, when is low, it means the data has less variability and high stability.In this work CV was calculated as the average of the coefficients of variation of each group identified for TF and ESC.All percentage value obtainedapplying CV criteria, representing high incidence for those specific intersection TF/ESC, generated the three Energy impact matricesfor costs related to direct, indirect and global energy use on operating costs.

3. Results

The analysis performed implies some important assessments: energy costs seems to affect Italian farms in relation to specific farm economic dimension and for giventype of farming.Considering direct energy impact matrix (Table 3), field cropsis the most affected class, presenting values above national average, especially in the last 3 economic size classes (VI, VII, and VIII). Considering also the agricultural surfaceavailable for those classes, it is probably due to the high use of tractor and field machinery, with high fuels consumption. The economic size classes where an high weight of direct energy costs is most widespread is the second class (SO form 4.000 to 8.000 Euro), characterized byhorticulture, permanent crops, grazing livestock, mixed cropping and mixed crop-livestock. A consistent impact of direct energy use costs appears also for the VIII economic size class, particularly for horticulture and mixed-livestock. Also this evidence seems to be correlated with the farms size as,for instance,large size greenhouses for horticulture require high electricity and gas consumption for cooling, as well as large surfaces for mixed-livestock farms have great direct energy consumption, mainly electricity for irrigation of forage crops often associated with livestock,milking and stable activities.

Table 3: *DirectEnergy Impact Matrix*

	EconomicSize Class (ESC)							
Type of Farming (TF)	I	**II**	III	IV	V	VI	VII	VIII
Field crops						**23%**	**20%**	**21%**
Horticulture		**25%**						17%
Permanentcrops		**26%**						
Grazing livestock	42%	**30%**						
Granivore								
Mixed cropping	60%	**23%**						
Mixed livestock			31%					16%
Mixed crops-Livestock		**29%**					19%	
Italy	***37%***	***19%***	***27%***	***24%***	***22%***	***18%***	***14%***	***10%***

Concerning indirect energy consumptionscosts (Table 4), a strong correlation between farm size and operating costs is clear.Five TF classes out of eight(field crops, horticulture, permanent crops, mixed cropping and mixed crop-livestock) present a percentage impact even four time above the national average in the VIII ESC. Horticulture is clearly the he specific type of farming most affected by indirect energy consumptions, presenting high levels of impact for all economic size classes except the field crops.Similar results can be recordedalso for field crops, mixed cropping and the for permanent crops. The fact that such kind of farms are significantly affected by indirect energy costs probably depends on the huge quantity on chemical inputs needed, especiallyfor big farm sizes.

Table 4: *IndirectEnergy Impact Matrix*

	EconomicSize Class (ESC)							
Type of Farming (TF)	I	II	III	IV	V	VI	VII	**VIII**
Field crops			44%	46%	49%	48%	51%	**53%**
Horticulture		**53%**	**53%**	**48%**	**54%**	**52%**	**44%**	**48%**
Permanentcrops	34%	27%				30%	29%	**30%**
Grazing livestock								
Granivore								
Mixed cropping		35%		39%	43%	51%	63%	**45%**
Mixed livestock								
Mixed crops-Livestock								**27%**
Italy	***22%***	***22%***	***35%***	***33%***	***31%***	***26%***	***18%***	***12%***

Table 5 presents the results for global costs; it highlights that concerning the economic size classes, the occurrence of an impact above national average, appears mostly for all economic size classes,except for the first and the third one: four times for ESC II, VI, VII and VIIIand three times for IV and V.This seems to show once again a direct correlation with farmssurface, a part from their specialization, with peak values between 70% and 80% in classes VI, VII and VIII for field crops and mixed cropping.

Horticulture and mixed cropping (seven classes on eight are over average), but also field crops (from III to VIII class) are the type of farming most affected and considerably sensible to energy.

Table 5: *Global energy Impact Matrix*

	EconomicSize Class (ESC)							
Type of Farming (TF)	I	**II**	III	IV	V	**VI**	**VII**	**VIII**
Field crops			72%	73%	74%	**72%**	**71%**	**74%**
Horticulture		**79%**	**74%**	**69%**	**74%**	**69%**	**57%**	**66%**
Permanentcrops	73%	**54%**				**49%**	**46%**	
Grazing livestock								
Granivore								
Mixed cropping	**70%**	**58%**		**62%**	**65%**	**71%**	**80%**	**59%**
Mixed livestock								
Mixed crops-Livestock		**46%**						**38%**
Italy	***59%***	***41%***	***62%***	***57%***	***53%***	***44%***	***32%***	***22%***

4. Conclusions and recommendations

This kind of analysis is an useful tool to identify specific targets in the agricultural sectors most affected by energy expenses, where to obtain better operational results in terms of environmental and economic performances.

Results suggest that reducing energy costs is a crucial topic for future policy strategiesaddressed at improving energy efficiency and competiveness of farms.

Acknowledgements of regulatory framework on energy management and technical approaches in use, such as certifications systems (adoption of EMS – Energy Management System) allow us to consider energy audit as the right tools to evaluate farm's energy consumptions andincrease the level of knowledge on energy uses in agriculture.

The general audit technique, is based on the *Deming Cycle* which represent a continuous improvement methodology with four stages: plan, do, study, act (Dean and Evans, 1994)[4].

Performing an energy audit in a given structure means to do an objective analysis of energy management so it is an essential tool for achieving a reduction in energy consumptions and hence, costs.

[4]Specifically, the audit technique is referred to the traditional procedures adopted for quality and/or environmental management systems derived from ISO 19011:2003 "Guidelines for quality and/or environmental management systems auditing".

It could be useful to look at other experiences, where, in order to be properly developed and spread, energy audit has been included in a nationalenergy performance plan for agriculture, as happened in France with the *Plan de Performance Energètique*(PPE)[5].

To reach such important objectives, farmers should be fully aware of their potential and research institution and policy makers can play a central role in increase the level of public awareness.

[5]It was an holistic plan, integrated with France Rural Development Plan, made of eight axis and aimed at getting a better knowledge of energy consumption and production on French farms, spreading farm energy audits in great numbers. It also promoted research and innovation activities encouraging partnerships of public institutions with the private sector and allowed the awareness on energy efficiency as a long term issue (http://agriculture.gouv.fr/ministere/le-plan-de-performance-energetique-2009-2013-des-exploitations-agricoles).

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Evaluating Revenues and Economic Growth for Farms Producing Renewable Energies: an Investigation Based on Integration of FSS and EOAH2013 Survey Data

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ABSTRACT

Recently there has been a growing interest in multifunctional farms. In this paper we focus on some characteristics of the Italian agricultural holdings which produce renewable energy. To better investigate this topic it is necessary to integrate data collected in two sample surveys: the Farm Structure Survey and the Survey concerning Economic Outcomes of Agricultural Holdings. The paper presents a particular approach to the integration problem; the integration permits a deeper investigation of the characteristics and the economic performances of the interest agricultural holdings by analysing relationship between variables not jointly collected in a single survey.

Keywords: agriculture surveys, hotdeck imputation, statistical matching, multifunctional farm.

1. Introduction

Recent studies show an increase of the multi-functional Italian farms, i.e. holdings carrying out diversified activities such as tourism activities, contractual work, processing of farm products and renewable energy production, among the most popular ones. The focus of this paper is on activities related to the production of energy for self-consumption and/or for sale, and their corresponding earnings. The information about the production of renewable energy have been collected in occasion of the 2010 Italian Agriculture Census, and more recently by the 2013 Farm Structure Survey. Unfortunately these structural surveys are not able to catch revenues of such activities. These information can be retrieved from the survey on the Economic Outcomes of Agricultural Holdings, which is carried out annually on a sample basis. Unfortunately this latter survey does not collect data on costs and revenues related to the production of renewable energy. For this reason a deeper analysis of the phenomena requires an integration of the data collected in both the surveys.

The paper will describe a first approach for integrating the two surveys in order to investigate the economic characteristics of agricultural holdings producing renewable energy. In particular Section 2 describes the data sources, while the integration process is described in Section 3. Section 4 provides some results concerning the phenomena under investigation.

2. Data sources on agricultural holdings

The Farm structure survey (FSS) is regulated at European Union level and provides harmonised data on agricultural holdings (AHs), including: number of holdings, land use and area (main crops), livestock, farm labour force (by age, gender and relationship to the holder), type of activity, economic size of the holdings, other gainful activity on the farm, system of farming, machinery, organic farming. It is run at regular intervals, every three years on a sample basis while every 10 years it coincides with Agricultural Census. FSS data are also used in other policy areas such as environment, regional development and climate change. In addition to the contents, the regulation defines also coverage and precision requirements as well as the sampling strategy: stratified random sampling where the stratification shall include the size and type of the AHs. Italian 2013 FSS edition sampled 44,168 holdings (the sampling frame was the 2010 Agriculture Census list consisting of about 1.6 millions of AHs), out of which 40,166 were active and respondent. The number of holdings considered in the present work is of 39,656, where new holdings have been disregarded.

The economic performances of Italian agricultural holdings are investigated annually by means of the sample survey on "Economic outcomes of agricultural holdings" (EOAH). In practice it consists in two independent surveys carried out on two non-overlapping subpopulations: the medium-large sized AHs are investigated via the Farm Accountancy Data Network (FADN) survey, while smallest farms are observed by means of an ad hoc survey with a relatively short questionnaire. The size of the farms is measured in terms of Standard Output (SO; the gross agricultural output expressed in monetary terms): in 2013 holdings with SO (derived using 2010 Census data) greater or equal to 4,000€ were included in the FADN target population. Such a two-fold survey is carried out jointly by Istat and Crea, the liaison agency as far as FADN is concerned. The variables observed in EOAH consists mainly in costs and revenues of the AHs. The data being considered in this paper are those referred to 2013 accountancy year; the sample consisted of about

19,000 holdings (15,000 for FADN and 4,000 for the remaining part of the population). The available data refer to about 11,000 responding AHs; however for practical purposes in this study we will refer to a slightly smaller subset, consisting of 10,757 units, obtained by discarding the new holdings emerged after splitting or fusion of sampled AHs.

3. Integration of the data sources

For the sake of simplicity, in this Section the EOAH survey will be denoted as *A*, while FSS will be denoted as *B*. The union of the two surveys ($A \cup B$) returns the situation illustrated in Figure 1.

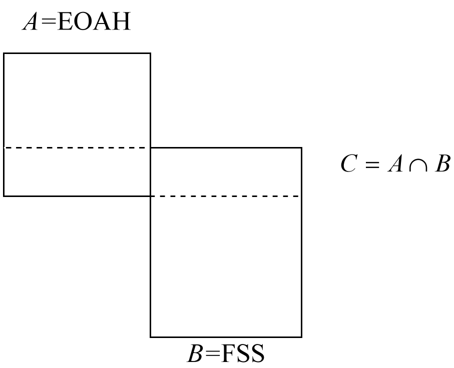

Figure 1: *Union of EOAH and FSS surveys.*

In practice, *A* consists of $m_A = 10,757$ AHs while *B* includes $m_B = 39,331$ units; their intersection, $C = A \cap B$, provides a non-empty set with $m_C = 3,724$ AHs; these results were obtained after a file merging based on error-free AH identification code.

The subset *C* contains all the variables observed both in *A* and *B*; given its non-negligible size, it would allow in-depth analysis of phenomena involving variables not jointly observed in a single survey. In our case the interest is in the relationship between revenues of holdings and the presence of equipment for energy production. The revenues are observed in EOAH survey (*A*); the attention here is on revenues due to some unclassified other gainful activities, denoted as *Y*. The presence of equipment for renewable energy production is observed is FSS (*B*) and hereafter will be denoted as *Z* (1='Yes'; 2='No').

The units in *C* permits the investigation of the relationship between *Y* and *Z*, but it is not straightforward to generalize results to the whole population of Italian AHs. First of all, the probabilistic sampling design underlying both the surveys (stratified random sampling) tends to assign higher probability of being included into the sample to large AHs, for this reason it is expected that the intersection set *C* includes medium-large size farms, but, since more than 3,700 have been randomly included in both surveys, a deeper analysis of the structural characteristics must be performed. Moreover, two equivalent alternative set of survey weights (weights derived as the inverse of the probability of including a unit into the sample, usually corrected to account for unit nonresponse and coverage errors) can be used to derive estimates from *C* : those arising from *A* and the ones from *B*. For instance, Table 1 provides the results of crossing the variable *Z* and a categorized Y variable denoting the presence of 'other' revenues (1 if $y_k > 0$ and 2 otherwise), where the word 'other' refers to unclassified revenues not due to sales of agricultural products nor to activities like tourism, processing of food products etc.; in practice Y includes production of renewable energy but not solely refer to that.

Table 1: *Estimated joint distributions of Y and Z derived from the intersection of the two surveys.*

	Subset *C*, *A* weights			Subset *C*, *B* weights			*Y* distribution	
	Z=1	*Z*=2	Tot.	*Z*=1	*Z*=2	Tot.	Estimated in *A*	
Y=1	0.40	2.71	3.11	0.38	2.24	2.62	*Y*=1	***5.95***
Y=2	1.19	95.70	96.89	0.96	96.42	97.38	*Y*=2	***94.05***
Tot.	1.59	98.41	100.00	1.34	98.66	100.00	Tot.	***100.00***
	2.07	***97.93***	***100.00***	***2.07***	***97.93***	***100.00***		

In general, the joint distributions of Y and Z, estimated with the different weighting systems, seem quite close; but if we look at the marginal distributions the results are not satisfactory; as far as Y=1 is concerned, the obtained estimates, 3.11% and 2.62% respectively, are far from the "reference" estimate 5.95% derived considering in the whole survey A (in italic-bold text there are the marginal distributions of Y and Z estimated from the whole survey they are directly observed, A and B respectively). This gap confirms the idea that C cannot be considered a representative sample of the population of Italian AHs. Indeed, by looking at the main characteristics of the AHs belonging to the various subsets, it seems that C tends to over-represent small-medium farms.

Table 2: *Main characteristics of the agricultural holdings observed in both the surveys.*

Source	No. of units	**Weighted averages**					
		LSU		UAA (in ha)		SO (euros) Census	
		A weights	*B* weights	*A* weights	*B* weights	*A* weights	*B* weights
A-C	7 033	10.4		5.9		38,616.2	
C	3 724	6.6	4.9	4.8	4.5	27,362.0	26,122.4
B-C	36 207		9.3		5.6		33,616.8
Whole sample (*A* or *B*)		8.4	8.4	5.3	5.4	32,639.9	32,230.4

*computed considering aggregated livestock categories

In particular, Table 2 shows that AHs in C provide estimated average values of *utilized agriculture area* (UAA), *livestock size unit* (LSU) and SO smaller than the remaining units, thus indicating that using C as base for inferences would provide a picture of medium-small AHs. For this reason it is not advisable to perform inferences using solely C, even in the hypothesis of modifying the survey weights of units in it, e.g. by using Renssen's (1998) weights' calibration approach, in order to obtain a representative set, in terms of size, of the whole population of AHs. Furthermore weights' calibration performed on C may be problematic because of the relatively small number of units if compared to the possible constraints to be set.

In order to make inference valid for the whole population the problem can be tackled by resorting to the approaches developed to integrate survey data that are commonly denoted as *statistical matching* or *data fusion* (cf. D'Orazio *et al.*, 2006), by using the set C as the joint information. Statistical matching techniques are developed to integrate survey data related to the same target population with the scope of investigating the relationship between variables not jointly observed in a single source. Integration is based on the information shared by both the sources. The situation described in Figure 1 corresponds to a particular framework, commonly encountered when integrating data concerning business or agricultural units In this case, the challenge is to perform the matching by exploiting the information in C (see e.g. Ballin *et al.*, 2008, 2009; Torelli *et al.* 2009). An approach suitable to manage such a situation is the Rubin's (1986) *file concatenation*, where the base of the inference is $A \cup B$. For this purpose two steps are necessary (i) computation of a new set of weights for each unit in $A \cup B$, to account for the probability that a single AH is included in survey A, in B or in both; and (ii) imputation of the target variables in subsets where they are missing. The first step is not straightforward (cf. Ballin *et al.*, 2008) and however the Rubin's procedure is thought to integrate theoretic samples by means of direct survey weights available for the whole population, while in practice the data sources include just responding units and the corresponding weights obtained by correcting direct survey weights to compensate for representativeness problems. The second step can be tackled in different manners, and, in our case, the problem is that of imputing variables available in $B - C$ which is very large ($n_{B-C} = 36,207$) if compared to $A - C$ ($n_{A-C} = 7,033$). The main risk is that of imputing unreliable values whose marginal distribution does not correspond to the reference one.

A viable way of working may be that of applying nonparametric procedures based on *hot deck imputation* methods. These methods consist in imputing the missing variable into the *recipient* data source by selecting suitable donors from the other data source, the *donor*. The recipient data set filled in with the missing information, called *synthetic data source*, becomes the base for final inferences. Imputation relies on the information shared by both the data sources (cf. Section 2.4 in D'Orazio *et al*., 2006). The common practice consists in choosing as recipient the smallest data source while the other one plays the role of donor.

In our integration problem, applying the standard version of hot deck matching procedures, would mean imputing in A values of Z observed on the donor units in B, based on some variables (X) shared by both the data sources. Unfortunately, the available common variables X are not good predictors of the target variables Y and Z, and, in any case, such a way of working would not allow to exploit the information in the subset C, in particular with respect to the relationships between the variable Z and those only observable in set A. For these reasons we decided to consider only A and use C as a donor for the remaining units for A (subset $A - C$) where Z was missing, even if the donor data set is smaller than the recipient one. The method chosen for imputing Z (production of renewable energy) in $A - C$, is a particular version of *random hot deck*; in practice for each recipient unit with a given legal form (company or not) the $k = 10$ closest donors sharing the same legal form are searched in C, then one of the donors is randomly picked up (cf. D'Orazio, 2016); closeness between recipient and donor units is measured in terms of a Euclidean distance and the algorithm is based on an approximate nearest neighbour (ANN) research tree, a balanced box-decomposition BBD tree (cf. Arya et al., 2015). The distance is computed on the following variables: geographical area (North-West, North-East, Centre, South and Islands); costs for purchasing electric energy, gas, etc.; amount of 'other' revenues; overall revenues.

To get an idea about the reliability of the imputation procedure we check whether the marginal distribution of the imputed variable Z is coherent with the "reference" one, i.e. estimated from the whole survey B. The Table 3 provides the different estimates; in survey B, where the variable is originally observed, the estimated percentage of units producing renewable energy is about 2% (about 30,000 over 1.5 million of AHs); two alternative estimates can be derived from C, according to the chosen weighting system (i.e. weights from A or from B); in both the cases there is a tendency to underestimate the percentage of AHs producing renewable energy. Finally, considering A after imputation of missing values for the subset $A - C$, it comes out an estimate of 2.55% units producing renewable energy; a value that slightly overestimates the fraction estimated in survey *B* (2.07% is the reference estimate). This result seems quite good and, more in general, it can be said that the imputation procedure provides in EOAH survey (*A*) a reasonable estimate of the distribution of *Z* (production of renewable energy).

Table 3: *Marginal distributions of the Z variable estimated from different datasets.*

Z	Survey *B*	Subset *C* (weights *B*)	Subset *C* (weights *A*)	Synthetic *A* (weights *A*)
1	2.07	1.34	1.59	2.55
2	97.93	98.66	98.41	97.45
Tot	100.00	100.00	100.00	100.00

4. Analyses on the synthetic dataset

The synthetic data set obtained by imputing the production of renewable energy (Z) in survey *A* allows a series of analyses involving *Z* itself and some economic variables observed just in *A*. First of all it is possible to check the presence of association between the production of renewable energy and the presence of "other" revenues, i.e. not attributable to revenues categories of AHs explicitly listed (sales of products, animals, transformed products, aquaculture, tourism, etc.).

Table 4: *Joint distribution of presence of 'Other' revenues and production of renewable energy.*

	Prod. Renewable energy		
	Yes	No	Total
"Others" revenues > 0	9 934	80 080	90 015
Row. rel. freq. (%)	*11.0*	*89.0*	*100.0*
Col. rel. freq. (%)	*25.8*	*5.4*	*6.0*
"Others" revenues = 0	28 567	1 393 574	1 422 142
Row. rel. freq. (%)	*2.0*	*98.0*	*100.0*
Col. rel. freq. (%)	*74.2*	*94.9*	*94.0*
Total	38 502 *2.5* *100.0*	1 473 655 *97.5* *100.0*	1 512 157

Table 4 shows that the fraction of AHs having nonzero vales for "other" revenues is higher for those having equipment for renewable energy production (25.8% vs. 5.4%). In addition, among the AHs that produce renewable energies, those that declare other non-agricultural revenues are roughly one third of the ones having only agricultural revenues (25.8% vs 74.2%). This suggests that within Italian agriculture the production of renewable energy is more likely to be employed to lower costs and because of other benefits, including rural development support, rather than for the direct sale of energy, thus representing an additional gainful activity producing other revenues.

Table 5 goes more in detail by considering the overall revenues. It can be seen that the marginal distribution of the revenues ("row pct" in Table 5) changes passing from AHs with production of renewable energy to those without; in particular, the share of revenues due to non-agricultural activities (column non-agr. 'other') in the first case is much higher (8.4%) than in the second (2.3%). Furthermore, even if among the AHs that declare other revenues only 11% of them produce renewable energy, these AHs cover the 36.9% of revenues deriving from other non-agricultural activities, thus showing that the gainful activity linked with the sale of energy is much more profit-making than other gainful ones. Moreover when comparing average revenues due to sales of products (transformed or not), the AHs without installations for the production of renewable energy (which contribute for the 95.4% of total revenues vs 90.2) in average gain 42.5 thousands of Euros, less than one third of the average revenues of the same type achieved by holdings with production of renewable energy (140.0 thousand of Euros). This result confirms that AHs producing renewable energy tend to be "larger" in terms of revenues than the remaining ones.

Table 5: *Production of renewable energy and revenues of agricultural holdings*

Production of	No. of	Agriculture		Non-agr. (exc. "other")		Non-agr. "Other"		**Overall revenues**	
renew. energy	Holdings	tot.*	ave.**	tot.*	ave.**	tot.*	ave.**	tot.*	ave.**
Yes	38 502	5 390.2	140.0	83.4	2.2	499.3	13.0	**5 973**	**155.2**
row pct		*90.2*		*1.4*		*8.4*		*100.0*	
col pct	*2.5*	*13.5*		*9.3*		*36.9*		*14.1*	
No	1 473 655	34 657.3	23.5	817.8	0.6	852.7	0.6	**36 328**	**24.7**
row pct		*95.4*		*2.3*		*2.3*		*100.0*	
col pct	*97.5*	*86.5*		*90.7*		*63.1*		*85.9*	
All	**1 512 157**	**40 047.5**		**901.3**		**1 352.1**		**42 301**	**28.0**
row pct		*94.7*		*2.1*		*3.2*			
col pct		*100.0*		*100.0*		*100.0*			

*Millions of Euros; **Thousands of Euros

Finally, Table 6 provides some results concerning the costs incurred by the AHs. The attention is just on the costs for electricity, gas etc. and on the overall costs. In particular, the average cost for electricity is much higher for the holdings producing renewable energy (about 6 times higher); this result seems a consequence of the fact that AHs producing renewable energy are "larger" than the other ones in terms of costs, in fact their overall costs are larger too (in average 7 times greater than the holding not producing renewable energy). As a consequence the incidence of cost of electricity with respect to overall costs is smaller for the farms producing renewable energy (3.9% vs. 4.5%).

Table 6: *Production of renewable energy and some costs of agricultural holdings*

Production of	No. of	Electricity, gas		Overall costs		Electr./
renew. energy	holdings	*tot.**	*ave.***	*tot.**	*ave.***	Overall
Yes	38 502	121.0	3.1	3 140.9	81.6	3.9%
No	1 473 655	774.2	0.5	17 175.9	11.7	4.5%
All	**1 512 157**	**895.1**	**0.6**	**20 316.8**	13.4	4.4%

*Millions of Euros; **Thousands of Euros

5. Conclusions

So far in Italy some characteristics of farms producing renewable energy cannot be easily investigated due to the absence of a single data source providing all the interest information. In fact, Italian Farm Structure Survey (FSS) collects data concerning production of renewable energies for self-consumption and/or sale while EOAH collects information on revenues and costs but not the presence of such a production activity. The integration problem within this framework has been tackled by applying statistical matching techniques suitable to deal with two different sources. The intersection of the two samples, i.e. the common complete available information on subset *C*, has been used as donor in a nonparametric imputation procedure. Under these assumptions, revenues and costs-observed in EOAH have been investigated after having imputed the presence of - the production of renewable energies. Results clearly suggest that Ahs producing renewable energy are characterized by much higher overall revenues than others, even in terms of other non-agricultural revenues as hypothesized, but also in terms of agricultural competitiveness, since average agricultural revenues are more than three times higher when compared with other farms. Furthermore this practice lowers cost associated to electricity. More in general, it seems that the sale of energy is still a minor reality for Italian farming, but economic performances of agricultural holdings that produce renewable energy are on average much higher than those who do not, thus this practice should be encouraged, and the growing phenomenon also deeper analysed.

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Assessing Bioenergy Sustainability through the use of the Global Bioenergy Partnership (GBEP) Sustainability Indicators for Bioenergy

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ABSTRACT

The Global Bioenergy Partnership (GBEP) is an international initiative that brings together public, private and civil society actors to cooperate on a voluntary basis in the areas of bioenergy for sustainable development, climate change mitigation, and food and energy security as per the mandate of the 2005 G8 Summit. FAO is a founding partner of GBEP and hosts its Secretariat since its establishment in 2006. In 2011, GBEP agreed on a set of 24 science-based, technically sound, voluntary and highly relevant indicators concerning the sustainability of all forms of bioenergy. The measurement of these indicators can inform policy-makers and other stakeholders in countries seeking to develop their bioenergy sector to help meet national goals of sustainable development. Measured over time, the indicators will show progress towards or away from a nationally defined sustainable development path.

To date the GBEP indicators have been applied in a number of countries to various extents including Japan, Germany, Indonesia, Colombia, the Netherlands, Ghana and Argentina, and several others have announced their intention to perform the assessment or are already carrying out the assessment including Kenya, Ethiopia, Viet Nam, Paraguay, the United States of America, Jamaica, Italy and Brazil.

In this paper the results of and lessons learned from the “Pilot testing of Global Bioenergy Partnership (GBEP) indicators for sustainable bioenergy in Colombia and Indonesia” will be shared.

Keywords: Bioenergy, Sustainable development, Colombia, Indonesia.

1. Introduction

The production and use of bioenergy is growing in many parts of the world as countries seek to diversify their energy sources in a manner that helps promote sustainable development. Modern bioenergy can provide multiple benefits, including promoting rural economic development, increasing household income, mitigating climate change, and providing access to modern energy services. On the other hand, bioenergy can also be associated with risks, such as biodiversity loss, deforestation, additional pressure on water resources, and increased demand for agricultural inputs, land, and commodities.

The Global Bioenergy Partnership (GBEP), an international initiative established in 2006 and of which FAO is a founding partner, has developed a science-based, technically sound, and highly relevant set of 24 indicators (Table 1) that can inform policy-makers and other stakeholders in countries seeking to develop their bioenergy sector to help meet national goals of sustainable development. Measured over time, the indicators will show progress towards or away from a nationally defined sustainable development path.

The indicators were intentionally crafted as a voluntary tool to report on the environmental, social and economic aspects of sustainable development. Each indicator was developed with three parts: a name, a short description, and a multi-page methodology sheet that provides in-depth information needed to evaluate the indicator.

Table 1: Indicator names.

GBEP INDICATORS		
Environmental	**Social**	**Economic**
1. Lifecycle GHG emissions	9. Allocation and tenure of land for new bioenergy production	17. Productivity
2. Soil quality	10. Price and supply of a national food basket	18. Net energy balance
3. Harvest levels of wood resources	11. Change in income	19. Gross value added
4. Emissions of non-GHG air pollutants, including air toxics	12. Jobs in the bioenergy sector	20. Change in consumption of fossil fuels and traditional use of biomass
5. Water use and efficiency	13. Change in unpaid time spent by women and children collecting biomass	21. Training and requalification of the workforce
6. Water quality	14. Bioenergy used to expand access to modern energy services	22. Energy diversity
7. Biological diversity in the landscape	15. Change in mortality and burden of disease attributable to indoor smoke	23. Infrastructure and logistics for distribution of bioenergy
8. Land use and land-use change related to bioenergy feedstock production	16. Incidence of occupational injury, illness and fatalities	24. Capacity and flexibility of use of bioenergy

In order to establish the feasibility of these indicators and enhance their practicality as a tool to support policy-making towards sustainable development of bioenergy, it was suggested to pilot test them, supporting countries with required technical and financial assistance.

As of July 2016, the GBEP indicators had been implemented in nine countries (i.e. Argentina, Colombia, Egypt, Germany, Ghana, Indonesia, Jamaica, Japan and Netherlands) and another dozen countries committed to implement or were in the process of implementing them.

With this paper, the results of the "Pilot testing of Global Bioenergy Partnership (GBEP) indicators for sustainable bioenergy in Colombia and Indonesia" will be shared.

The overall objective of the project was to pilot the GBEP sustainability indicators in Colombia and Indonesia, and build the capacity of these two countries to apply the indicators and use them to inform the sustainable development of their bioenergy sectors.

The project aimed to:

- assess and enhance the capacity of the two countries to measure the GBEP indicators and use them to inform bioenergy policy-making; and
- learn lessons about how to apply the indicators as a tool for sustainable development and how to enhance the practicality of the tool.

2. Results of the pilot testing

2.1. Main findings in Colombia

The testing of GBEP sustainability indicators in Colombia focused on ethanol from sugarcane and biodiesel from palm oil. The testing provided Colombia with an understanding of how to establish the means of a long-term, periodic monitoring of its domestic bioenergy sector based on the GBEP indicators. Such periodic monitoring would enhance the knowledge and understanding of this sector and more generally of the way in which the contribution of the agricultural and energy sectors to national sustainable development could be evaluated. Furthermore, the testing in Colombia provided a few lessons learnt about how to apply the indicators as a tool for sustainable development and how to enhance their practicality. These lessons learned, which were shared and discussed with neighbouring countries at regional level, as well as the trainings carried out during the project showed the importance of these activities in the measurement of the GBEP Indicators and in the facilitation of South-South cooperation.

2.1.1 Sustainability of bioenergy in Colombia

A number of environmental, social and economic issues associated with the sugarcane-based ethanol and palm oil-based biodiesel supply chains were identified during the testing of the GBEP indicators in Colombia.

On the environmental side, fertilizer and pesticide applications were identified as key sources of GHG emissions and water pollution along both supply chains. Few data could be found on this, due to the limited extent of ongoing monitoring and analysis of water quality in Colombia. Therefore, despite the limited interest in this issue expressed by Colombian stakeholders during the testing of the GBEP indicators, further data collection and analysis would be needed on the impacts of bioenergy feedstock production and processing on water quality. In parallel, good practices that reduce fertilizer and pesticide application while improving efficiency and profitability, such as Integrated Plant Nutrient Management and Integrated Pest Management, should be promoted. Wastewater is another source of GHG emissions and water pollution along the sugarcane-based ethanol and palm oil-based biodiesel supply chains. In this case, methane capture and use should be promoted, including through carbon offset programmes, as is already being done in the palm oil industry in Colombia.

In addition to water quality, issues related to water availability and use in bioenergy feedstock production were identified. In particular, water withdrawals for sugarcane production (including for ethanol) in the *Cauca* watershed might trigger medium-high water stress in dry years. Therefore, irrigation efficiency should be closely monitored and improved technologies and management practices promoted. Finally, with regard to soil quality, both the *Valle del Cauca* (the main sugarcane production area of Colombia) and the Northern region of the *Caribe*, where oil palm is cultivated, show high susceptibility to salinization.

On the social side, in addition to the aspects already discussed above, other issues were explored, for instance with regard to the quality of the jobs associated with biofuel feedstock production and processing. Overall, compared to the average agricultural worker, sugarcane and oil palm workers seem to benefit from a higher level of formalization of employment, better wages and benefits and better protection against occupational risks. Another interesting aspect relates to the business models and the level of smallholder inclusion along the biofuel supply chain. During the last decade, there was an important transformation in the palm oil supply chain in Colombia, with the emergence of the so-called *Alianzas Productivas Estratégicas.* The *Alianzas* are strategic business partnerships formed by small-scale producers, which organize themselves in order to improve their access to credit, strengthen their bargaining power with the mills, and ensure a secure market for their produce thanks to contracts with the latter. As of 2010, around 16 percent of the planted area of oil palm was under an *Alianza*, up from less than 1 percent in 1999. In addition to having contributed to the growth of the palm oil sector, these strategic business partnerships have been quite effective in strengthening the inclusion of smallholders in the palm oil supply chain and in increasing their profitability. The *Alianzas* should be further researched and analyzed and the potential for their future expansion in the palm oil supply chain and eventually in the sugarcane supply chain should be explored.

With regard to the economic aspects, the Colombian biofuel sector can count on a high level of productivity in feedstock production, especially with regard to sugarcane, with an average annual yield among the highest in the world (i.e. 120 t/ha). From an energy balance perspective, Colombian sugarcane-based ethanol and palm oil-based biodiesel supply chains are rather efficient compared to the production of other first-generation liquid biofuels. This is true especially for sugarcane-based ethanol systems, which use the energy content of the biomass rather efficiently, through co-generation of electricity and steam from bagasse, in addition to the sugar and ethanol output.

While the gross value added generated by the biofuel industry in Colombia is relatively small compared to the GDP (e.g. 0.031 percent in the case of ethanol in 2010), the demand for goods and services associated with this industry was found to trigger multiple indirect and induced effects on the economy, including in terms of employment.
Furthermore, even though in 2009 ethanol and biodiesel accounted for only 1.05 percent and 0.7 percent respectively of the total primary energy supply (TPES) in Colombia, these biofuels substituted fossil fuels worth 103 million USD (ethanol) and 215 million USD (biodiesel) in 2012. However, the contribution of these biofuels to energy security was limited by their lack of diversity in terms of feedstock and geographic location, exposing their production to risks related to pest outbreaks and adverse weather conditions, especially in the case of sugarcane-based ethanol. Bagasse, which is a co-product of sugarcane processing used for cogeneration, contributed 3.49 percent to TPES in 2009. On other hand, in Colombia, where woodfuel was still accounting for 8.7 percent of TPES in 2009, modern bioenergy technologies have not played a significant role yet in displacing traditional uses of biomass and in providing access to modern energy services.

2.2. Main findings in Indonesia

The testing of GBEP sustainability indicators in Indonesia focused on palm oil-based biodiesel, reflecting the indications emerged during discussions with relevant stakeholders in Indonesia and the relevance of biodiesel within Indonesia's modern bioenergy mix. The testing provided Indonesia with an understanding of how to establish the means for a long-term, periodic monitoring of its domestic bioenergy sector based on the GBEP indicators. Such periodic monitoring would enhance the knowledge and understanding of this sector and more generally of the way in which the contribution of the agricultural and energy sectors to national sustainable development could be evaluated. The testing in Indonesia also provided a series of lessons learnt about how to apply the indicators as a tool for sustainable development and how to enhance their practicality. These lessons learnt, which were shared and discussed with neighbouring countries at regional level, as well as the trainings carried out during the project showed the importance of these activities in the measurement of the GBEP Indicators and in the facilitation of South-South cooperation.

2.2.1 Sustainability of bioenergy in Indonesia

A number of environmental, social and economic issues associated with palm oil-based biodiesel supply chains were identified during the testing of the GBEP indicators in Indonesia. In Indonesia, the growing demand for palm oil, including as biofuel feedstock, has triggered a supply response, in the form of an expansion in the harvested area of oil palm. Thanks to this increase in production, there was no diversion of palm oil from the food market to the biofuel market, as confirmed also by the data available in national and international statistics. According to FAOSTAT, between 2008 and 2012, the supply of palm oil for food increased in Indonesia. However, the land-use changes associated with the oil palm expansion have given rise to a range of environmental, social and economic impacts.

In 2010, around 8.4 million hectares were planted with oil palm in Indonesia, of which 91.6 percent in the islands of Sumatra, Kalimantan and Papua. Between 1990 and 2010, about 6.35 million ha of land were converted to oil palm in these three islands.

According to the Life Cycle Analysis (LCA) of GHG emissions that was performed during the project, under indicator 1, this expansion led to the conversion of high carbon stock areas (e.g. forests, timber plantations, etc.), causing significant emissions of carbon dioxide. In addition, about 1.25 million ha of peatland were drained and converted to oil palm cultivation, resulting in high, continuous GHG emissions from peat decomposition. Overall, the results of the LCA confirmed that land-use change, especially from forests, is the most important contributor to total GHG emissions from the Indonesian palm oil industry.

Other important consequences of land use change associated with oil palm expansion are habitat loss and impacts on biodiversity. As of 2010, 17 percent of Indonesian oil palm plantations were found in High Conservation Value areas.

Another important source of GHG emissions along the palm oil supply chain is the methane released by the anaerobic fermentation of palm oil mill effluent (POME). As of 2012, only around 5 percent of the over 600 Indonesian palm oil mills were equipped with methane capture systems. An analysis of the economic viability of these methane capture systems should be conducted and, if necessary, measures to promote their wider adoption might be considered.

In addition to land-use change and the associated effects in terms of GHG emissions and biodiversity, a number of other environmental issues were assessed and analyzed.

With regard to soil quality, in East Kalimantan, soil erosion affects oil palm production areas. Concerning soil organic carbon, data is scarce due to the lack of periodic monitoring.

Regarding water quality, it was found that large quantities of pollutants, mainly nitrate and phosphate, are discharged into the bodies of water near the oil palm plantations. As a result, in several areas pollutant concentrations in rivers often exceed the thresholds set by law, particularly around smallholders plantations on peat soils. Further and more refined investigations of pollutant loadings in the internal waters in Indonesia due to biodiesel feedstock production are needed, including mathematical modelling of material transport. With regard to non-GHG airborne pollutants, the low level of mechanization in oil palm cultivation results in relatively low emissions of such pollutants. Concerning tailpipe emissions, tests have demonstrated that biodiesel can significantly reduce the emission of most non-GHG pollutants when compared to fossil-based diesel, showing the potential environmental and health benefits of a shift from traditional fuels to biofuels, especially in densely populated urban areas.

With regard to social sustainability, in addition to the food security implications mentioned earlier on, other issues were explored as well, for instance with regard to the income effects and the number and quality of jobs associated with biofuel feedstock production and processing. As explained above, the increased in the demand for palm oil for biodiesel in Indonesia has triggered a supply response, leading to a significant expansion in the planted area (and subsequently harvested area) of oil palm. This has resulted in a considerable increase in the number of people employed in palm oil production. Regarding the quality of the jobs created in this sector, compared to the average agricultural worker oil palm workers seem to benefit from a higher level of formalization of employment, better wages and benefits, and better protection against occupational risks. The increase in the demand for palm oil for biodiesel production has also provided additional income-generating opportunities for agricultural producers, including smallholders, who accounted for around 35 percent of total palm oil production in Indonesia in 2012.

With regard to land tenure, a few cases of land conflicts were reported in literature, including in the context of oil palm plantations, with lack of adequate legal recognition of customary rights to land identified as one of the main causes.

Last, but not least, concerning energy access, it was found that to date modern bioenergy has not played a significant role in providing access to modern energy services and in displacing traditional uses of biomass, which still accounted for over 18 percent of the Total Primary Energy Supply (TPES) in 2012.

With regard to the economic sustainability aspects, the Indonesian biofuel sector appears to be cost-competitive. However, yields have been stagnant for many years, whereas higher yields have been obtained in experimental trials thanks to the research and development of improved varieties and management regimes.

While the gross value added generated by the biofuel industry in Indonesia is relatively small compared to the GDP (e.g. 0.026 percent in 2012), the demand for goods and services associated with this industry has been reported to trigger multiple indirect and induced effects on the economy, including in terms of employment.

From an energy balance perspective, the Indonesian palm oil-based biodiesel supply chain is rather efficient compared to the production of other first-generation liquid biofuels. However, there appears to be room for further improvement in the feedstock production phase of the supply chain (particularly in the case of independent smallholders), as well as for the refinery component of the processing phase.

Furthermore, even though in 2012 biodiesel accounted for only 0.19 percent of the total primary energy supply (TPES) in Indonesia, this modern bioenergy led to around 282 million USD of estimated savings from avoided oil imports and generated 657 million USD of export revenues.

With regard to the logistics of the biodiesel supply chain, distribution to the easternmost provinces of the archipelago, namely Papua and Maluku, may be difficult due to the lack of efficient infrastructures and this is considered the main cause that has prevented the country from fulfilling the B10 mandate in 2012. Distribution hurdles are also found in the two main producing islands, i.e. Sumatra and Kalimantan. The latter, in particular, suffers from limited availability of processing facilities and poor internal distribution routes (e.g. dirt roads and shallow ports). For this reason, large quantities of feedstock need to be transported in relatively small batches from Kalimantan to Sumatra. In order to meet higher biofuel mandates, these logistical issues are expected to be thoroughly assessed and managed.

3. Conclusions and recommendations

During the pilot testing of the GBEP indicators, both in Colombia and Indonesia, only partial analyses could be conducted due to the limited data available. Filling these data gaps will be essential in order to enable an effective monitoring of the GBEP indicators in the future and thus assess over time the sustainability of bioenergy production and use in the two Countries. Data gaps were particularly significant for the social sustainability indicators. In order to fill these gaps, surveys should be carried out. In addition, as already mentioned above, as the bioenergy sector continues to expand and higher biofuel mandates are considered, it is essential to monitor land-use changes associated with bioenergy feedstock expansion, given the important implications that land-use changes can have for a range of environmental, social and economic sustainability issues. Remote sensing, field visits and stakeholder consultation are complementary tools that should be used in order to study and analyze the land-use changes associated with bioenergy feedstock expansion.

Furthermore, as anticipated above, the pilot testing in Colombia was focused on sugarcane-based ethanol and palm oil-based biodiesel and, to a certain extent, cogeneration from bagasse, while the pilot testing in Indonesia was focused on palm oil-based biodiesel. This reflected the indications emerged during discussions with relevant stakeholders in the two countries. However, as different bioenergy technologies start being deployed in both countries, the impacts associated with these technologies should be assessed as well. In Colombia, in particular, wood fuel still accounts for an important share of total primary energy supply (TPES) and rural households rely heavily on fuel wood and charcoal for heating and cooking. Traditional uses of biomass are inefficient and lead to a number of detrimental environmental and health effects. Therefore, the potential for displacing these traditional uses of biomass with modern bioenergy technologies and for providing access to modern energy services through them should be explored and promoted, and the resulting environmental, social and economic effects should be assessed.

Regarding the long-term measurement of GBEP indicators in Colombia and Indonesia it is recommended to involve all relevant stakeholders in the process, ranging from relevant government departments/ministries (e.g. those dealing with agriculture, energy, environment, rural development, food security, infrastructure, etc.) to producer associations, universities and NGOs. Stakeholder engagement and ownership of the process is key in order to get access to the necessary data and information, receive inputs and feedback, discuss and interpret the results, and ultimately inform policy discussions and decisions.

In addition to this, a network of focal points within each relevant organization could be considered in the future as a means to strengthen institutional coordination and stakeholder engagement for regular national activities related to bioenergy.

With reference to the objective to enhance the practicality of the GBEP indicators, during the testing in Colombia and Indonesia it was realized that more clarity and guidance from GBEP would be needed regarding both methodological and practical issues related to the implementation of certain indicator methodologies. An implementation guide would be needed in order to complement the GBEP report on the sustainability indicators.

On this matter, further guidance would be necessary, in particular, on the complex and crucial issue of the attribution of impacts to bioenergy production and use. For each indicator a range of suitable approaches should be identified and illustrated in detail providing specific examples, and the pros and cons of using one approach versus another should be discussed.

Furthermore, in order to significantly reduce the time, skills and cost required to measure the GBEP indicators, an Excel and/or web-based application should be developed. This would allow users to easily enter all data required for the 24 indicators into one single data entry sheet and to get a set of results for each indicator based on the related methodologies. In addition to the aforementioned benefits, this process would also simplify considerably the data collection process, and it would allow to easily save and share the results and to re-run the tool over time with up-to-date information.

Last, but not least, given the global nature of the GBEP indicators, the report containing the methodology sheets should be translated into other official languages of the UN beside English, e.g. French and Spanish. This would greatly facilitate the dissemination and implementation of the indicators in developing countries around the world.

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THEMATIC SET

E27

SUSTAINABLE DEVELOPMENT FRAMEWORKS AND AGROENVIRONMENTAL INDICATORS

Session Organizer
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ABSTRACT

Agriculture plays a fundamental role in climate change, both as a driver at local to global scale through land use change and emissions of greenhouse gases, and as a sector that will be significantly exposed to climatic damage in coming decades, with possible negative impacts on food security. This session investigates the role of statistical information, existing and required in coming years, in support of sound decision making towards reducing climate change threats within sustainable rural development strategies, with adaptation, mitigation and food security dimensions rolled into a consistent package. Papers are invited investigating the application of agri-environmental indicators for monitoring progress within the climate change convention and the SDGs, with a focus on applicability to developing countries.

This session will present four selected papers on the following topics on the use of agrienvironmental statistics: Adaptation of food systems;

- GHG reporting and analysis;
- National mitigation plans;
- Climate change and food security indicators within the System of Environmental and Economic
- Accounting for agriculture, forestry and fisheries (SEEA-Agriculture)

LIST OF PAPERS

Green economy in East Kalimantan province: achieving emission reduction target and economic trade-off in agricultural sector
Y. J. Nababan | Statistics Indonesia Rep. Office of Samarinda City | Samarinda
DOI: 10.1481/icasVII.2016.e27

Bridging planned and autonomous climate change adaptation approaches for sustainable agricultural productivity: evidence from the ecosystem-based adaptation in the Talensi District by smallholder farmers
B. B. Jabik | ISSER | Legon | Ghana
S. Bawakyillenuo | ISSER | Legon | Ghana
DOI: 10.1481/icasVII.2016.e27b

Farm structure survey - key data source for environmentally related farm management practices
C. Turtoi | Institute of Agricultural Economics, Romanian Academy | Bucharest | Romania
O. Cara | FAO | Rome | Italy
DOI: 10.1481/icasVII.2016.e27c

The challenge of collecting and publishing data on organic agriculture worldwide
H. Willer | Research Institute of Organic Agriculture FiBL | Frick | Switzerland
J. Lernoud | Research Institute of Organic Agriculture FiBL | Frick | Switzerland
R. Zanoli | Università Politecnica delle Marche | Ancona | Italy
DOI: 10.1481/icasVII.2016.e27d

THEMATIC SET

E27

The productivity and environment nexus through farm-level data. The case of carbon footprint applied to Italian FADN farms

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Green Economy in East Kalimantan Province: Achieving Emission Reduction Target and Economic Trade-off in Agricultural Sector

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ABSTRACT

East Kalimantan economy is heavily relied on natural resource sectors. Aside from a gigantic output produced, the economy also creates a significant amount of emission. In the long term, this situation is believed could create environmental risks for East Kalimantan Province. Therefore, East Kalimantan Government has formulated Regional Action Plan in Reducing Greenhouse Gas (RAD GRK) in 2012 for all sectors. The document provides framework for reducing emission and implementing green economy policy in East Kalimantan Province. This paper evaluates emission reduction target of Provincial Emission Reduction Plan (RAD-GRK) in East Kalimantan Province, Indonesia. Using Input-Output Table of year 2013, which disaggregates the agriculture sectors into several subsectors, and employing optimization model; this paper assesses the possibility of achieving the emission target. The paper shows that implementing emission reduction target, as well as maximizing level of output, hampers the economy to reach both economic and environmental targets. There is a trade-off between economic output and emission reduction. Moreover, it shows that there is macroeconomic cost of emission reduction policy for East Kalimantan economy. Even though there is a trade-off in terms of economic output, agricultural sector tends to contributes more to the economy. It implies that in order to achieve the emission target, there is a necessity economic structural transformation towards agriculture sector.

Keywords: *Emission reduction, Trade-off, Optimization, Agricultural sector output*

1. Introduction

Nowadays, natural scarcity and degradation has become an issue discussed in many countries. Natural resources, renewable and unrenewable, have been intensively exploited without considering its impact on environmental quality. Meanwhile, climate change and global warming are haunted the earth and they reduce the earth ability in providing resources for human needs. Therefore, there has been a transition on development paradigm from business as usual (BAU) to sustainable development.

Sustainable development was introduced by the UN World Commission on Environment and Development (Brundtland Commission) in 1987. It is defined as a societal development "… that meets the needs of the present without compromising the ability of future generations to meet their own needs". The idea of sustainability combines three goals, economic power with ecological responsibility and social justice. Moreover, the concept of sustainability that connects the economic activity of people with the nature as resource provides the idea that economic processes must be sustainable if long-term development goals shall not be sacrificed to short-term prosperity. Sustainable development is also defined as the increase of utility or welfare per capita along the time or the increase of a set of development indicators (Pearce, 1996).

UNEP (2011) stated that in order to deliver the goal of sustainable development, one economy should implements a green economy policy. Green economy is defined as: "*One that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities. It is low carbon, resource efficient and socially inclusive. In a green economy, growth in income and employment should be driven by public and private investment that reduce carbon emissions and pollution, enhance energy and resource efficiency, and preven the loss of biodiversity and ecosystem services*".

National Development Planning Agency (BAPPENAS) states that there are four pillars in achieving sustainable development. There are social, green economy, environment and governance. In Indonesian context, the concept of green economy is applied through green growth program. Green growth program is a new approach to achieve several goals in order to create sustainable development in Indonesia. The notion of the program is to stimulate green growth that recognizing the value of natural capital, increase resilience, building local economic and that is inclusive and fair. There are five dimensions of green growth: (1) sustained economic growth, (2) greenhouse gas emission reduction, (3) social, economic and environmental resilience, (4) inclusive and equitable growth and (5) healthy and productive ecosystems providing services. Therefore, although it is not explicitly stated, the concept of green economy in Indonesia is believed to be similar with the concept of inclusive green economy.

As a response to the national policy of green growth, East Kalimantan Government takes an active part by launching Kaltim Green (Kaltim Hijau) Program on 7th January 2010. Kaltim Hijau is defined a condition where East Kalimantan is equipped by policies, system of government and development programs that provides social and ecological protection, long term assurance of welfare and security for people of East Kalimantan, as well as environmental sustainability. Moreover, East Kalimantan Government has formulated Regional Action Plan in Reducing Greenhouse Gas (RAD GRK) in 2012 for all sectors. East Kalimantan Government has also developed Strategy and Action Plan for REDD+ (Strategi dan Rencana Aksi atau SRAP REDD+). The documents are providing framework for reducing emission. However, some challenges remain in implementing inclusive green economy policy in East Kalimantan.

Firstly, East Kalimantan economy is heavily relied on natural resources. This puts East Kalimantan as one of biggest emitter in Indonesia. In 2008, East Kalimantan Province emits 255 million ton CO_2e as a result of its economic activities. Therefore, some alternative sectors aside from natural resource-based sectors should be considered as exit strategy to the East Kalimantan economy. In other words, there is an urgent need to make an economic structural transformation shifting from natural-resource-based sectors dominance into others.

However, some empirical studies show that there is an economic cost by implementing emission reduction policy. Fan et. al. found that there is a positive correlation between emission reduction and output or value added decline. The higher the target of emission reduction, the bigger the output decline. Moreover, the decrease of the output occurs because of activity restriction of the sectors that have high emission intensity, and these sectors are dominant sectors in the economy (Yang 2000).

This paper focuses on assessing the inclusive green economy in East Kalimantan Province to shed more lights on the existing situation and the potential regarding its sustainable development. Moreover, it analyzes the impact of emission reduction target policy to the economy in terms of output and also measures the economic cost of the policy. The organization of the paper is as follows. In the next section, there is a discussion about emission reduction in agricultural sector. It elaborates how agriculture and emission are related and agricultural contribution in creating emission. Section III explains models used to measure economic trade-off due to emission reduction in East Kalimantan. Section IV reveals the economic optimal structure of East Kalimantan that may provide a pathway to sustainable development and shows the economic cost that occurs due to the policy implementation. Last section will summarize the findings of the previous sections and discuss possible effects as well as some recommendations in order to minimize the economic cost of the emission reduction policy.

2. Emission Reduction in Agricultural Sector

East Kalimantan economy is characterized by highly-dependent on natural resources, such as mining sector, which produces oil, gas and coal. Based on its structure, in 2015 mining sectors contributes more than 44 percent of total the economy. Compared to previous years, its contribution decreases overtime. This indicates that East Kalimantan Province economy slows down and its growth would be unsustained.

However, these dominant sectors contribute to the carbon emission so that they make East Kalimantan as the third largest emitter Province in Indonesia. Mining sector contributes significantly in creating emissions. Based on analysis result carried out by Mc Kinsey Company, DNPI (National Council of Climate Change) and East Kalimantan Government (2011), dominant sectors, such as forestry, mining and coal, as well as oil and gas, are main sectors that create CO_2 emission. In 2010, from the total of 251 million ton of CO_2e, 90 percent of emission is produced by those sectors, or called as land use sectors especially forest land use (Figure 1).

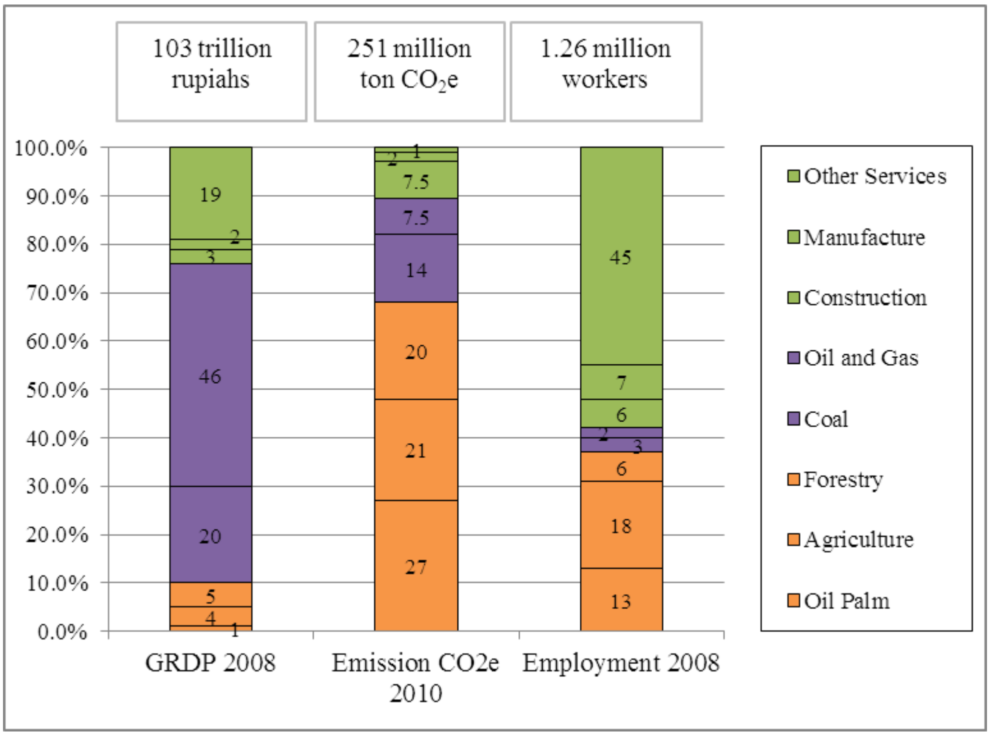

Figure 1. GRDP Distribution at Constant Price Year 2008, CO_2e Emission Year 2010 and Employment Year 2008 by Sector

In contrary, agricultural sector tends to increase overtime, from around 5 percent in 2010 to more than 7 percent in 2015. The increase of agricultural contribution to the economy due to expansion of the oil palm plantation in East Kalimantan. The area of oil palm plantation consists of 85.9 percent from the total planted area of estates in East Kalimantan. The oil palm plantation rises overtime and it reached around 1 million hectares in 2014.

However, the rise of the agriculture sector, especially in oil palm plantation sector, is likely followed by an increase in emission intensity. Government of East Kalimantan calculated emission generated during period 2007-2020 and documented in the Regional Action Plan of GHG Emission Reduction (RAD GRK). The calculation is based on assumption that the economy applies the strategy of business as usual (BAU). It shows that there is a sharp positive trend of generated emission. Land sector is the biggest emitter, especially mining sector.

Land sector is classified according to its land use, such as mining, forest, housings, open area, mangrove, and swamp; including agricultural activities, for instances estate and crops. Carbon stock of each classification has been calculated based on its land cover. If there is a land conversion, carbon stock difference will be calculated as a base in measuring emission that is produced because of the conversion in the land sector.

The calculation of emission in land sector is based on land use planning using assumptions what land use would be in 2020. There are 21 classifications in land use planning, such as food estate, protected forest, production forest, road, industrial estate, crops, wildlife preserve, housings, and peat land. There are some scenarios of emission reduction applied to each sectors. First scenario is conserving primary and secondary forest, while rehabilitating opened area to thicket area. Second scenario is pushing private sector to plant in opened area. Third scenario is conserving forest area. Fourth scenario is applied on plantation area, that is planting oil palm on the opened and bush area, and total plantation area is conserved. Fifth scenario is encouraging establishments accelerates reclamation and replanting so that in 2020 about 50 percent of mining area has been recovered. Sixth scenario is reforestation so that 30 percent of opened area can be converted to be bush area.

Seventh scenario is conserving area by applying eco-friendly practices. Eighth scenario is conserving area.

Method used in estimating emission and making projection is Land Use Planning for Low Emission Development Strategy (LUWES). Firstly, based on changes in land use or its canopy, total emission produced is predicted. Then, applying scenarios on the 21 plans of land used accordingly, total emission is measured and projected up to year 2020. This calculation shows the total amount of emission due to land conversion caused by development activities in East Kalimantan.

Estimation result shows that plantation is responsible for largest amount of emission, that is 29.94 percent and it is followed by mining which produces emission up to 12.81 percent from the total emission. However, it also significantly contributes to the total emission reduction when the scenario of emission reduction is applied. Plantation would contribute to 75.61 percent of the total reduction, while mining would reduce 7.95 percent of emission.

3. Method

Goal Programming (GP) is employed to analyze what is the impact of emission reduction policy on the economy in terms of output level. Moreover, GP model also estimates the economic cost of the policy when it is applied. Furthermore, the model provides a new alternative economic structure that is considered to be "green" as the emission reduction policy is applied to the economy. Therefore, GP model formulates an appropriate or optimal economic structure that is considered to be more environmental friendly.

Adopting Cristóbal model (2012), Goal Programming model can be applied in order to find the optimal economic structure that consider three goals that are social, economic and environmental to achieve IGE. In matrix form, Goal Programming model is formulated as follows:

$$\textit{Minimize } f = P_i . d_1^+ + P_i . d_2^+ + \dots + P_i . d_n^+$$

Subject to:

$$(I - A)X + \boldsymbol{d_1^-} - \boldsymbol{d_1^+} = \boldsymbol{a}$$

$$\hat{L}X + \boldsymbol{d_2^-} - \boldsymbol{d_2^+} = \boldsymbol{b}$$

$$\hat{E}X + \boldsymbol{d_3^-} - \boldsymbol{d_3^+} = \boldsymbol{c}$$

Where: X is the total output; $\hat{L}$ is a vector of direct impact coefficient of output on the employment; $\hat{E}$ is a vector of direct impact coefficient of output on the emission; P_i is rank or priority. i = 1, 2 or 3.

For economic objective, the target level refers to the output level in 2013 or it is equivalence with 1.59 percent of economic growth. The level of employment in 2013, that is 1,378.61 thousand labors, is used for social objective. As environmental objective in the model, emission target data taken from RAD-GRK is used, 563.29 million Ton CO_2e, and the classification of emission sector is modified to match IO classification. Additionally, IO Table of East Kalimantan Province Year 2013 is employed as constraints for GP model to represents level of technology in the economy of East Kalimantan.

The result of the model is expected to provide new economic structure of East Kalimantan that satisfies the economic, social and environmental goals. Moreover, the model will allow us to find the effects on output in different sectors of a reduction in the emission levels. Furthermore, the model provides a role model of systematic procedure for examining the different goals that policymaker must implement in order to achieve IGE in East Kalimantan.

4. Optimal Economic Structure toward Sustainable Development: a Goal Programming Application

Economic transformation requires changes in the structure of the economy. However, an appropriate economic structure that is in line with IGE has not been provided. To formulate appropriate or optimal economic structure, it would need to firstly identify what are challenges and potential natural resources that are available in East Kalimantan economy. Moreover, other factor such as human capital is also should be taken into account in formulating the optimal economic structure.

To achieve sustainable development condition, therefore development in an economy should simultaneously consider among economic objective, as well as social and environmental objectives. Goal Programming model can be employed in assessing the achievement of an economy toward sustainable development. Moreover, model output suggests the new alternative economic structure that is optimal in order to achieve sustainable development. The result of the GP model is given in Table 1.

Table 1 the Impact of Emission Reduction on Output

No.	Sector	Output 2012 (Billion Rupiahs)	Output 2013 (Billion Rupiahs)	Maximize Value Added		Minimize Emission	
				Optimal Output (Billion Rupiahs)	Change Contribution Relative to 2012 (%)	Optimal Output (Billion Rupiahs)	Change Contribution Relative to 2012 (%)
1	Food Crops	7.11	7.25	7.24	0.021	7.24	0.021
2	Oil Palm	3.55	3.89	3.04	-0.081	3.89	0.054
3	Livestock	2.51	2.62	2.61	0.016	2.61	0.016
4	Logs	6.48	6.46	6.47	-0.002	6.46	-0.003
5	Other Forest Products	0.69	0.69	0.68	-0.002	0.69	0.000
6	Fishery	7.26	7.83	7.82	0.089	7.82	0.089
7	Oil and Gas	76.35	72.19	72.36	-0.633	69.52	-1.083
8	Coal	175.78	179.22	179.21	0.544	168.45	-1.163
9	Quarrying	2.01	2.34	2.34	0.052	2.34	0.052
10	Oil Refinery Products	79.83	79.03	78.19	-0.260	0	-12.661
11	LNG	97.98	89.76	89.76	-1.304	89.76	-1.304
12	Food Industry	8.34	8.9	8.89	0.087	8.89	0.087
13	Plywood	7.4	7.4	7.4	0.000	7.4	0.000
14	Other Industries	25.69	28.32	28.27	0.409	28.25	0.406
15	Electricity and Gas	2.32	2.42	2.42	0.016	2.4	0.013
16	Water	0.35	0.38	0.37	0.003	0.37	0.003
17	Construction	31.41	36.08	36.05	0.736	36.01	0.730
18	Trade	44.15	47.77	47.47	0.527	47.34	0.506
19	Transportation	26.07	28.08	27.86	0.284	27.71	0.260
24	Bank and Real Estate	10.64	12.27	11.91	0.201	11.8	0.184
26	Government	12.75	14.25	14.21	0.232	14.24	0.236
27	Other Services	1.84	2.06	2.02	0.029	2.03	0.030

No.	Sector	Output 2012 (Billion Rupiahs)	Output 2013 (Billion Rupiahs)	Maximize Value Added		Minimize Emission	
				Optimal Output (Billion Rupiahs)	Change Contribution Relative to 2012 (%)	Optimal Output (Billion Rupiahs)	Change Contribution Relative to 2012 (%)
Natural-Resource Based Sector		431.95	422.54	421.86	-1.600	330.06	-16.159
Non Natural-Resource Based Sector		198.56	216.67	214.73	2.565	215.14	2.630
Total		630.53	639.20	636.60	0.963	545.21	-13.531

In general, there is a decline in the output level due to the emission reduction policy. First scenario is carried out by maximizing output level as first priority. It shows that there is a reduction in the output level by 33.45 percent compared to the output level in 2013. In 2013, East Kalimantan economic growth was 1.59 percent, however, if the policy of emission reduction is applied then there is a slower growth occurs in the economy. The economic growth would be expected to be only around 1.15 percent. Meanwhile, the environmental objective of emission reduction cannot be achieved. By considering output level as a priority policy, the emission level is 599.67 million ton or 6.5 percent higher than the level of emission target.

In details, significant output reduction share are given by natural-resource-based sectors, such as Oil and Gas (1.96 %), Coal (6.67 %), Oil Refinery Products (4.93 %) and LNG (5.20). These sectors are biggest emitter in the economy, and given the policy implementation, they contributes more to the total output reduction. This finding is similar to a study carried out by Cristóbal (2012) that is all output level declines in the Spain economy when the environmental policy of emission reduction is implemented. This indicates that there is a trade-off between emission reduction policy and output level. Moreover, aside from Coal sector, the highest shares to the total output reduction are given by industrial sectors, Oil Refinery Products and LNG. This result is also similar with study in Canada where the industrial output should reduce to meet the Kyoto Protocol target (Lixona *et al*. 2008).

Furthermore, second scenario is applied to the model by putting environmental objective as top priority provides the expected result of emission reduction. However, the economic cost is bigger compared to the result of previous scenario. The economic output is lower compared to the output level in 2013, it is a difference of 13.53 percent, when the emission reduction policy is being implemented and put as the priority. This decline is equivalence to a contraction in the economy, an economic growth of -9.04 percent.

The result shows that in general there are output declines in all sectors of the economy, and some sectors are recommended to have zero level of output, especially services. Natural-resource-based sectors, such as Coal, Oil Refinery Products, and LNG contribute more to the emission reduction compared to other sectors. Moreover, the shares are higher compared to their shares of the first scenario. This indicates that these sectors are quite responsive to the emission reduction policy.

In addition, the result shows there is a shift in the sectoral emission structure in East Kalimantan when the emission reduction policy is implemented. Due to the significant output reduction of the natural-resource-based sectors, there is also a significant in the emission reduction, especially from Oil and Coal sector activities, whereas there is an increase in the other sector emission, such as agriculture. This indicates there is a transformation in the economy from natural-resource-based sectors to the agricultural sectors, such as food crops and palm.

This finding is confirmed by Figure 2. In general, it shows that emission reduction policy tends to change the economic structure of East Kalimantan Province compared to baseline data on

2012. If the policy is applied while maximizing value added, there is a decline in natural resource contribution to the economy, and a greater contribution of the non-natural resource-based sectors. More significant contribution is given by non-natural resource-based sectors when emission reduction policy is applied while minimizing emission is prioritized. This implies that dominant sectors in East Kalimantan economy are significant emitters. Therefore, in order to achieve green economy, there has to be a slowdown in production activities of these sectors.

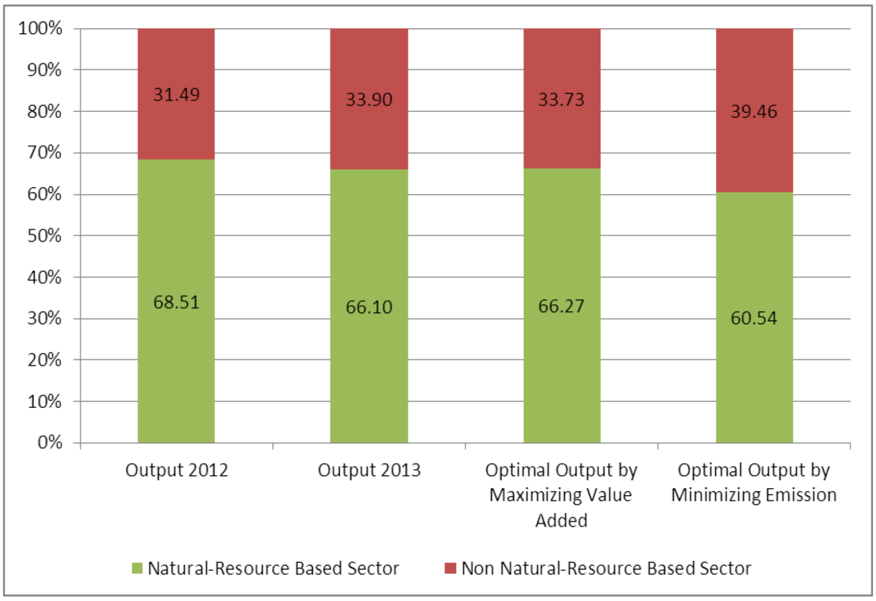

Figure 2. Structural Transformation of East Kalimantan Province due to Emission Reduction Policy

Figure 3 shows that there is structural change when an environmental objective is taken into account in the economy. In terms of output level, applying emission reduction policy causes a lower output level compared to the level of it should be that is output level in 2013. However, it may be successful in reducing emission level. Although in first scenario of maximizing value added, the level target of emission still cannot be achieved, the level emission is lower compared to the level of emission when Business as Usual practices applied in the economy and East Kalimantan economy still experiences a positive growth. Whereas, if second scenario is applied, there would be an even lower output level compared to output level in 2013, and East Kalimantan economy experiences negative growth. However, the level emission targeted can be achieved by applying this scenario.

These scenarios suggest that in order to achieve a greener East Kalimantan, emission reduction policy should be applied. However, there are consequences in applying this policy, lower output level that may cause a slower growth or even a negative growth of the economy. Aside from a slowdown in the economy, model also suggests that there has to be a structural transformation in East Kalimantan economy. In order to ensure a sustainable development, there is a necessity to shift from natural resource-based economy into non-natural resource-based economy, such as agricultural or industry.

Figure 3 shows that as the policy is applied, there is a tendency that agricultural sector contributes more to the economy. As the economy moves to more environmental practices, agricultural sector contributes more to the economy. This because emission intensity produced by agricultural activities is relatively lower than one produced by natural resource-based sector. This indicates that development in agricultural sector may benefit and support to create a green economy of East Kalimantan.

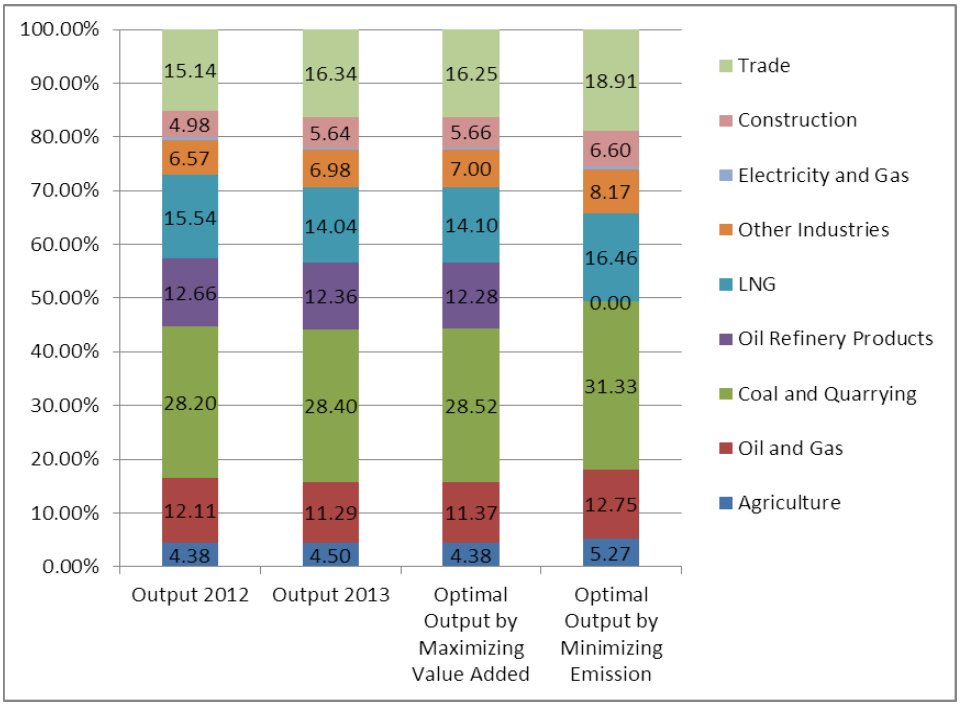

Figure 3. Economic Structure of East Kalimantan Province due to Emission Reduction Policy

5. Concluding Remarks

East Kalimantan economy is heavily relied on natural resources. It creates externalities. East Kalimantan becomes one of biggest emitter in Indonesia.

The performance of greenness aspect of East Kalimantan is indicated by emission intensity and energy intensity. During period 2000-2012, there is an increase in the emission intensity assuming that economy applies BAU practices. Moreover, there is also a tendency to use more energy per capita overtime. This suggests that the sustainability would be threatened given that there is no other new energy reserve found. Furthermore, DEA model indicates that East Kalimantan becomes less efficient overtime in terms of utilizing its natural resources and environmental management.

Emission reduction policy is believed to be a way in achieving sustainable development by creating a greener economy. However, there is economic cost in applying the policy. There is trade-off between emission reduction and output level. As it is expected, natural-resource-based sectors contributes more to the total output reduction. This implies that there is a contraction in these sectors; hence it reduces more emission compared to other sectors. The economic cost is even bigger when environmental objective of emission reduction becomes first priority. Therefore, it should be considered alternative policies in order to outweigh the incurred cost.

By applying the environmental policy, there is a change in the economic structure of East Kalimantan. A significant decrease in the output level of natural-resourced-based sectors implies that there is a transformation towards agriculture, especially palm plantation. Moreover, this indicates that there is an opportunity for East Kalimantan economy to be less dependent to the natural-resources-based, as well as be greener. Thus, this implies that sustainable development in East Kalimantan can be achieved by developing agricultural sector.

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BRIDGING PLANNED AND AUTONOMOUS CLIMATE CHANGE ADAPTATION APPROACHES FOR SUSTAINABLE AGRICULTURAL PRODUCTIVITY: EVIDENCE FROM THE ECOSYSTEM-BASED ADAPTATION IN THE TALENSI DISTRICT BY SMALLHOLDER FARMERS

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ABSTRACT

The effects of climate change in Ghana pose a threat to sustainable development, hence food security. Phenomena including drought, prolong dry season, flooding, storms and increased temperatures have become prevalent in the country, with several implication for food production. Particularly, the small-scale farmers in the country who account for about 80% of domestic agricultural production have limited resources to invest in appropriate technologies in order to adapt to the changing climate variability. In the Talensi district several staple cereal crops as well as tubers are affected by the shortening of the growing season. Small-holder farmers in the district have considerably relied on traditional knowledge for the production of food in the communities in the mist of this variability. World Vision Ghana with support from World Vision Australia started the implementation of a climate change project in the district in 2009 with the aim of improving the resilience of the people through improved adaptive capacity of small-holder farmers. This paper seeks to understand the synergistic relationship between the autonomous practices by the indigenes and the planned adaptation measures in shoring up food security in the communities. Focus group discussion, individual and group interviews were adopted to collect data from respondents in three purposively sampled beneficiary communities. Findings from the study revealed that bridging indigenous knowledge with the planned approaches leads to higher food crops yields and thereby strengthening the adaptive capacities of beneficiaries in these communities. These findings imply that planned adaptation programmes need to identify and incorporate indigenous knowledge and practices into their activities in order to achieve greater success.

Key words: Food security; resilience; indigenous knowledge; smallholder farmers

1.0 INTRODUCTION

Conventional agricultural land preparation activities in the research area are often slash and burn at the beginning of each farming season prior to planting which contribute to land degradation. This manifests in declining agricultural yields and loss of environmental services such as wild foods that traditionally subsidized household diets, wood stocks, etc. World Vision Ghana (WVG) with support from World Vision Australia (WVA) started Farmer Manage Natural Regeneration (FMNR) project with the aim of improving the livelihood of the people through improved adaptive capacity of small-holder farmers in 2009 in the Talensi District o the Upper East region. The project approach involved blending the planned ideas with the local approaches that were adopted by the small scale farmers. This paper is a presentation of the bridged points of the project and its impact on the output of the small-scale farmers in the region.

1.1 BACKGROUND

In Ghana, underlying structural factors of vulnerability such as population pressure, declining ecosystems, poverty, conflict, vulnerable rural livelihood activities amongst others have been exacerbated by climate change leading to increase in human vulnerability to environmental factors, (IOM …). In recent years, annual rainfall volumes have been declining, forest cover and the associated indigenous biodiversity and arable soils disappearing. The net result is a population that is staggering between food crises with shorter recovery periods, (WVI, 2012), thus posing a threat to sustainable food security, (WFP, 2013). Effects of climate change including drought, prolong dry season, flooding, storms and increased temperatures have become prevalent (CC DARE (…), affecting the activities of the small-scale farmer. Integrating adaptation into development strategies will address the impact of climate change thereby reducing pressure on natural resources, improve environmental risk management, improve the resilience of people, and increase the social well-being of the poor, (United Nations 2013).

Adaptation practice is both planned and autonomous. Planned approaches are consequence of deliberate policy and project decisions while autonomous approaches are more reactive to the changing climatic conditions. People in hazard-prone areas have adapted to the effect of climate change using their own capabilities, skills, knowledge and technologies to improve resilience and self-sufficiency, (Ensor and Rachel, 2009). Because of the frequent occurrence of climate extreme events, local people have developed extensive reactive beneficial skills, knowledge, and management systems that enable them to interact with their environment which sustains the livelihoods that they depend on, (IPCC, 2012). These knowledges have sustained rural societies and their environment in many parts of the world for centuries, (Ensor and Rachel, 2009). Little of these approaches have been incorporated into formal climate change mitigation and adaptation strategies, (Nyong, et al 2007).

Small-scale farmers in Ghana account for about 80% of domestic agricultural production, and about 84% of farming households in the upper east region, (WFP, 2013). However they have limited resources to invest in appropriate technologies in order to adapt to the changing climate variability. They have considerably relied on traditional knowledge for the production of food in the communities, (Arndt et al 2014, Nyong et al 2007). The main objective of the study is therefore to understand the synergistic relationship between the autonomous and planned adaptation measures in shoring up food security in the beneficiary communities of the FMNR project.

1.2 METHODOLOGY OF THE STUDY

The study assessed the synergy between planned and autonomous climate change adaptation approaches by small-scale farmers in the Upper East Region for improved output. Primary data was collected from the communities and complemented by secondary information from the district and the program office level. The research adopted mixed approach but with much emphasis on participatory research approach, (Chambers, 1994). This approach was adopted because; community-based inquiries can provide more knowledge about changes in a situation, (Anirudh et al, 2004). The approach was used to illicit information from small-scale farmers on the approaches adopted and its effect on their outputs. Three farming communities (two beneficiary communities and one non-beneficiary) were purposively sampled. Primary data as well as both published and unpublished secondary data were used to provide the basis for analyses and conclusion of the study. Focused group discussion; community group discussion; observation, in-depth interviews and questionnaires were used to collect the data. Both qualitative and quantitative techniques were adopted to analyze the data.

2.0 THE STUDY AREA

The three communities studied are located in the Talensi District of the Upper East Region of Ghana. About 84% of the households in the region are farmers as compared to 45.8% in the country (GSS, 2013). Also, about 90% of the inhabitants livelihoods depend on climatic condition and about 49.1% of the inhabitants are food in-secured (WFP 2013). The climatic condition is tropical and has two distinct seasons – a wet season with erratic rainfall that runs from May to October and a long dry season that stretches from November to April. The mean annual rainfall ranges between 88mm-110mm with the maximum being 950mm while the maximum temperature is 45°C in March and April with a minimum of 12°C in December (DMTDP, 2014). The visible environmental problems in the district include: deforestation; silting of water bodies; soil erosions and Bush fires which are mainly caused by poor agriculture practices, charcoal production, activities of herdsmen, hunting, honey tapping and surface mining.

2.1 RESULTS AND DISCUSSION

Farmer Managed Natural Regeneration (FMNR) is a technique that improves lands that have been degraded leading to loss of biodiversity and soil fertility. It encourages regrowth from the stumps of cut-down trees, protects and prunes the regrowth into new trees. The approach has a 100% success rate of trees survival. It can be implemented as an on-farm agroforestry activity or managed as a community forests. The two beneficiary communities of interest implemented the two approaches: community forestry; and on-farm mixed agroforestry. The community forests are protected from agriculture activities, over-exploitation, and it's managed by the communities' FMNR Lead Farmer Groups. The groups are made up of 20 Lead Farmers each who are responsible for pruning and protecting the site and its regrowth. In return, they are allowed to harvest their off-cut as firewood and other natural resources such as grasses. The on-farm approach is a mixed agroforestry practice that allows the farmers to prune shrubs on their farms to become trees. Other complementary activities implemented by the project include: education on behavioural change; skills and occupational training; provision of improved and drought tolerant crops; climate information gathering and communication amongst others. The autonomous approach adopted by the farmers before the project included: wage labour temporal migration; assets portfolio diversification; changing production technology; occupational diversification; formation of farming associations amongst others.

2.2 CONVERGENCE OF THE TWO ADAPTATION APPROACHES

This section analyses the convergence of the two approaches adopted by the beneficiary communities. FMNR and the autonomous approaches converged at most points that resulted in the benefits of the project.

2.2.1 Production technology (Composting, mulching and soil conservation)

Prior to the implementation of the project, farmers in the beneficiary communities valued and practised organic fertiliser techniques inputs such as manuring and mixed farming. Farmers gathered animal droppings during the dry season and spread it on their lands during the lean season before ploughing. They also piled up household scraps over the year, and then scattering the pile over a small area, such as a vegetable plot during the lean season. These local approaches were improved by the project by training farmers on composting and its application in the communities. The improved technique involved collecting the stalks and debris and transferring it into a pit dug on the field (which preserves moisture in the dry season, permitting decomposition), then adding smaller quantities of manure, leaves, weeds and household waste and allowing it for some time before spreading it on the farm. Prior to the project, all crops stalks would be burned off annually after harvesting which exposed the land to erosion and degradations. The expansion of improved composting has made organic fertiliser available to more household without sufficient number of livestock. The project approach also included leaving crop stalks on fields to prevent erosion and; encouraging livestock and birds to graze and defecate on the farms. These techniques are used to increase soil fertility and crops yields by farmers.

2.2.2 Livelihood diversification

As a way of minimizing the effects of climate change on their livelihoods, local people diversified some of their livelihood activities including sale of convenient items in the villages; processing of shea butter; occupational diversification amongst other activities. To help improve on the livelihoods of these people, the project supported the Lead farmers to create Group bank savings account; establishment of village savings and loans associations (VSLA); support of two bullocks for field ploughing and income generation activities, bee keeping etc. The groups were further trained in association management skills, and encouraged each group member to build up a capital reserve for future farming investments by saving a little of their income with the VSLA. The bullocks provided affordable traction or service for members and a source of income generation by hiring them out to other farmers. Through the VSLA, the members mobilized savings from the group members and offered business capital to group members which was used to expand their businesses such as shea-butter extraction, selling of salt, pepper, gari amongst others at the community levels.

2.2.3 Communal pooling

The farmers in the communities formed associations and groups which were used to support each other in their farming activities. Members of the groups benefited from the entire group through rotational services among members. These groups were useful for the project since the lead farmers who were responsible for the community forestry was dependent on this background. Through this group climate information was easy to spread from one member to another since they constantly met to take decision on the community forestry. The groups also served as grounds used to demystify traditional fear that growing trees causes the planter to die as well as demonstrated that trees do not suppress crop growth when pruned effectively and the suppression of bushfires that does not expose the land to harsh weather conditions. Planting of trees especially economic ones like mango, shea and dawadawa was encouraged through the groups.

2.2.4 Market exchange

Some community members had started selling various items in the communities and beyond to supplement household income and provide basic needs for the family. These items included the sale of wild fruits, soap, pepper, salt and the introduction of new items in the communities as well as the sale of seeds and other farm inputs. The project improved these processes by introducing training on business management practices such as record keeping; customer care; group dynamic etc. The introduction of bee keeping in the communities and the training on bush fire suppression increased the sale of honey in the communities and the sale of fruits. The collective decision-making and agreements have strengthened the unity and collaborative spirit of the project communities to fight bush fires which is yielding positive results on the environment and their crops yields.

3.0 BENEFITS OF THE PROJECT

An assessment of the benefits of the project during the survey revealed that numerous benefits were achieved as a result of the synergetic approach that was adopted by the project. These benefits are enumerated below.

3.1 IMPROVED SOIL FERTILITY AND CROPS YIELDS

In all the focused group discussions of the FMNR adopters, participants revealed that the key benefits of the project was improved soil fertility and increased crops yields. One of the farmer groups indicated that;

"The applications of compost, agroforestry, bushfire suppression and mixed farming have resulted in increased in soil fertility. We use to burn the stalks after harvesting but now we leave them to decay into the soil as well as use some of it for composting. Previously we cleared the entire shrubs on the field but now we prune the shrubs and the leaves drop back on the land which increases soil fertility. Also the mixed farming allows the droppings of the animals to fertilize the farm lands. In the past, the traditional notion was that trees affect the growth of crops negatively. But we have come to realise that it is untrue. Rather, where there are trees and they are well pruned, soil fertility increases, leading to good crop yields." (Tongo-Beo Men)

This information was corroborated with the World Vision Ghana office who revealed that 94% of the project beneficiaries revealed an improvement in soil fertility, of which about 75% indicated that it was improving a lot and has resulted in increase in crops yields. The non-adopters in the observed community indicated that their soil fertility was decreasing. According to them, they had started learning how to prepare composting since they saw the change it was bringing in the yields of those communities that adopted the FMNR approach.

"We have also started learning how to prepare composting. This is because we are seeing how it is improving the yields of our colleague farmers in Yameriga and Tongo-Beo. The soil fertility is decreasing drastically and there is nothing we can do to improve on it than to try what the others are doing and it is helping them" (Kaare community leaders).

The FGDs at the communities and the KIIs at the implementing agency offices attributed the increased in soil fertility to: FMNR increased leaf-drop, wind protection and run-off; bushfire suppression; elimination of field-burning; grazing livestock in the dry season; and improved Compost' technique.

"Some of us have our outputs increased by three folds, for instance, I used to get three to four basins of sorghum from my field. After applying compost, manure and not burning the stalk on my field I got close to three bags on the same field [equivalent of 12 basins)" (Yameriga Lead farmer)

A corroboration of the output levels of crops at the District MOFA Monitoring and evaluation Office revealed that between 2009 and 2010, the average output of maize increased from 1.95metric tonnes/hector to 2metric tonnes/hector while vegetable crops increased from 2.39metric tonnes/hector to 5.2metric tonnes/hector between 2009 and 2013 in the district. The increment was dominated by the FMNR project communities. The benefit of the improved crops yields contributed to improved household food security and income as well as creating a cost saving to the household.

3.2 IMPROVED ACCESS TO FODDER AND LIVESTOCK SECURITY

Fodder for domestic animals in the Upper East Region of Ghana has become very scarce. This is because, the bushes are burnt in the dry season and since the dry season has become so long, it becomes difficult to get feeds for the animals. Cattle, sheep and goats get lose as a result of the scarcity. The animals travel long distances in search for food in the dry season. In the two beneficiary communities that the research covered, fodder in those communities are progressively increasing and reducing the number of animals that get lose in the dry season. They also indicated that their animals are fatter and healthier and have up to 3-4 times market value than the animals in the non-beneficiary communities. This is because the community forest and the individual farms that are not burnt serve as feeding grounds for these animals. The animals do not wander around looking for feeds. The implication is that more time is saved as young boys have more time to attend school as they spend less time herding their cattle and ruminants in the forest and the grown-ups also spend more time on other activities than looking after the herds.

"Our animals no longer roam far for pasture because there is ample feed around. The grasses in the community forest are not burnt. The landscape is also cooler and attracts animals all over the surrounding villages that come to graze. Our animals look more healthy and fatter such that we can bargain for a better price when they are offered for sale." (Tongo-Beo Lead Farmers)

"We sell our animals to cater for household needs like children's school fees; health; buy consumables for the household. Animals are very important assets in our lives. Previously some of our animals used to die due to hunger, but with the introduction of FMNR, there's more pasture for animals and they don't roam far. We didn't know and we were always burning the bush, but now we don't burn the bushes and our animals feed there. Children now spend more time in school than looking for animals in the bush. We also spend less time looking for the animals in the dry season. They are always around the community forest all time grazing" (Yameriga Chief)

As compare to the non-beneficiary community that was survey, the Tindana and elders complained that the chance of their animals being stolen by people outside their communities is higher. They spend much time looking for their animals which wander around for food in the dry season. Some end up being stolen while others too loses their market value because they do not get enough fodder to feed.

3.3 IMPROVED DIET: WILD FRUITS AND ANIMALS (BUSH MEAT)

The study revealed that there is increased in availability and access to local wild foods such as fruits, nuts and wild animals such as rabbits and partridges in the beneficiary communities. The increase in the access leads to increase in access to diet which translate to increase in nutritional values for both children and grownups. The major cause of this achievement is due to the suppression of bushfires which allows mature fruit trees to bear fruit, and also serve as habitat for the wild animals. When the information was corroborated with WVG and district level MOFA, it was revealed that about 46% of the project beneficiaries observed that the FMNR practices have generated more wild fruits and food in the communities. The community members also expressed that there are more wild animals which are used for bush meat and improves household diet. The improved diet and income is also as a result of the project supplementing bush meat with breeder rabbits to some lead farmers.

"*Some wild animals that were almost extinct are returning in the forest. For some time now we have begun experiencing the return of wild animals such as partridge, birds, rabbits and mice. These animals are hunted for and used as food in the household as well as sold for additional household income in the family" (Yameriga chief).*

3.4 INCREASED ACCESS TO NATURAL RESOURCES SUCH AS CONSTRUCTION MATERIALS AND FIREWOOD

In the research area, over 95% of the households depend on fuelwood and charcoal for their household energy. Construction materials are also mainly local materials like rafter, grasses (for thatch) and wood for other building purposes. This study revealed that access to these materials improved in the beneficiary communities over the period. The firewood is gotten from the pruned branches while some of the matured branches are harvested for building or construction materials.

"We prune the trees and use the pruned branches for firewood. We also cut the dried branches on the trees and use them for firewood. Because we don't burn the forest too, the grasses are there all year round and they are much taller than before. We harvest those grasses and use them to roof our buildings. We also select and cut the matured branches and use them as rafters" (Yameriga Chief).

"In the past, we used to travel long distance to obtain grasses for thatch. These days we don't go far and get the grasses for the thatch. A lot of time is saved and we are able to do other activities other than using the whole day to search for the grass" (*Tongo-Beo Lead Farmers*).

This situation was different in the non-beneficiary community (Kaare). They still face the challenge of spending much time to look for rafters and grasses to roof their buildings.

"*We travel long distance to look for rafters and grasses to roof our buildings. One can spend the whole day searching for only two bundles of grass", (Kaare Tindana and elders).*

Corroborating this information with the WVG office and the MOFA district office revealed that FMNR beneficiary households harvest four times more rafters from their own fields, and twice as many harvest firewood from their own fields than the non-beneficiary communities in the project area.

3.5 PROTECTION FROM CLIMATIC EXTREME EVENTS LIKE STORM

Climatic extreme such as storm is very frequent and causes devastating effects to crops and lives. The severe winds can rip off the roof of buildings; cause wind erosion; level or push crops on the ground and even push down trees including economic trees. The community forest and the agroforestry practices on the farms serves as wind breaks and the consequence of the effects of storm have reduced in the project communities. The fire suppression has also increased the quantity of leaves on the farms which checks erosion when there is heavy rain.

"Previously there used to be heavy storm that carried away our crops and rip off our buildings. Though we still experience heavy storm, it doesn't affect our crops like before. The trees serve as wind breaks and reduces the effect on our lives. The time we used to spend on reworking on our roofs and buildings after storm is no more. Times are saved and use it on other activities including farming. Leaves of trees also prevent soil erosion. The leaves also serves as mulching and the land does not dry in time" (Yameriga Lead Farmers).

4.0 CONCLUSION AND IMPLICATION

Bridging autonomous adaptation with the planned approaches leads to higher commitment and therefore improves on outcomes that go a long way to strengthen the adaptive capacities of beneficiaries. The indigenous and planned approaches converged at various points and this has resulted in increased commitment in the implementation of the project leading to higher achievement in the outcomes of the project. Local adaptation approaches are relevant for food security and environmental protection and should be identified and incorporated in planned approaches. These findings imply that planned adaptation initiatives need to use consultative and participatory process to identify and mainstream context-relevant autonomous and indigenous knowledge and practices in order to achieve greater success and increase sustenance of outcomes.

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Farm structure survey – key data source for environmentally related farm management practices

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ABSTRACT

Assessing the integration of environmental requirements into agricultural practices is a difficult exercise, aimed at evaluation of the state of the environment, the interaction between agriculture and environmental outcomes, as well as of the influence of other factors, such as general market trends, technological development and weather events.

Measuring the impact of agriculture on environment for designing, implementation and evaluation of economic policies aimed at its mitigation is crucial. Relevant and timely information on the response of agricultural practices to data requirements for designing and monitoring the environmental policy became mandatory. To meet these high demands, international and national organizations accelerated the transition from the development of agri-environmental indicators to the actual production of such data.

Farm Structure Survey (FSS) is one of the main tools for collecting data for the calculation of agri-environmental indicators in European Union (EU)'s member countries. Starting with FSS 2010, Romania integrated in its survey program the required information for calculation part of the agri-environmental indicators according to Eurostat standards and recommendations. Having in view the deficiencies related to data collection, still a number of limitations need to be overcome for the set of agri-environmental indicators to become fully operational. However, for analyzing the relationship between agriculture and environment and for identifying main trends in this evolving interaction, efforts are done to gather supplementary information, scattered among various institutions, to improve, develop and compile the entire set of indicators needed, according to Eurostat recommendations. Administrative data sources can fill important gaps, but efforts should be done to obtain more added value, improving such data in line with statistical requirements and georeferencing principles. From this perspective, FSS, even if confronted with increasing and more complex data demands, became a core instrument for collecting primary data on environmentally related farm management practices indicators.

The paper presents a brief overview on data needs and availability at national level for assessing the farm management practices in Romanian agriculture, aiming to appraise the set of agri-environmental indicators related to soil management practices towards environmental sustainability based on FSS data.

Keywords: agri-environmental indicators; soil management practices; soil conservation methods

1. Introduction

Agricultural production systems based on intensive farming led to increased pressure on the environment. The dynamic relationship between the processes taking place in agriculture and environmental phenomena grounds the “sustainable agriculture” concept. The series of reforms of the Common Agricultural Policy (CAP) that have taken place in the 1990s, 2000, 2003, 2008 and 2013, led to a ‘greening’ of the CAP (O. Oenema et al. 2011).

Implementation of agri-environmental measures started in 1980 on own initiative of several Member States of the EU. This initiative was taken by the European Community in 1985, by Article 19 of the Council Regulation (EEC) No 797/85 of 12 March 1985 on improving the efficiency of agricultural structures, but remained optional until 1992 when it was introduced as “accompanying measure” of the CAP for all EU Member States. Subsequently it became subject of a specific regulation[1], encouraging farmers to carry out environmentally beneficial activities on their land, and Member States were required to introduce agri-environment measures “throughout their territory”. In 1999, the Agri-Environment Regulations were incorporated into the Regulations for Rural Development[2], as part of the CAP reform “Agenda 2000”. Compliance with the rules of conditionality (cross-compliance) accompanying the single farm payment scheme (stated during CAP Reform for 2007-2013), introduces a cross-cutting approach support system for farmers, which is based on accomplishing of the strict conditions to be met for getting the aid requested from the community. All farmers receiving direct payments must comply with a “list of priorities”, which refers to respecting different European standards in the following areas: (i) environmental protection; (ii) food security; (iii) animal health and welfare.

Agri-environment measures are the main tools for implementing the environmental policy for fulfilling environment objectives established through the Rural Development Programs (RDP). They are accompanying the mechanism of single farm payment scheme and are a key instrument

[1] Council Regulation (EEC) No. 2078/92 on agricultural production methods compatible with the requirements of the protection of the environment and the maintenance of the countryside.
[2] Council Regulation (EEC) No 797/85 of 12 March 1985 on improving the efficiency of agricultural structures.

for achieving environmental objectives agreed in the development programs at EU level. Agri-environment measures are proposed by Member States or regions and submitted for approval to the Commission according to Regulation 1698/2005 as part of their RDPs.

For the assessment of trends over time of (i) the effects of agriculture on the environment, and (ii) the effectiveness and efficiency of agricultural and environmental policy measures, and for monitoring the implementation of agri-environment measures, a set of 28 agri-environmental indicators (AEIs) were identified in the Commission Communication COM(2006) 508 and subsequently approved by the Agricultural Council.

Following the analysis of data requirements for the calculation of agri-environmental indicators, Eurostat has identified a total of 97 different types of data, of which 25 are related to surface. Twenty types of data can be obtained from the Farm Structure Survey (FSS) and 12 from the Survey on Agricultural Production Methods (SAPM). In addition to FSS and SAPM there were identified 43 other different data sources.

In some EU member states the SAPM was surveyed as a sample survey, in others as a census, while the FSS was carried out as a census in all countries in 2010. The SAPM was in most countries carried out at the same time as the FSS 2010.

2. Analytical framework

Given the flexible framework offered by OECD model DSPIR (Driving forces - Pressures - States - Impacts - Responses), the 28 AEIs were identified under DPSIR analytical framework[3]. Most sets of indicators presently used by nations and international bodies are based on DPSIR-framework or a subset of it (Gabrielsen&Bosch).

Farm management practices are defined as decisions and operations practices that shape the effective management of farms, such as land preparation (soil cover and methods of preparing the soil for cultivation) and the type and capacity of manure storage farm manure and slurry. In order to assess the relations between farm management practices and environment, under the DPSIR domain "Driving Forces" sub-domain *Farm management*, there were defined three main agri-environmental indicators[4]: (i) Soil cover - AEI 11.1, (ii) Tillage practices - AEI 11.2 and (iii) Manure storage - AEI 11.3.

2.1 Soil cover – AEI 11.1

Conservation agriculture encompasses a set of complementary agricultural practices which minimize alteration of the composition and structure of the soil. Soil conservation is one of the ways to reduce land degradation due to soil erosion, pollutants, pesticides etc., contributing, at the same time, to enrich soil organic matter by soil cover in winter. Conservation agriculture tries to keep the soil covered with a cover crop or with crop residues. Soil cover can improve soil fertility and reduce erosion risk while, thereof, preventing leakage of nutrients and pesticides.

[3] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2006:0508:FIN:EN:PDF
[4] http://ec.europa.eu/eurostat/web/agri-environmental-indicators/analytical-framework

This indicator provides information on the periods of the year when soil is covered with: (i) normal winter crops (winter crops), (ii) protecting crops / crop cover or intermediate, (iii) residues of crops or (iv) soils uncovered.

The AEI *soil cover* can be measured by the following indicators[5]:

Main indicator:

Share of the year when arable land is covered with plants or plant residues.

Supporting indicators:

• The share of arable land covered by winter crops (winter cereals and winter rape or grass)

• The share of the arable crops covered by annual green crops.

• The share of arable land covered by maize.

FSS, SAPM and Crop Statistics are the main sources of information for AEIs with reference to farm management practices classified. Data on farm management practices are not collected regularly. These data were required for the first time in the SAPM, held together with the FSS in 2010 (year of agricultural census in EU Member States).

2.2 Tillage practices - AEI 11.2

Tillage practices refer to cultivation operations carried out between harvest and the next sowing operation /cultivation. It is included only the area of the main crops. The sum of land under conventional tillage + conservation tillage + zero tillage = arable land - arable land not sown/cultivated during the reference year. Arable land which is not sown/cultivated during the reference year can be areas under glass or other protective cover, temporary grasslands, leguminous plants, industrial crops like hops or aromatic plants etc.

Tillage practices are defined as the share of arable surfaces under conventional tillage, conservation tillage (reduced cultivation) and zero tillage (direct sowing), and is measured by the following indicators[6]:

Main indicator:

The share in total area of arable land of the arable land on which there were practiced the following cultivation methods: (i) conventional plowing (ii) cultivation of conservation (iii) zero tillage and (iv) not tilled.

Supporting indicators:

Arable areas under conventional tillage, under conservation tillage and under zero tillage.

2.3 Manure storage - AEI 11.3

AEI on manure management provides information on manure storage facilities on agricultural holdings and related storage capacity, which depends on the time required for storage and the number and type of animals.

[5] http://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_soil_cover
[6] http://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_tillage_practices

The storage capacity for manure can be measured by the following indicators[7]:

Main indicators:

- Share of holdings with livestock which have manure storage facilities in total holdings with livestock.
- Share of holdings with different manure storage facilities.

Supporting indicators:

- Share of manure applied with different application techniques and manure incorporation time
- Share of animals in different housing systems

There are delineated the following types of storage facilities:

- Storage facility for solid manure (dung): impermeable surface with drain insulation, with or without roof;

- Storage facilities for liquid manure: watertight tank, open or covered, or lined lagoon;

- Storage facility for semi-liquid manure (suspended) slurry tanks, open or covered, or lined lagoon.

This indicator is primarily of relevance for emission of ammonia (NH3) and nutrient leaching losses from animal manures. The main indicator is related to storage facilities and supporting indicators to spreading of manure or slurry and to housing facilities

3. AEI on farm management practices in Romania

Agri-environmental indicators related to farm management practices were calculated based on the results of FSS and SAPM carried out in Romania in 2010 (full scope survey).

3.1 Soil cover – AEI 11.1

Over 96% of the total number of farms in Romania (3.9 million farms) operated agricultural areas in 2010, of which 71.5% operated arable land (2.8 million farms). About 79% of the farms that operated arable land (2.2 million farms) have applied one or more methods of soil conservation: 34 % applied winter crops, 4% applied protective cultures, 15% applied crop residues and 82% have applied bare soil method. Total arable land under soil conservation methods was 6.5 million hectares, representing 73.8% of total arable land of the country (8.3 million ha). 53% of total arable land under soil conservation methods was operated by holdings sized more than 100 ha, 14% by holdings sized between 2-5 ha, 9% by holdings sized 1-2 ha, 7% by holdings up to 1 ha, while the rest of 17% by holdings sized in classes between 5-100 ha. The structure of the total arable land under conservation methods, according to the methods of conservation applied was: 47.2% under bare soil, 44.9% under winter crops, 6.6% under residues crops and 1.4% under intermediate crops. The application of soil conservation methods differ depending on size classes of arable land area The areas under winter crops increase with the increase of the size classes of the holdings, while the

[7] http://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_manure_storage

areas under bare soil, covering more than 70% in holdings sized less than 0.5 ha, decrease to 40-50% in holdings bigger than 10 ha. Intermediate crops amounts up to at most 3% in all size classes, while soils covered with plant residues amount 9-12% in holdings sized up to 10 ha, 6-8% in holdings sized between 10-100 ha and 4% in holdings larger than 100 ha (Figure 1).

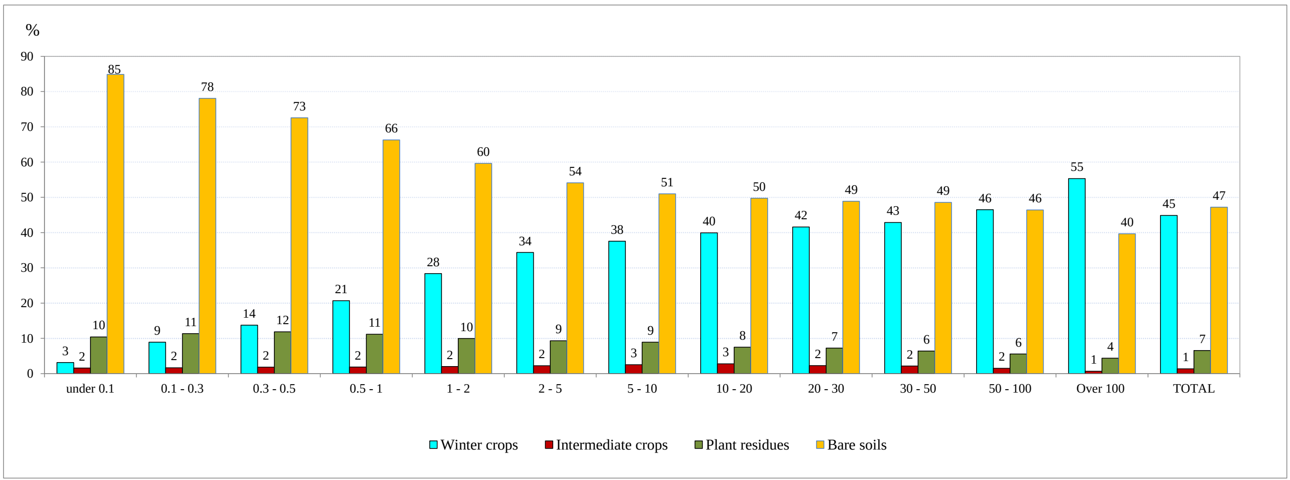

Figure 1: *Structure of arable land area on which were applied soil conservation methods, after the method of soil conservation applied, by size classes of arable land area*

3.2 Tillage practices - AEI 11.2

About 94% of the total number of farms with arable land (2.8 million farms) have practiced one or more tillage methods: 89% have practiced conventional tillage on 6.9 million hectares (83% of the total arable land), 2% farms have practiced conservation tillage on 193 thousand hectares (2% of the total arable land) and 13% farms practiced zero tillage on 584 thou hectares (7% of the total arable land). About 8% of the total area of arable land area (652 thou ha) was not tilled (without cultivation) (Figure 2).

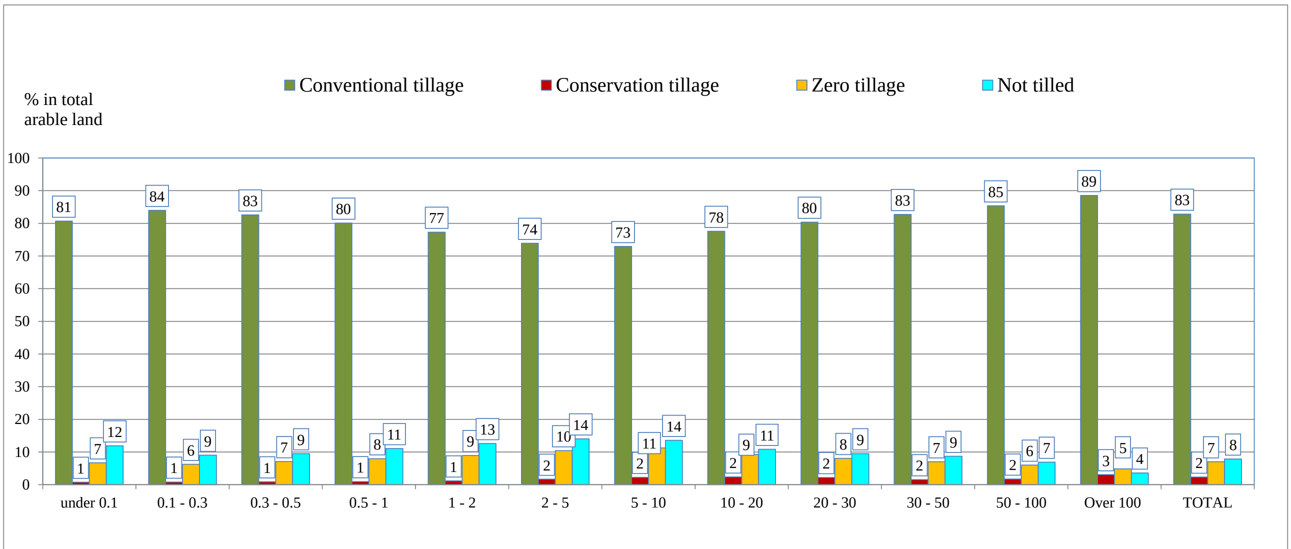

Figure 2: *Structure of arable land area on which were applied tillage practices, after the tillage method applied, by size classes of arable land area*

Over 80% of farms under each size class of arable land practiced conventional tillage, covering a total area of 6.9 million ha (83% of total arable land). Conventional tillage was practiced on 89% of total arable land operated by holdings larger than 100 ha, and on 73-85% on arable land operated under each size class of arable land area.

3.3 Manure storage - AEI 11.3

Romania is among the countries with a low potential for manure storage compared to other EU Member States. Thus, out of the total holdings with livestock (2.8 million holdings), only 15% have solid manure storage facilities. Out of the total holdings with storage facilities for solid manure, only 3% have storage facilities covered. Out of the total holdings with storage facilities for liquid manure, about 28% have storage facilities covered. Out of the total holdings with storage facilities for semi-liquid manure in basins, about 15% have storage facilities covered, while from total holdings with storage facilities for semi-liquid manure in reservoir 7% have storage facilities covered (Figure 3).

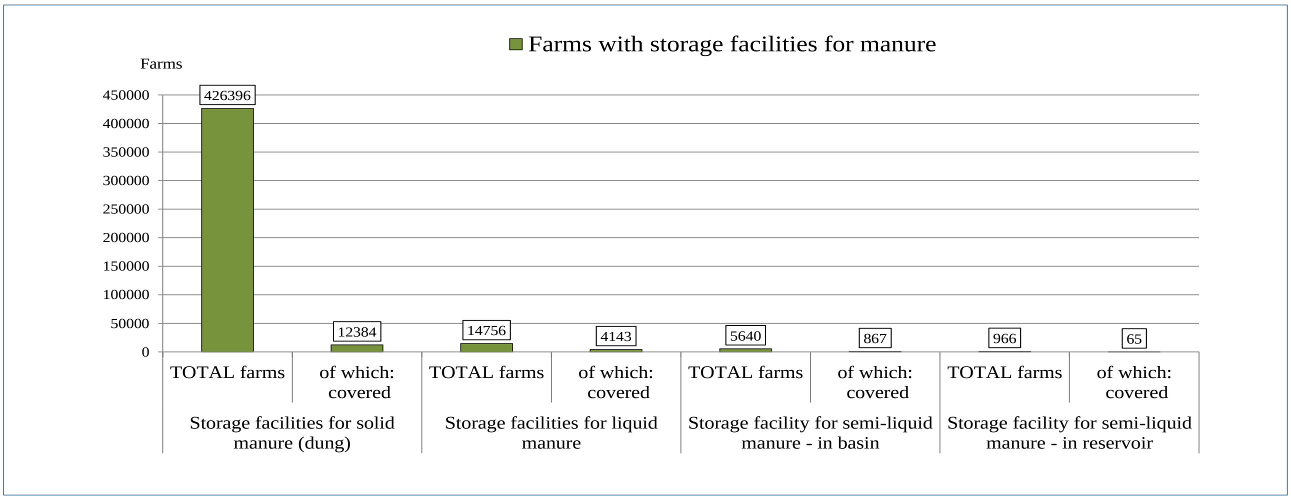

Figure 3: *Agricultural holdings with manure storage facilities, by type of manure storage*

Understanding farm management system is essential in order to implement the concepts of sustainable resource management. A relevant indicator giving a good insight in understanding the managerial approach at farm level is the *Share (number) of farm managers having practical experience, basic training, and full agricultural training* (one of the supporting indicators used for measuring AEI 3[8] related to the domain Responses in the DPSIR model). For Romania, this AEI indicates that from the total 3.9 million Romanian farmers[9] 0.4% completed full agricultural training, 2.1% had basic training in agriculture and 97.5% had only practical experience, ranking Romania on the last place among EU-28 in relation to the shares of farm managers with only practical experience.

4. Conclusions and recommendations

Winter covered soils are most effective against surface runoff and soil erosion, as well as nitrogen leaching during winter. This is why the extent to which winter crops protect against leaching and

[8] Farmers' training level and use of environmental farm advisory services
[9] Full scope Farm Structure Survey 2010

runoff is correlated with the presence of winter crops. AEI 11.1 can be further improved by including information about topography (Vinther Finn P. at al, 2011). A territorial approach rather than a national approach is essential to capture the diversity in farming systems and the environment.

Reduced tillage may in the short term lead to increased use of herbicides in order to compensate for the reduced mechanical weed control, but also can contribute to carbon sequestration in soil and thereby may alter the emissions of greenhouse gases, especially CO2 and N2O. The differentiation between reduced and conventional tillage is rather difficult, and clear definitions of reduced, minimal and conventional tillage would be needed. Reduced/minimal tillage may relate to both reduced frequency of tillage and to reduced soil depth of tillage (Vinther Finn P. at al, 2011).

SAPM, main data source for the AEI related to farm management practices, was carried out so far only in 2010. Collecting the data required for calculating these indicators by a statistically representative survey once every 2-3 years, together with FSS, would be useful for analysis the trend of these indicators, having in view that cropping systems and manure storage systems do not change significantly from year to year. This necessitates greater policy relevance and increased quality and timeliness of basic data sets, as well as a closer link between environmental data and existing economic and social information systems. It also necessitates more work to complement the indicators with information reflecting sub-national differences (Linster M. at al., 2001).

The set of AEIs have much in common with policy requirements, and even those that are not required directly for policy are useful for monitoring the outcomes of policy implementation. AEIs provide much of the needed coordination for data collection at an EU level to meet the needs of the key agri-environmental policies. Nevertheless, the results of monitoring and evaluation of sustainable development concepts based on AEIs must take into account that making decisions about the use of natural resources at their disposal, belongs directly to agricultural producers. Therefore, the successful implementation of any of the conclusions drawn from monitoring the indicators for the sustainable management of soil resources will depend on their acceptance by farmers.

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The challenge of collecting and publishing data on organic agriculture worldwide

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ABSTRACT

Globally, organic farming continues to grow and, in many countries, has reached wide acceptance amongst farmers, consumers, market actors, policymakers, and the public. According to the latest available data (per 31.12.2014), 43.7 million hectares are under organic agricultural management, and this constitutes almost one percent of the global agricultural land; the global market is estimated to be 80 billion USD (Willer & Lernoud 2016). These data, which are mostly based on national data sources, are annually compiled by FiBL, which has been collecting and publishing data on organic agriculture worldwide since 2000. They are widely used and quoted by governments drawing up action plans for organic agriculture; researchers; market actors; market research companies, and the media.

However, with the collection of these data, there are challenges, including data gaps and incomplete data, issues related to definitions, classifications, data quality, and data access. Based on the work of the European research project OrganicDataNetwork, suggestions for the improvement of organic data at national level and in Europe have been made (Zanoli 2014). This paper highlights latest data and trends, illustrates current challenges and good examples, and makes recommendations related to data collection on organic agriculture based on the European experience.

Keywords: Organic agriculture, market data, data collection, data harmonisation

1. Introduction and background

Organic farming, which emerged in the first decades of the past century (Vogt 2000), continues to grow globally and has reached wide acceptance amongst farmers, consumers, market actors, policy makers and the public in many countries. Organic agriculture has garnered increasing official attention and support in the past few years, in particular since 2000. Among other reasons, governments support organic farming because it responds to consumer demand for high-quality food and environmentally friendly farming practices. The benefits of organic agriculture are documented in many peer-review scientific papers. Recent examples are publications on the positive effects on food quality (Branaski et al. 2014, Średnicka-Tober 2016 a,b), biodiversity and the environment (Schader et al. 2012), food security (Reganold & Wachter 2016), and climate change mitigation (Skinner et al. 2014), to name just a few. Organic agricultural land area and organic share of the total agricultural land is seen as an agri-environmental indicator by the OECD (2013), the European Environmental Agency (2015), and Eurostat (2015).

In many parts of the world, support is granted for organic agriculture in many ways; the most common is the establishment of organic regulations/laws, of which 87 exist today (Huber et al. 2016). Further support schemes include action plans e.g. in the European Union (European Commission 2014a) and many European countries (Sanders and Schmid 2014), institutional support for sector development, e.g. in Saudi Arabia (Hartmann and Bernet 2013), rural development support, e.g. in Brazil (Meireilles 2016), research support e.g. in Canada (Hammermeister 2016), support for export, e.g. Peru (Donahue et al. 2011), or an overall political commitment in Africa (African Union 2011). More information on the private-public collaboration in the field of organic agriculture is available from Bowen (2016).

However, a positive environment for organic sector development does not only require reliable policy support for farmers and food businesses but also a reliable information system (Stolze et al. 2016). Therefore, many governments have established collection systems for data on the organic sector. These are often linked to the establishment of regulations/laws about organic agriculture, such as the EU regulation on organic agriculture, which describes precisely what data should be provided (European Commission 2014b). Once such a regulation/law is established, there are rules about the registration of certifiers with a national authority, which opens up access to data from the certifiers. Public data collection systems mostly cover the organic area and operators and sometimes cover production and, rarely though, international trade data, but they mostly exclude data on the domestic market. There are some countries though, such as Denmark or Sweden, where the statistical offices (Statistics Denmark and SBC) collect retail sales data and, in the case of Denmark, also international trade data.

At the international level, the Research Institute of Organic Agriculture (FiBL) has been compiling and publishing data on organic agriculture since 2000 and continuously expanding the number of indicators on which data are collected. The data are published annually in a yearbook (Willer&Lernoud 2016) and online (FiBL 2016). Whereas in the beginnings of FiBL's data collection activities, only data on the organic area and the number of producers were collected, data collection has been expanded in the past few years, and today, data on all commodities/products and further indicators are collected, e.g., area, livestock numbers, retail sales, exports, and imports. Data collection is carried out in collaboration with many partners among a network of 200 data providers, including governments, private sector organisations, market research institutes, and certification bodies. The data is published together with the IFOAM – Organics International, the international umbrella of the organic sector. With the expansion of FiBL's global data collection, other activities have emerged, such as the collection of data on Voluntary Sustainability Standards (VSS), e.g., Fairtrade International, UTZ Certified, Rainforest Alliance/SAN, and others (Lernoud et al. 2016). Also, FiBL's organic crop data are of particular interest and can be used for a detailed analysis of certain commodities (Granatstein et al. 2015).

FAOSTAT, too, publishes global organic surface area/land use data online, partly based on the annual FAO land use survey, partly on data from FiBL (FAOSTAT 2016).

In Europe, Eurostat publishes data annually, covering a wide range of indicators such as area, livestock numbers, production, operator types including processor by NACE code (Eurostat 2016). These data are complemented by retail sales and trade data compiled by the FiBL and partners (Willer and Schaack 2016).

2. Organic agriculture world-wide – latest trends

According to the latest FiBL survey on certified organic agriculture worldwide (Willer&Lernoud 2016) as of the end of 2014, data on organic agriculture was available from 172 countries (up from 170 in 2013). There were 43.7 million hectares of organic agricultural land in 2014, including in-conversion areas. The regions with the largest areas of organic agricultural land are Oceania (17.3 million hectares, 40 percent of the world's organic agricultural land) and Europe (11.6 million hectares, 27 percent). Latin America has 6.8 million hectares (15 percent), followed by Asia (3.6 million hectares, 8 percent), North America (3.1 million hectares, 7 percent) and Africa (1.3 million hectares, 3 percent). The countries with the most organic agricultural land are Australia (17.2 million hectares), Argentina (3.1 million hectares), and the United States (2.2 million hectares). For 2014, almost 500'000 more hectares of organic agricultural land were reported than for 2013; since 1999, the organic farmland has quadrupled (See Table 1).

Currently, one percent of the agricultural land in the countries covered by the annual survey is organic. By region, the highest organic shares of the total agricultural land are in Oceania (4.1percent) and in Europe (2.4 percent). In the European Union, 5.7 percent of the farmland is organic. However, some countries attain far higher shares: Falkland Islands (36.3 percent), Liechtenstein (30.9 percent), Austria (19.4) percent. In eleven countries, more than ten percent of the agricultural land is organic.

Forty percent of the world's organic producers (at least 2.3 million) are in Asia, followed by Africa (26 percent) and Latin America (17 percent). The countries with the most producers are India (650'000), Uganda (190'552), and Mexico (169'703).

Global retail sales of organic food and drink reached 80 billion US dollars in 2014 according to Organic Monitor (Sahota 2016). North America and Europe generate most of the sales of organic products, comprising approximately 90 percent of organic food and drink sales. Many of the organic crops grown in other regions, especially Asia, Latin America, and Africa, are destined for exports. The global market for organic food and drink has expanded over fivefold between 1999 and 2014, and Organic Monitor projects growth to continue. According to Willer & Lernoud (2016) in 2014, the countries with the largest organic markets were the United States (27.1 billion euros), Germany (7.9 billion euros), and France (4.8 billion euros). The largest single market was the United States (approximately 43 percent of the global market), followed by the European Union (23.9 billion euros, 38 percent) and China (3.7 billion euros, 6 percent). The highest per-capita consumption with more than 100 euros was found in Switzerland, Luxembourg, and Denmark. The highest organic market shares were reached in Denmark (7.6 percent), Switzerland (7.1 percent), and Austria (6.5 percent in 2011).

However, some challenges are associated with the collection of organic data, which include data gaps and incomplete data, issues related to definitions, classification, and quality and data access. Even in the European Union, despite the efforts of private organic sector institutions and the fact that EU organic farming legislation requires the collection of relevant statistical information as a tool for market operators and policymakers, organic market data is not nearly as detailed and reliable as general agricultural and food industry statistics (Stolze et al. 2016). Therefore, it is necessary that data suppliers, and in particular governments, pay more attention to the collection and dissemination of data on organic agriculture.

Table 1: *Organic Agriculture Worldwide: Key indicators 2014*

	World	**Leading region**	**Leading countries**
Organic agricultural land	43.7 million hectares	Oceania (17.3 million ha)	Australia (17.2 million ha), Argentina (3.1 million ha), USA (2.2 million ha)
Share of total agricultural land	0.9%	Oceania: 4.1%	Falkland Islands (Malvinas) 36.3%; Liechtenstein (30.9%), Austria (19.4%)
Organic retail sales	62.8 billion Euros	North America (29.6 billion euros)	USA 27.1 billion euros, Germany 7.9 billion euros; France 4.8 billion euros
Organic per capita consumption	8.3 euros	North America 82 euros	Switzerland 221 euros, Luxembourg 164 euros, Denmark 162 euros

Source: Willer & Lernoud 2016

Challenges

From the experience of FiBL's long-standing data collection, there are a number of challenges related to organic data collection that need to be tackled. These include (see also Willer & Schaack 2014):

- Lack of data and incomplete data: In most countries, only very basic data such as data on certified organic farms, land areas and livestock numbers are reported; in fact, for many countries only the total organic area is available without any further details. Currently, reliable, detailed market data, such as data on domestic markets, international trade, and consumer prices do not exist or exist only as rough estimates in most countries.
- Lack of common classifications/aggregation rules across countries: Countries use different definitions, nomenclature, and classifications; only a few use international classifications (exceptions: Denmark uses the UN's Standard International Trade Classification SITC for its organic trade data; the Czech Republic uses EUROSTAT's CPA codes for its import data). Therefore, country-to-country data comparisons are very difficult. Another problem is that data is often aggregated, and only incomplete breakdowns by crop or product are available, which may make data of little use for some purposes. What makes things worse is that there is no harmonized

way of aggregating these data. In addition, aggregation may change from one year to another even in one country, so that times-series comparison becomes impossible.

- Lack of common definitions: A good example is that of livestock data. The commonly used indicator (e.g., Eurostat and FAOSTAT) is "number of heads," which is interpreted in different countries as the "average stock per year" or "animals slaughtered." These differences in definition make country-to-country comparisons of livestock impossible.
- Inconsistent data: The plausibility checks carried out annually by FiBL (such as year-on-year comparisons and comparison with the overall total) show many inconsistent data sets, as simple quality checks are often not performed by the data providers, even though these basic plausibility checks often allow inconsistencies to be identified.

3. Recommendations

The European OrganicDataNetwork project, funded under the 7th Framework programme for research and technological development in the European Union, has developed recommendations from the project results on principles of desirable organic market data development, production, and dissemination (Zanoli 2014). These have been elaborated in the OrMaCode, the ORganic market data MAnual and CODE of Practice (Zanoli et al. 2014) based on the European Statistical Code of Practice (Eurostat, 2011).

Recommendation 1: Extend the mandate for statistical data collection

There is still a major lack of data on organic agriculture in many countries. Therefore, it would be beneficial if more governments set up data collection systems for organic data or expanded the scope of existing data collection efforts by increasing the number of indicators collected, in particular, related to volume and value of production, retail sales, and imports and exports by product or product groups. In addition, the collection of price data should be considered. In order to ease this process, countries could follow the example of the European Union, which makes the collection of basic data mandatory in the organic regulation (European Commission 2014). In addition to the authorities in charge of organic data and the supervision of the control system, it would be beneficial if this mandate could be expanded to other bodies such as statistical offices, customs authorities and, where relevant, individual companies. Better data availability at a country level could then lead to better data availability at a global level, for data currently provided by FiBL for area, area by crop, operators, and market data (FiBL 2916) and by FAO for area and land use data, partly based on the data from FiBL (FAOSTAT 2016).

Recommendation 2: Develop better statistical processes to increase accuracy of data collection on the organic market

There is a clear need for data providers, be they governmental or private, that develop improved statistical processes to increase the accuracy of data about the organic market, specifically by paying more attention to coverage and adopting improved sampling procedures in the case of data that are not based on a census (in particular, retail sales). In cases where only expert estimates are available, these need to be checked against other sources, and overall, it would be good if the principles as laid down in the OrganicDataNetwork's (2014) OrmaCode would be applied.

Recommendation 3: Harmonise the statistical processes for data collection on the organic market to increase coherence and comparability

National statistical institutes and national authorities should harmonise statistical processes for data collection on the organic market to increase coherence and comparability, specifically by harmonising the national definitions, nomenclature, and classification of statistical outputs to international classifications and by harmonising aggregation rules. Following these rules would make international data sharing a lot easier, and it could be the task of international organisations to help national data collection efforts follow international standards.

Recommendation 4: Establish a system of routine quality checks

Data providers should establish a system of routine quality checks for organic market statistical data by balancing data accuracy versus timeliness in data publication and dissemination, by applying plausibility checks, and by comparing and cross-checking non-official statistical data from at least two independent sources to increase accuracy and consistency. Again, this needs to happen at a country level, but also, any transnational compilation of data at a global or regional level needs to apply quality checks.

Recommendation 5: Strengthen the institutional framework for statistical data collection on the organic market

Institutional support for statistical data collection on organic data should be strengthened, specifically by increased data collection efforts of FAOSTAT and national statistical offices, by establishing and funding permanent, long-term networks of data providers and users at the global, regional, and national levels, and by developing training initiatives to improve the quality of organic market data collection.

Outlook

The positive development of the organic sector, which has seen the continuous growth of the organic market and land under organic management, reflects the dynamic and innovative nature of organic food and farming in response to the expectations of policymakers and the demands of consumers for high-quality food production. On a global level, availability of data on organic agriculture has improved considerably in the past years, in particular for data on organic agricultural land. However, with the collection of these data, there are challenges, including data gaps and incomplete data, issues related to definitions, classifications, data quality, and data access. Therefore, data suppliers must pay more attention to data collection on organic agriculture in order to fill data gaps, harmonize data and improve data quality. Better support for data collection from governments and international institutions could help to improve the situation.

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The productivity and environment nexus through farm-level data. The Case of Carbon Footprint applied FADN to Italian farms.

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ABSTRACT

The most fundamental challenge faced by European agriculture in the early 21st century is how to increase production in order to respond to the significant growth in global food demand while preserving natural resources and the environment. Thus, the productivity and environment nexus of farms is particularly relevant, also in a policy perspective.

The central empirical question addressed by this paper is to assess whether, and by how much, productivity and environmental performance affect each other in the presence of farm heterogeneity. To examine these implications empirically, we have assembled a uniquely detailed dataset of Lombardy FADN farms observed over the period from 2008 to 2013 that merges FADN information on farm structure and economic performance, a productivity index and an environmental indicator, both properly reconstructed at farm level.

We firstly calculate a farm-level total factor productivity index and then estimate a farm-level greenhouse gases (GHG) emissions intensity indicator. The use of micro data to obtain farm-specific parameters is one of the novelty of the approach that can allow better capturing the actual heterogeneity of farms in production and environmental efficiency. We then investigate the nexus of this productivity index with emission intensity on a farm-by-farm basis.

Results are not only informative on the nexus between TFP and GHG emissions, but could be also used to gain insights in the direction of obtaining a unique indicator of the joint economic and environmental performances of farms: i.e. an Environmentally-Adjusted TFP.

Keywords: Total Factor Productivity, GHG emissions, FADN, farm-level indicator

1. Introduction

Increasing food production while preserving natural resources and the environment is the most fundamental challenge faced by European agriculture in the early 21st century. However, assessing to what extent EU agriculture is really moving along this innovative path of, at once, higher productivity and higher sustainability (i.e., better economic and environmental performances), remains a complex methodological challenge.

Productivity gains are typically measured as Total Factor Productivity (TFP) growth (OECD, 2001). However, TFP measures do not account for those inputs and outputs that represent non-marketable resources (i.e. for goods, or “bads”, for which private markets do not exist or are poorly functioning). This could lead to a systematic bias in productivity calculations and incorrect policy conclusions, mostly for the agricultural sector, which has a peculiar relationship with non-marketable goods (OECD, 2010). Some of these environmental effects produced by agricultural activities, like greenhouse gases (GHG) emissions, can be quite well captured and measured by appropriate environmental indicators that accompany the TFP in order to provide a multivariate representation of the joint economic and environmental performance of agriculture.

Whether, and by how much, productivity and environmental performance affect each other in the presence of farm heterogeneity is largely an empirical issue. The central question addressed by this paper is measuring such a nexus with micro data, which represents a novel approach to this topic so far and the main value added of the methodology proposed. In fact, both in TFP and GHG calculation, aggregation bias can highly affect estimates and, consequently, the relationship between economic and environmental performance, concealing micro performances.

The first step of the analysis is to elaborate a farm-level indicator of both economic and environmental performance and then to investigate the nexus between the two. A uniquely detailed dataset of Lombardy FADN farms observed over the period from 2008 to 2013 has been assembled merging FADN information on farm structure and economic performance, a TFP index and an Emission Intensity (EI) estimation, both properly reconstructed at farm level.

The structure of the paper is as follows. Section 2 illustrates the sample analysed and the methodology and data used to reconstruct TFP index and agricultural GHG emissions with micro data and presents the farm-level performances across the FADN balanced sample to highlight the main trend and differences across farm size and typology. Section 3 analyses the farm-level relationship between TFP and CF, then section 4 highlights some concluding remarks.

2. Farm-Level Performances

2.1 The FADN sample

The use of micro data is one of the novelty of the approach that can allow better capturing the actual heterogeneity of data and detecting and comparing both economic and environmental performances of single farms. To our knowledge, the nexus between productivity and sustainability in the agricultural sector, has not yet been explored by the literature using micro data, while the prevalent literature that focused on the micro level, analyses the wider economy and the nexus between trade and environmental efficiency (see among others Cui *et al*., 2016).

In our work the sample analysed to reconstruct the farm-level indicator, is the constant sample of FADN farms of one Italian region, Lombardy (362 farms), observed over the period 2008-2013. The choice of Lombardy is due the importance of the regional agricultural sector both in terms of production and in terms of GHG emissions.

It is worth reminding that the FADN sample is not fully representative of the whole national agriculture. The reference population from which the FADN sample is ideally drawn, is only representative of a sub-population of Italian farms, those farms that can be here refereed as professional or commercial farms (Sotte, 2006).

2.2 The farm-level TFP index

In calculating TFP, micro level data can better approximate a real productivity measure through the complete information provided by FADN (detailed input and output quantities and prices) that help the analysis of structural sources of productivity. However, trying to measure a multilateral indicator of productivity is challenging mostly if the calculation is referred to a panel dataset. In this research, relative productivity levels are derived at farm level for each year between 2008-2013 using the index number approach. Transitivity is achieved by chaining bilateral comparisons across a spanning tree as suggested by Hill (HIll, 2003). The spanning tree identified is the one that minimizes the sum of the Paasche-Laspeyres spreads between the nodes of the tree. Bilateral comparisons are made using the Fisher index number formula.

In the following table some summary statistics on the distribution of farm-level relative TFP levels are presented by farm specialization and economic size. The minimum, median and maximum value of farms' TFP relative levels are presented for each group. Production performances can be compared only within each group.

Table 1 *Summary statistics of TFP index by Specialization and by Economic Size.*

Specialization	**TFP min**	**TFP median**	**TFP max**
Dairy	0.035	0.554	4.693
Rice	0.062	0.455	3.967
Wine	0.023	0.205	1.339
Arable crops	0.022	0.204	2.993
Mixed crops and livestock	0.035	0.201	4.222
Cereals	0.009	0.175	1.42
Fruits	0.014	0.164	1.365
Garzing Livestock	0.015	0.154	1.707
Horticulture	0.002	0.136	4.32
Granivores	0.007	0.095	2.067
Economic Size			
Large	0.007	0.562	4.693
Medium	0.014	0.310	4.222
Small	0.002	0.124	1.25

Source: Authors' elaborations

Table 1 is useful to highlight the heterogeneity in the production performance of different categories of farms. In terms of specialization, the distribution of the farm-level TFP index is concentrated around a higher median for Dairy farms followed by Rice and Wine. Less clear is the production performance for farms specialized in Arable crops, Horticulture, Mixed crops and livestock and Grazing livestock. Their distribution of TFP levels are markedly dispersed around their median and present either low minimum TFP values and high maximum TFP values. In terms of Economic size, there seems to be a positive relation between size and production performance. Larger farms are those with a higher median value of TFP levels followed by medium-sized and small-sized ones.

However, the relation is not clear cut as there is a number of large and medium-sized farms with a low production performance.

2.3. The farm-level CF index

The environmental indicator analysed in this study are farm-level GHG, as a by-product (bad-output) of the production process. The choice of this environmental externality has been made for the relevance of the climate change mitigation objectives in the international (Gerber, 2013) and in EU political agenda, were climate policy sets important mitigation targets also for agriculture (European Commission, 2011) and the Common Agricultural Policy (CAP) gives instruments and incentives to reach these targets (European Council, 2014). In particular, at international level, agricultural GHG emissions are a relevant issue for they are largely determined by developing countries and the role these countries play in their mitigation has important implications in terms of development opportunities. Thus, relevant studies (Tubiello *et al*., 2015), have estimated agricultural GHG emissions at global level also to understand how targets on these emissions could affect different countries in the world. Both at European and global level, the main concern is how to curb agricultural GHG emissions without affecting productivity, i.e. without increasing costs or decreasing output. Studying GHG performances together with productivity ones, and deriving their joint performance can thus be more informative on this topic. To reconstruct a GHG farm balance, we have adapted the Intergovernmental Panel on Climate Change (IPCC) methodology (IPCC 2006) at the farm level, using activity data connected to the main agricultural activities (Coderoni and Bonati 2013). Methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2) emissions are estimated from the following source categories: livestock production, crops, land use, fuel and fertilizers. These different farm-level GHG emissions are then summarised into a unique indicator using each GHG's Global Warming Potential (GWP). The conversion factors updated over time by the IPCC are used. Currently, Italy uses GWPs in accordance with IPCC Fourth Assessment Report, i.e. 25 for CH_4 and 298 for N_2O (ISPRA, 2015). GHG emissions expressed in CO_{2e} represent what we define the Carbon Footprint (See Baldoni *et al*. 2016 for a more detailed description of the methodology used). Table 2 shows which FADN data have been used to estimate the respective CF category and the corresponding emission source.

Table 2 *Summary of GHG emission sources considered and the respective FADN activity data used.*

Emission sources	CF category	FADN data
N_2O manure management	Cf livestock	Animal numbers
CH_4 manure management	Cf livestock	Animal numbers
CH_4 enteric fermentation	Cf livestock	Animal numbers, milk production, pasture, % birth, animal average weight
CH_4 rice cultivation	Cf crops	Rice area (UAA)
N_2O agricultural soils:	*Various*	
-Use of synthetic fertilisers	Cf fertilizers	N quantities or fertilisers exp.
-Animal manure	Cf crops	Manure reuse
-Histosols	Cf crops	Crop area (UAA)
-Crop residues	Cf crops	Crop area (UAA) or crop yield
-Atmospheric deposition	Cf fertilizers/ic crops	N quantities or fertilisers exp.and animal numbers
-Leaching and run-off	Cf fertilizers/ic crops	N quantities or fertilisers exp.and animal numbers
CO_2 Urea	Cf fertilizers	Urea quantities
CO_2 Energy	Cf fuel	Fuel expenditure or quantities
CO_2 Forest land	Cf land use	UAA
CO_2 Cropland	Cf land use	UAA
CO_2 Grasslands	Cf land use	UAA

Source: Authors' elaborations

The main value added of this study, respect to others with a similar approach (Coderoni and Esposti 2015) is estimation of a "farm-specific" emission factor, i.e. an emission factor that varies according to farm characteristics or management practices (i.e. more or less intensive management of livestock population). For data availability this has been possible only for emissions from enteric fermentation (that account for 45.6% of national emissions in 2013) for three animal categories - bovine, buffalos and sheep - that represent 95.2% of total emission from enteric fermentation (ISPRA 2015). Table 3 shows minimum and maximum values of EF calculated with the farm-specific methodology. Data show a high difference with respect to national specific or default values.

Table 3 *Minimum and maximum values of EF calculated with the farm-specific methodology for cattle and sheep for year 2008 and 2013. (Kg CH_4 head-1 year-1).*

		2008		2013	
Livestock category	**National (or default) values**	**Min**	**Max**	**Min**	**Max**
Cattle–male	47.53	1.95	90.41	1.95	72.3
Cattle–dairy	134.21	60.62	198.47	54.3	174.18
Cattle-female	47.53	1.95	69.62	1.95	43.69
Sheep (>1 year)	8	4.56	14.3	2.28	16.74
Sheep (<1 year)	8	1.6	10.05	1.6	17.68

Source: Authors' elaborations

To allow comparisons with the TFP, which is scale independent, the CF has been divided for the Standard Output (SO) at farm level, obtaining the Emission Intensity (EI) (or carbon intensity), i.e. the level of GHG emitted to produce each euro of SO. In fact, as noticed by Coderoni and Esposti (2014) the scale effect always makes the emission growing with the size of the farm (e.g. livestock farms who are on average very big in Lombardy sample, show the highest CF), but what is interesting to analyse here, is if there are scale effect in relative terms, i.e. if biggest farms are more or less efficient than others even when we control for their dimension. The analysis of the emerging evidence in table 4 only concerns some descriptive indicators about the evolution of the EI over time across farm typologies and sizes; this makes emerge some major heterogeneity in terms of emission performance. Size evidently matters: the larger the economic size (ES), and the physical one (UAA), the larger is EI. On trend, smallest farms have the sharper decline. Even looking at data for UAA small farms have a lower EI and sow a better performance over time. However, in this case, the correlation between EI and UAA is positive (and higher than the previous one), meaning that biggest farm have worst environmental performances. Among the agricultural specializations, rice specialist farms and rice and other cereals, have the higher impact on GHG emissions, which also increases over time. Rice cultivation is relevant in the Region (32 farms in the sample) and farm size is particularly high, with medium to big farms and 60 ha of average rice UAA. Activities associated to livestock, show high EI, confirming the evidence of absolute values, but they show also declining median variation. From table 1 and 4 there seems to be a relationship between the two performances. This, however, is very influenced by the size and farm specialization. Thus, it is worth asking whether the nexus between TFP and EI exists, and how it behaves, beyond this obvious dependence on size and product specialization.

Table 4 *2008-2013 evolution of the farm-level Emission Intensity across different farm typologies (Kg CO_{2e}/€).*

Farm typology:	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**% median year to year var.**

Economic Size:							
Small	2.070	2.272	1.159	1.132	1.330	1.145	-6.6
Medium	2.434	2.263	1.562	1.567	1.630	1.610	-5.1
Big	2.906	2.906	1.479	1.562	1.563	1.446	-5.0
Correlation coefficient ES-EI	-0.082	-0.051	-0.089	-0.080	-0.098	-0.090	
UAA:							
UAA < 10 ha	1.649	2.066	0.927	0.904	0.892	0.852	-13.9
UAA 10-50 ha	2.571	2.411	1.420	1.422	1.572	1.430	-4.5
UAA > 50 ha	3.337	3.087	2.193	2.336	2.422	2.397	-2.1
Correlation coefficient UAA-EI	0.204	0.112	0.346	0.231	0.343	0.374	
Specialization	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**% median year to year var.**
Rice	5.555	5.705	4.257	4.517	4.512	4.168	-1.4
Dairy	4.096	3.952	1.832	1.789	1.828	1.826	-4.6
Grazing livestock[a]	3.382	3.034	1.688	1.663	1.866	1.826	-4.1
Mixed crop and livestock	2.379	2.381	0.899	0.864	1.059	0.824	-9.3
Cereals	1.303	1.504	1.096	1.142	1.291	1.167	-2.3
Arable Crops	1.094	0.905	0.919	1.056	1.375	1.154	1.9
Granivores	0.851	0.909	0.379	0.390	0.317	0.319	-6.7
Horticulture	0.466	0.644	0.211	0.369	0.309	0.359	-1.9
Fruits	0.293	0.299	0.248	0.077	0.158	0.104	-61.7
Wine	0.206	0.418	0.134	0.082	0.167	0.304	-67.1

[a]: Grazing livestock contains bovine, sheep and goats.
Source: Authors' elaborations

3. Farm-Level Nexus Between TFP and CF

As already mentioned, the micro level of analysis of both TFP and CF, could be very informative of synergies between productivity growth and GHG mitigation (the so called win-win mitigation strategies), that are not unusual in the agricultural sector. The farm-specific parameters calculated are meant to be a summary statistic representing various forms of heterogeneity in production and environmental efficiency. The first stage of analysis investigates how the productivity index correlate with emission intensity on a farm-by-farm basis. Table 5 shows the correlation coefficient between the farm-level total CF and TFP (calculated for each farm as if all the years were pooled into one period). Correlation is low and significative only for some farm typology. This results suggest the idea that nexus between CF and TFP could be hidden by the large heterogeneity of data.

Table 5 *Correlation between the farm-level total CF and TFP OP across different farm typologies.*

Specialization:	TFP-EI correlation coefficient	Number of obs.	
Granivores	0.236	123	***
Grazing livestock	0.227	172	***

Mixed crop and livestock	0.180	98	*
Dairy	0.050	563	
Horticulture	-0.026	70	
Rice	-0.074	165	
Fruits	-0.104	129	
Wine	-0.111	111	
Cereals	-0.130	511	***
Arable crops	-0.155	128	*
Total	0.201	2070	***

Source: Authors' elaborations

To put forward this concept, our empirical analysis focused on the estimation of the nexus of environmental and economic performance assuming that different level of carbon intensity can influence the TFP of the farm. In other words, the carbon intensity is perceived as an addition input of the production process. The relationship is estimated as follows by using a polynomial functional form (quadratic), including other relevant control variables and the interaction between EI and economic size:

$$\ln(TFP)_{it} = \alpha + \beta EI_{it} + \gamma {EI^2}_{it} + \sum_k \varphi_k d_{t,k} + \sum_m \delta_m s_{it,m} + \sum_m \theta_m s_{it,m} * EI_{it} + \sum_m \pi_m s_{it,m} * {EI^2}_{it} + \varepsilon_{it}$$

Where: TFP is the farm-level TFP, the EI is emission intensity, α is the constant term; *d* are time dummies; s are dummy variables that flag if farm i is of m type (i.e. small, medium or large) and ε is the stochastic error term (assumed i.i.d); *i* is the ith farm and *t* is the time dimension (2008-2013). Results are shown in table 7. The hypothesis of the existence of a nexus between EI and TFP performance seems to be confirmed by statistically significant parameters associated with EI and EI2. However, trying to define uniquely this nexus is not an easy task, for the presence of interactions between variable that make more difficult to delineate a relationship. However, two major evidences emerge: the nexus is different among firm sizes, in particular weaker (in absolute value) for smallest farms, and it also changes when EI interacts with farm size.

Table 6 *Results of the estimation of the relationship between the farm-level EIand TFP (stand. error in parenthesis).*

Coefficient	Estimates (st.dev.)
α	-1.886 ***
	(0.090)
φ_2009	-0.009
	(0.064)
φ_2010	0.079
	(0.065)
φ_2011	-0.043
	(0.065)
φ_2012	-0.074
	(0.065)
φ_2013	-0.094
	(0.065)
β (EI)	0.931***
	(-0.067)
γ (EI^2)	-0.109***
	(-0.012)
δ_medium	0.412***

	(0.097)
δ_small	-0.238***
	(0.091)
θ_(EI)*medium	-0.679***
	(0.087)
θ_(EI)*small	-0.904***
	(0.072)
π_(EI^2)*medium	0.079***
	(0.015)
π_(EI^2)*small	0.107***
	(0.012)

* p<0.1; **p<0.05; ***p<0.01
Observations: 2,070
R squared: 0.367
Adj. R squared: 0.363
Residual Std. Error: 0.833 (df = 2056)
F Statistic: 91.871 *** (df = 13; 2056)

Source: Authors' elaborations

The nexus between the EI and TFP is not univocal. The relationship, in its in sample performance, not only is different for different farm sizes, but it also changes sign - if we sum all the influences of the different coefficients (see Baldoni *et al*., 2016) - drawing an inverted U shape, more evident for medium and large farms. This means that, in fact, there is a more sustainable way to produce and that, in particular, all the points in the left side of the turning point of the curve, represent a benchmark in terms of environmental sustainability than those that are in the right side. The hint that a same productivity performance can be obtained with different environmental performances is not new in the agricultural sector, were farm structures and management techniques are various and complex and there is no "one size fits all solution" to the mitigation of emissions. Findings of this study, if confirmed by larger sample analysis, give a quite complex picture: there is no dualism between productivity and sustainability, but more productive farms can also bring with them worst environmental performances. Foster productivity growth may thus not necessarily lead to greater sustainability. An efficient policy of agricultural GHG emissions mitigation should then stimulate the spread of best practices, reflecting the standards of the farms whose performances are environmentally more sustainable.

4. Some concluding remarks

This work aims to analyse the relationship between sustainability, in terms of GHG emissions and productivity at farm level. The micro level of analysis, which in fact is the main original content of the study, seems to be the most appropriate to analyse the nexus between productivity and sustainability. The farm-by-farm analysis can better capture the actual heterogeneity of data and connections between the evolution of TFP and EI, overcoming aggregation bias issues, which can conceal micro performances of specific territories, farm typologies or structures. Results firstly confirm the great heterogeneity of farm performance, strengthening of usefulness of the micro approach adopted. The nexus between the emission intensity and TFP not only seems to exists, but it is not univocal: it changes among farm sizes and within the same size, varying sign over certain threshold values. If this evidence would be confirmed for other regions, or at national scale, it would suggest that a more efficient way to pursue the relevant EU mitigation targets, would be to work on the dissemination of best practices at the sub-sectoral level. This works represents thus just an initial, though necessary, step in the direction of a joint indicator of both economic and environmental performance of agriculture at micro level. To this respect, results are encouraging. Starting from here, future researches are expected to put forward appropriate theoretical concepts, models and econometric approaches to estimate and Environmentally-Adjusted TFP at micro level.

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THEMATIC SET

E28

MEASURING THE IMPACT OF GLOBAL WARMING AND EXTREME WEATHER EVENTS ON AGRICULTURE

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ABSTRACT

Over the last decades scientists have extensively studied the greenhouse (GHG's) effects,which holds that the accumulation of carbon dioxide (CO_2) and other greenhouse gases emissions,due to human production and consumption activities, are the main causes of both global warming andsignificant climate changes (CC) such as extreme weather and out of season events (floods and droughts). CC impacts and vulnerabilities affects both human and natural systems, with heavy consequences in manycountries.In the long list of potential problems from global warming, it has been widely recognized that the risksto world agriculturestand out as among the most important.

CC can affects agriculture in direct and indirect ways as itdirectly depends on temperatures variation, shifting precipitation patterns, extreme weather events and water resources availability. Shifting in climate conditions bring tochanges in agricultural zones and crop and livestock production activities in many regions. Extreme weather events can threaten the development of the crops and value and quality of yields. Moreover, CC can affect both the demand and the supply for water in agriculture through variations in rainfall patterns, surface water and groundwater, snow and glaciers in many areas.

Non-climatic drivers can also affect water supply and demand as population growth and increasing urbanization.Globally the overall impact of global warming is a reduction of agriculture productivity in the long run. Climate change is already underway and is already influencing the productive potential of agricultural systemsin every countries.

Numerous studies underline that a heavy concentration of losses will be found in the developing countries and in particular in the poorest countries associated, in some cases, with the rising sea levels. On the one hand they have a less capacity to adapt to CC effects than do their wealthier neighbors and on the other side they are in warmer parts of the globe, in some of which temperature are already close to thresholds value for crops. As a result, CC will probably also increase the risk of food securityfor some vulnerable groups of population. Moreover, agricultural sector has become one of the main driving forces to climate changes through anthropogenic GHG's emissions and land use changes (conversion of non-agricultural land into agricultural one, deforestation, rural exodus).

Strategies and actions to mitigate and adapt to CC impacts are neededin particular driven by either developed countriesthat mainlyhave contributed in the past and big developing countries heavily contributing to the GHG'S emissionsin the last decade. Also promoting an environmental sustainable agriculture represent a central issue, as thissector strongly contributes toCO_2 concentration increasing.In this context, the role of official statistics is crucial to gauge climate changes and related impacts, meteorological variables, water availability and use, crops typologies and yields, irrigation systems and land use. This wide information represent the basis to define policy targetsand to monitor their achievement at different spatial scale and to integrate adequate measures into international and national policies and strategies. Rural development policies are already devoting significant financial resources to intervene, both for mitigation and adaptation to climate change. Therefore, it is necessary to provide adequate information on the evolution of the climatic conditions, for adequately supporting the planning and the actions of farmers and local institutions which apply these measures.

THEMATIC SET

E28

LIST OF PAPERS

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Addressing Italian official statistics to the measurement of climate change impacts and adaptation options on agriculture

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Climate Uncertainty and Dynamic Adjustment in Agriculture: The case of Cameroon

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ABSTRACT

This study aims to understand and quantify the link between climate and agriculture in Cameroon on one hand; and to analyze how the expectations of farmers on climate change affect investment and production decisions, and the process of adjusting factors of production, on the other hand. The data used come from Food and Agricultural Organisation, Surveys and Agricultural Statistics Division of Cameroon Ministry of Agriculture and Rural Development and the third Cameroonian survey on household. To achieve the first objective, we estimate the Ricardian model by the Ordinary Least Square method. While the second objective is achieved by estimating a dynamic stochastic model by the nonlinear three-stage least square method. Firstly, regarding the marginal effect, we found that an increasing for 1mm of precipitations leads to a decreasing for FCFA 2200.20 of farm income per hectare. While an increasing for 1°C of temperature leads to an increasing for FCFA 2322 of farm income per hectare. As for the elasticity of farm incomes, the results show that an increasing of 1% in temperature leads to higher farm revenues by 32.4 % while an increasing of 1% in precipitation leads to lower farm revenues by 12.9 %. Finally, under uncertainty and market price change, Cameroonian agricultural farmers take about two and a half years to fully adjust the desired level of their crops, about 24 years for capital, one and half year for labour and about nine months for fertilizer to their optimal level . So, in Cameroon's agricultural sector, crops adjust most rapidly than capital toward their respective optimal levels. So, under climate change, farmers gradually adjust production and inputs. These dynamic adjustments are due to adaptation measures implemented by farmers under uncertainty.

Résumé

Cette étude vise donc à comprendre et quantifier le lien entre le climat et l'agriculture au Cameroun d'une part; et à analyser la façon dont les anticipations des agriculteurs sur le changement climatique affectent les décisions d'investissement et de production ainsi que le processus d'ajustement des facteurs de production, d'autre part. Les données utilisées proviennent de la Food and Agricultural Organization, de la Division des études et statistiques agricoles du Ministère de l'agriculture et du développement rural et de la Troisième Enquête Camerounaise auprès de Ménages. Pour atteindre le premier objectif, nous estimons le modèle Ricardien par la méthode des Moindres Carrés Ordinaires. Tandis que le second objectif est atteint grâce à l'estimation d'un modèle stochastique dynamique par la méthode des Triples Moindres Carrés non linéaires. S'agissant de l'effet marginal, les résultats montrent premièrement que l'augmentation de *1mm de précipitations conduit à une augmentation de 2322FCFA du revenu agricole par hectare. Tandis qu'une augmentation de 1°C de la température conduit à une baisse de 2200.20FCFA du revenu agricole par hectare. Quant à l'élasticité des revenus agricoles, les résultats montrent qu'un accroissement de 1% de la température conduit à une augmentation de 32, 4% du revenu agricole alors qu'une augmentation de 1% des précipitations entraîne une baisse de 12,9% du revenu agricole. Enfin, face à l'incertitude et le changement des prix du marché, les ménages agricoles camerounais prennent environ deux ans et demi pour ajuster complètement le niveau de leurs récoltes, environ 24 ans pour ajuster le capital, un an et demi pour ajuster travail et environ neuf mois pour ajuster les engrais souhaité à leur optimal niveau . Ainsi, dans le secteur agricole au Cameroun, les récoltes s'ajustent plus rapidement que le capital vers leur niveau optimal respectif. Donc, face à l'incertitude climatique, les ménages agricoles ajustent graduellement leurs inputs ainsi que leurs productions. Ces ajustements dynamiques sont dus aux mesures d'adaptation mises en œuvre par les agriculteurs face à l'incertitude.*

Key words : Agriculture, Climate Change, Uncertainty.

1. INTRODUCTION

Cameroon, attic of Central Africa sub-region, is divided into five agro-ecological zones namely monomodal forest zone, bimodal forest zone, highland area, area of the high savannas and Sudano-Sahelian zone. The share of the agricultural sector in the Cameroonian economy is important. Indeed, this sector employs almost 60 % of the active population and contributes about 20% to gross domestic product (NIS, 2013). Exports of agricultural products represent 40% of total non-oil exports. However, in Cameroon, in recent years, climate changes cause instability in rainfall leading to disruption of the agricultural calendar and a substantial decline in agricultural productivity. Thus in the north of the country in the Sahel region, these climate variabilities cause desiccation of rivers, west drought surface water; and rising sea coast with flooding. This explains why IFPRI (2009) estimates that population in the developing world, already vulnerable and exposed to food insecurity, are likely to be most seriously affected.

High temperatures and current fluctuations in precipitation, combined with population growth, are a real and permanent threat to food security through their impact on agriculture in Cameroon. Indeed, rising in temperature causes lower yields of desirable crops and the proliferation of bad harvests in the short run on the one hand, and a substantial decline in agricultural production in long run on the other hand. With this in mind, resilience to climate variability and climate change becomes imperative in order to limit their socioeconomic impacts in the sub-region and particularly in Cameroon. Moreover, Molua (2009) shows a positive relationship between adaptation measures and increasing agricultural yields. For the author, adaptation is an operational strategy to deal with climate change. According to this study , 60% of surveyed Southwest farmers adjusted their farming practices to climate variability, and about 40 % of farmers have used for agricultural strategies aiming to conserve water and soil.

Our study aims answer the following research questions: are there a direct link between climate change and agricultural productivity in Cameroon? And how do farmers' expectations on climate change affect investment and production decisions and the process of inputs adjustment in Cameroon?

This study has two objectives. Firstly, it aims to assess the impact of climate change on agriculture in Cameroon. Secondly, it aims to analyze how famers' expectations on climate change affect investment and production decisions; and process of adjusting factors of production.

Ricardian approach, initiated by Nordhaws and Shaw (1994) and developed by Mendelsohn et al. (1994) is used to estimate the impact of climate variability on the production or agricultural yield in Cameroon. It is based on observation of David Ricardo that value of land would reflect its profitability in a perfectly competitive market. This method, linking regional differences in climate to value difference of land, permits to compare sensitivity to climate change in different regions (Ouedraogo, 2006). Furthermore, in order to analyze investment behavior of farmers under uncertainty and adjustment costs induced by climate variability, we build a stochastic model based on dynamic duality developed by Epstein (1981) and then developed by Vasavada Chambers (1986), Howard and Shumway (1988), and Agbola and Harrison (2005). The development of this model through the integration of expectations in the dynamic duality theory was recently done by Pietola and Myers (2000) and Krysiak (2006). Sansi and Schumway (2014) used this approach to analyze the structure adjustment of inputs and output in the US agricultural sector.

The uniqueness of this study is based on two main arguments. First, there are no studies in Cameroon, to our knowledge, on the modeling of the dynamic output supply and input demand in the cameroonian agricultural sector. In addition, our study is a contribution to the formulation of an expanded theoretical framework as well as the application of econometric models derived from the dynamic duality apporach under uncertainty. The remaining of the paper is organized as follows. Section 2 presents a review of dynamic input demand models. Section 3 presents the econometric estimation methods, while Section 4 discusses the data. The results are presented, analyzed and discussed in Section 5. Finally, Section 6 concludes.

2. Overview of the link between climate and agriculture in Cameroon

Cameroon is located in Central Africa and stretches from the Gulf of Guinea to Lake Chad. Cameroon has 475 650 km^2 of area with a long coastlines of 402km. The country is bounded on the north region by Chad lake, on the South by Congo, Gabon and Atlantic Ocean, on the east by Chad and Central African Republic and on the west region by Nigeria.
The Sudano-Sahelian zone covers North and Far North with 10 million hectares in which 0.56 million are cultured (IRAD, 2008). Regarding climate, it is characterized by a single mode type of rainfall varying between 400 and 1200 mm per year. The Temperatures vary between 28°C and 45 ° C. Given this climate the main agricultural products are cotton, sorghum, millet, rice, maize, groundnuts and cowpeas.

The Area of high Guinean savannas, for its part, covers entire region of Adamawa, a part of central region namely northern zone of Mbam and an Eastern region zone particularly Lome-et-Djerem. It has 138,000 km^2 of area; this means about 29% of total area of Cameroon. Climate is characterized by average annual rainfall which is around 1500 mm for about 150 days. Because of altitude, temperature on the other hand is moderate between 20 and 26 ° C. These climatic conditions certainly determine the quality of the soil in this area and therefore agricultural products which are primarily produced for human and animal living at the expense of trade activities. Thus, corn is the main crop followed by millet, sorghum, groundnut and yam.

The Highlands of western zone covers western and North West region with 3.1 million hectares of area. Type of climate "camerounien altitude" is structured in two seasons: a dry season from mid-November to mid-March and a rainy season extends from mid-March to mid-November. As for temperatures, they are low in average of 19 ° C and abundant rainfall ranging between 1500 and 2000 mm per year. Thus all kinds of crops (food and export) are practiced namely groundnut, banana, robusta and arabica coffee, cocoa, vegetables, corn and tea.

The Unimodal humid forest zone covers littoral and southwest regions and a coastal edge of the southern region. This zone covers 4.5millions hectares of area in which 282,000 are cultivated. The land includes the volcanic slopes of Mount Cameroon and the original rocky sediments along the coast. Under Cameroonian climate type, very wet and very hot, the rains vary on average between 2500 and 4000mm except Debunscha locality which is considered as one of the rainiest zone in the world. Indeed, in this locality, 11000 mm of rain fall per year according to a monomodal rainfall regime with a long dry season. As for the temperatures, they vary between 22°C and 29 ° C. Food crops for exports such as coffee, cocoa, tea, bananas, palm oil, etc, are also produced in this zone.

The Humid forest zone with a bimodal rainfall. It covers Cameroonian south plateau between 500m and 1500m of altitude, Central and Eastern region. Climate is Guinean, hot and humid, with 25°C of temperatures of and 1500-2000mm/year of rainfall. In this area, there are grown cocoa, robusta coffee, vegetables, various fruit trees, plantains, sugar cane, corn, tobacco and tubers.

3. Litterature review

The literature review focuses on the application of the Ricardian model and stochastic dynamic dual models. The approach used to assess the link between climate and agriculture is Ricardo approach.

3.1. Ricardian approach: review of applied models

The Assessment of impacts of climate change on agriculture began in the 1980s (Da Silva, 2009). Thus, through the Ricardian model, Molua (2002) examines impact of climate change on agricultural land in eleven African countries: Burkina Faso, Cameroon, Egypt, Ethiopia, Ghana, Niger, Senegal, South Africa, Zambia and Zimbabwe . Results of this study show that decline in rainfall and rising temperatures lead to a significant drop in farm net incomes in these countries. Furthermore, results show that farms in arid areas are particularly sensitive to climate. Global warming affects positively farms irrigated because they are in relatively cold regions of Africa. Mariara and Karanja (2006) analyze impact of climate change on agricultural net income of 816 are of Kenyan households. Authors identify three models. The first model takes into account impact of climate variables only, the second includes the hydrologic variables and soil and the third assesses impact of household characteristics. Using variables as net farm income, wage rates, rainfall, temperature and soil moisture indices, results show the effectiveness of impact of climate change on agriculture in this country. Indeed, hydrological variables significantly impact farm net income. On the other hand, even if rainfall has higher elasticity than those of temperatures, marginal effects of the former are smaller than those of the latter.

Kurukulasuriya and Mendelsohn (2008) use Ricardian approach to study impact of climate change on agricultural income of farmers following 9064 randomly selected regions of the eleven African countries. Authors also identify three models. The first takes into account all land under cultivation, the second not only integrates irrigated land and the last one integrates rainfed farms. Results show that effect of climate variables varies by model. Increasing in temperature has a significantly negative effect on net farm income of farmers operating on land depends on rainfall.

By cons, this increasing temperatures positively impacte net agricultural farmers' income of irrigated land. This study shows that irrigated agricultural lands are less vulnerable to climate variability. Furthermore, drylands are more sensitive to climate than irrigated land. Elasticity of temperature in arid land is 1.9, while this value is 0.6 for irrigated land.

Using the same Ricardian approach, Ouedraogo (2012) assesses impact of climate change on net farm income for 1530 Burkinabe farmers. The model includes variables such as climatic, edaphic, hydrological and socio-economic. Results show that there is a nonlinear relationship between net farm income and climate variables such as temperature and precipitations. Thus, marginal impact of temperature on net farm income is US $ -19.9 per hectare while marginal impact of precipitations on the same variable is US $ 2.7 per hectare. This shows that rising temperatures helps to reduce income of farmers while rainfall increases income in Burkina Faso.

From 184 randomly selected villages, consisting of 384 households over 8 regions namely Dioubel, Fatick, Kaolack, Kolda, Louga, Saint Louis, Tambacounda and Thies; Ahmadou (2014) analyzes impact of climate change on agricultural production, kilo-calorie consumption and lean period. Results show that climate change has significant effects that amplify vulnerability of Senegalese farmers. Indeed, rainfall has a positive impact on agricultural production and temperatures both in dry season and rainy season have a negative impact on agricultural production. When fixed effects of villages are taken into account, negative impacts of temperature on production decrease significantly. Moreover, temperatures have a negative effect on consumption of kilo-calories while impact of rainfall on calories consumed depends on whether its term is linear or quadratic. In the first case, impact of rainfall level has a positive impact on the consumption of kilo-calories while in the second case this effect is negative. This rainfall has a negative impact on weld time.

3.2. Stochastic dynamic duality approach: review of applied models

The Adjustment costs of factor demand that arise in response to market shocks have been widely sudied and documented in the litterature. For example, works of Lucas(1967),Caballero(1994), Hammermesh and Pfan(1996), Hall(2004), Lambert and Gong(2010). But, the fact that climate change may cause adjustment costs has received very little attention(Sansi and Schumway, 2014). However, adjusment costs that arise form environmental shock can not be ignored since they are very important in investment, production and factor adjustment process. For instance, decrease in pricpitation raise demand for water which in turn raises the demand for more efficient irrigation systems. To build new irrigation infrastructure takes time and effort, and therefore causes adjsutments costs. Kelly and al.(2005) examines adjustment costs in the context of profit loss in the process when a firm with incomplete knowlegde learns about the distribution of climate change over time. However, authors did not consider the case of quasi-fixed or strictly fixed factors. They assume that all factors of production are fully variable, ignoring the fact that adjustment of inputs cannot be done instantaneously and can make it difficult in short run any change in their amount. Knowledge and information have a very important role in the magnitude of adjustment costs to climate change. Indeed, if the farmer knows or anticipates future climate conditions, induced adjustment costs will be low or zero.

Since the second objectives of this study is to examine how adjustment costs affect input and output response both to price shocks and to stochastic climate change in the cameroonian agricultural sector, we make use of dynamic dual approach which is based on results of McLaren and Cooper (1980) and formalized by Epstein (1981). Application of this model is not recent. First applications are made in the work of Epstein and Denny (1983), Taylor and Monson (1985); and Vasavada and Chambers (1986) in the US agricultural sector. The second one includes the work of

Bernstein and Nadiri (1988), Howard and Shumway (1998) and Agbola (2005). The development of this approach has been made by Pietola and Myers(2000), Krysiak(2006).

Dynamic duality approach consist in transforming intertemporal value function of the firm in term of Hamilton-Jacobi-Bellman equation. This equation represents the present or discounted value of profits (or costs). The problem is therefore to maximize or minimize depending on whether we have profits or costs function. Solution obtained by hotelling lemma, is a dynamic equations describing optimal path of investment demand of quasi-fixed inputs and supply of the firm.

Pietola and Myers (1998) use dynamic duality approach under uncertainty in order to develop and assess on Finnish pork industry data, a generalized model of firm investment. In this study, effects of uncertainty on investment are estimated by making use of dummy variables. Results show that the greater the uncertainty on the prices of machinery and equipment increases, the less investment is important in this sector. Furthermore, employment decision is not sensitive to increased uncertainty. Sansi and Shumway (2014) derive and estimate a stochastic dynamic duality in order to examine adjustment structure of two types of output and three categories of inputs in the US agricultural sector under climate uncertainty. Results of this study show that, given uncertainty induced by changes in market prices and climate change, farmers gradually adjusting the two types of output and three inputs considered. For instance, crops adjust mostly toward equilibrium levels and capital adjusts most slowly.

4. Econometric Estimation Methods

According to Guerrien and Vergara (1985), the first task of econometrics is to put empirical *pulpits* around the theoretical framework. In this case, the theoretical model and their functional form have to be specified. In this section, we first specify the functional form of the the ricardian model and the firm value function as well as econometric form of input demand equations. Then hypothesis tests are performed as well as the estimation of the derived models.

4.1. Functional form of the ricardian model.

The formulation of the Ricardian model is obtained as follows:

$$RA = \beta_0 + \beta_1 C + \beta_2 C^2 + \beta_3 S + \beta_4 E + \beta_5 SA + \beta_6 TM + \delta_1 M + \delta_2 IR + \delta_3 ER + \varepsilon \quad . \qquad (1)$$

C et C^2 represent the linear and quadratic terms of climate variable. We introduce the nonlinear term in order into account for the nonlinear effect of the relationship between net income and Climate (Ouedraogo, 2012). S represents the soil variable , M market access, E is the flow of water, SA is agricultural land, TM is the household size, IR irrigation and ε error term. The irrigation and market access are dummy variables whose parameters are equal to one if the individual has used this practice and 0 otherwise.

Introduction of variables such as agricultural area, household size and irrigation allows to take into account the adjustments made directly by farmers and their effects on their income.

4.2. Theoretical Model and functional form of firm value

We build an intertemporal optimization problem in order to model the adjustment path of the inputs and outputs almost fixed in time. We assume that the firm purchases its inputs in a competitive market and its expectations on climate and market prices are rational. This means that farmers hardly make forecasting errors. In addition, investment and production decisions of farmers take into account the uncertainty induced by climate change following a stochastic process. To account for this uncertainty, we introduce the climatic elements such as temperature and precipitation in the production function of the farmer. In each period, the farmer's decisions depend on their expectations on climate and market prices.

Farmers use variable factors and quasi-fixed factors. They know current prices of all inputs and outputs, but they only formulate expectations about future developments of these prices and climate conditions. However, farmers must decide on production levels to be attained, the amount of inputs to be used and the level of investment in quasi- fixed factors to be achieve without ignoring adjustment costs.

We assume also that at each base period and for a price given by the market, agricultural firm determines its optimal policy by maximizing the present value of its expected future profits. Furthermore, we assume that this firm does not face the constraint opportunities when developing its production program. Since the choice of the stock of quasi-fixed factors today affects the adjustment costs of the future, the problem becomes dynamic. Therefore, the firm must solve the problem according infinite horizon:

$$J(K_0,p_0,w_0,r,C_0)=\max_{L\geq 0,I\geq 0,C\geq 0}\int_0^{\infty} e^{-rT}(1-\tau)\left[F(L,K,I,C)-{}^{t}wL-{}^{t}pK\right]dt \quad (3).$$

s/c

$$\dot{K}=I-\delta K \quad (4)$$

$$\dot{C}=\delta(C)+\rho\varepsilon \quad (5)$$

$$K_i(0)=K_0\geq 0, C(0)=C_0, (K,p,w)\in\Theta, \forall t\in\left[0;\infty\right[$$

$K_i(0)$ is a vector of quasi- fixed factors held by firm i at the initial period $t_0=0$

$\dot{K}_i(t)$ net investment in quasi-fixed factors, $w\in\Omega^2$ et $p\in\Omega^2$ are respectively vector prices of variable factors and quasi-fixed factors. C is climate vector that consists of temperature and precipitation indices. Its evolves stochastically and exogenously following Brownian motion with drift which is characterized by the transition equation (5). $\delta(C)$ denotes a non-random vector of drift parameters ; ρ is a vector with $\rho^t\rho=\sum$, ε is identically and independently distributed(iid) normal vector with , $E(\varepsilon)=0, \mathrm{var}(\varepsilon)=dT, E(\varepsilon_i\varepsilon_j)=0$, $i\neq j$. Θ open bounded set and domain definition of value function J, $r\geq 0$ is discount rate. It is equal to 5.5%.

Solution of the problem (2) is done by using dynamic programming, third approach of dynamic optimization problems. This approach, developed by Bellman (1957), has been successful in its application to problems in discrete and continuous time.

To derive demand functions of investment and employment, we use the dynamic duality approach. This method was initiated and developed for the first time in the theoretical work of Epstein (1981). This new duality provides a broad class of functional forms of application of inputs, which can be tested and applied to the theory of adjustment costs. The primal problem in our approach is the Hamilton-Jacobi-Bellman equation and the dual is the inverse of this equation:

$$rJ(T,K)=\max_{I}\begin{bmatrix} g(T_0,K_0,I)+{}^t wL+{}^t pK+J_K(T_0,K_0)\dot{K} \\ +J_C\delta(C)+0,5vec(J_{CC})^t vec(\Sigma) \end{bmatrix} \tag{6}$$

The above is Hamilthon -Jacobi -Bellman equation and is the primal problem. It is established as a necessary condition of equilibrium of a dynamic optimization program with a continuous time under constraint[1]. Indeed, Hamilton -Jacobi equation is a necessary and sufficient condition to maintain firm value at its maximum level in each period. It also allows transforming dynamic problem (3) in an easily handled form. This equation is a static form of the problem (3) and implies that firm value can be defined as the sum of the maximum current profit and the present value of marginal benefit resulting from the optimal adjustment in net investment. According to Epstein (1981, op.cit), firm's technology function can be determined and represents optimal behaviour firm supply as follows:

$$F(L,K,I)=\min_{(p,w)\in\Theta}\begin{bmatrix} rJ(K_0,p_0,w_0,r,C_0,T_0)+{}^t wL+{}^t pK \\ -J_K(K,p,w)(I-\delta K)- \\ J_C\delta(C)+0,5vec(J_{CC})^t vec(\Sigma) \end{bmatrix} \tag{7}$$

$$\left(L,K,I,C\right)\in\Phi$$

[1] Hamilton -Jacobi – Bellman equation is different from the Euler equation, also called Euler-Lagrange equation. This equation is the necessary condition of equilibrium in a dynamic optimization program in continuous time without constraint.

Suppose that J is a diffeomorphisme. That means this function is bijective, différentiable on Θ an its inverse on Φ, for all (K_0, p, w, C_0).

According to envelope theorem which consist of differentiating the above equation with respect to prices w and p, and rearranging, we obtain the following system equation which represent dynamic quasi-fixed inputs and output; and variable inputs.

$$\dot{K}^* = {}^tJ^{-1}_{Kw}(r^tJ_p + K) - J_C\delta(C) + 0{,}5vec(J_{CC})^t vec(\Sigma) \tag{8}$$

$$L^* = -rJ_w + {}^tJ_{Kw}\dot{K} - J_C\delta(C) + 0{,}5vec(J_{CC})^t vec(\Sigma) \tag{9}$$

The first equation describes the dynamics of quasi- fixed factors. While the second equation expresses the optimal path of variable factors.

According to Vasavada and Chambers(1982), and Sansi(2014), functional form for the Hamilton-Jacobi-Bellman equation form of value function that allows for linear homogeneity in prices and concavity in quasi-fixed inputs is a modified generalized Leontief:

$$J(K_0, p_0, w_0, r, C_0, T_0) = \left[pw\right]AK + {}^tpB^{-1}K + \left[{}^tp\,{}^tw\right]HC + \left[{}^tp\,{}^tw\right]Ivec(C^tC) + \left[{}^tp^{1/2}\,{}^tw^{1/2}\right]C\begin{bmatrix} p^{1/2} \\ w^{1/2} \end{bmatrix} + \left[{}^tp\,{}^tw\right]DY \tag{10}$$

This function allows taking into account the quasi- fixity of inputs and output. Then the specified form of equation (8) is:

$$\dot{K}^* = (rI - A)K + AH(rC - \delta(C)) + AI(rvec(C^tC) - vec_C(C^tC)\delta(C) - 0{,}5vec(\Sigma)) + rA\left[diag(K^{1/2})\right]MK^{1/2} \tag{11}$$

Approximating $\dot{K}$ discretly as $\dot{K} = K_t - K_{t-1}$, we have the final functional form of equation (10) as:

$$K_{iT} = (I + M_a)K_{it-1} + AH(rC - \delta(C)) + AI(rvec(C^tC - vec_C(C^tC)\delta(C) - 0{,}5vec(\Sigma)) + rA\left[diag(K^{1/2})\right]MK^{1/2} \tag{12}$$

Econometric specification of demand equations is then done by adding error terms for each one of the system equation. The error term measures the difference between actual observed values of the dependent variable and the values that should have been observed if the functional relationship was strictly accurate. Specification of equations (12) is then made by adding the error terms for each of the system equations. These terms reflect also errors and optimization technology shocks

Consequently, system of quasi-fixed factors demand can be written in the following form:

$$\begin{aligned} K_{iT} &= (I + M_a)K_{it-1} + AH(rC - \delta(C)) \\ &+ AI(rvec(C^tC - vec_C(C^tC)\delta(C) - 0{,}5vec(\Sigma)) \\ &+ rA\left[diag(K^{1/2})\right]MK^{1/2} + \varepsilon_{iT} \end{aligned} \quad (13)$$

5 . Sources and data definition

In this framework, data definition consist to neutralize price effect in the variables, and to normalize factors with respect to output price.

5.1. Data sources and identification of agricultural production units

The data used in this study come from Food and Agricultural Organisation (FAOSurveys and Agricultural Statistics Division (SASD) of Cameroon Ministry of Agriculture and Rural Development (MINADER) and the Cameroon National Institute of Statistics (NIS). Climate data including temperature and precipitation indices are collected from observation posts régionaless of the ten regions of Cameroon namely Abong-mbang, Ambam, Batouri, Ebolowa, Garoua, Lobe, Maroua, Menoua, Nkambe, Ngaoundere, Nkolbisson, Nkongsamba, Tibati and Yagooua. This is data were completed by those of World Bank (2015) and especially Climate Change Knowledge Portal. Moreover, since investment is intermittent at the firm level, we use data aggregated at the national agricultural sector. This aggregation of data is justified by the fact that the model we have derivative is a convex adjustment model. This aggregation can also be justified by reasons statistic: achieve significant results.

To assess the impact of climate change on agricultural income, we estimate Ricardo model on a sample of 2132 households identified in the Cameroonian Survey on households or *Enquête camerounaise auprès des ménages*(ECAM3, 2007), available at the National Institute of Statistics (NIS). It is important to recall that NIS is undertaking the fourth Cameroonian survey on household

(ECAM 4), but results of this survey are not yet available. So, we then use data on agricultural household provided by ECAM 3. It should also be important to note that ECAM 3 was carried out in six of the ten existing regions namely Centre, Littoral, Far North, West, Southwest and Northwest region. The reason is that in these areas, most of households practice agriculture. Then, to analyze the dynamics of adjustment of inputs and outputs, we make use of data aggregated at national level provided by FAO for the period 1961-2013 STAT.

5.2. Data Definition

Variables used in this study are defined as follows:

a- The Physical capital stock which includes machinery, equipment and land.

b- The Labour. It is used taking into account degree of qualification of workers. Thus, this factor contains two categories, namely the number of workers (family labour) and the number of qualified employees. The first category perfectly fit into the variable factors, while the latter category is stored in the so-called *quasi-fixed* factors.

c- The total value of the energy. For energy, we mean fuel, electricity and water. The value is obtained by aggregating data in order to obtain the level of annual energy consumption in the agricultural sector.

d- The total value of inputs: fertilizer

The price of workforce or hourly rate of pay is relative to the number of hours worked on average

f- Price of capital.

g – The Farm net income. It is the difference between production and associated production costs (seed costs, inputs, pesticides, storage, equipment and agricultural equipment, etc.)

h-The Temperatures and annual precipitation. They are computed as the sum of monthly precipitation and temperatures. Moreover, since according to the Intergovernmental Panel on Climate Change (2007) observed changes in temperature and rainfall at the regional level are often correlated. To take into account this correlation, we use a VAR model. Im-Pesaran-Shin test (IPS) shows that the VAR model (2) better explains this temporal correlation.

We also added two dummy variables including irrigation and measures against erosion. These two variables are useful in estimating Ricardo model because they allow to capture adaptation measures undertaken by farmers under climate change. Irrigation permits to see what is the effect of the measures taken during the drought. while the second variable informs about effect of adaptation measure during rainy periods.

6. Presentation and analysis of results

The Results in this section relate to the estimation of the Ricardian model and interdependence and quasi-fixity hypothesis tests. Ricardian model informs about climate impacts on incomes of farm households. While interdependence and quasi-fixity tests inform about dynamics of production adjustment and quasi-fixed inputs to their respective optimum levels. Regression is done in two stages. In a first step, we introduce socioeconomic and climatic variables except irrigation and measures against erosion in Model 1 called model without adaptation. In the second step, especially in model with adaptation we introduce practice of irrigation and measures against erosion (both dichotomous variables) in order to assess impact of these adaptive measures on incomes of farm households. Parameters are estimated by ordinary least squares method (LSQ). Results obtained are shown in **Table 1** below.

6.1. Estimation results of Ricardian model

Table1 – Estimation results of the ricardian models

Variables	Modèle 1		Modèle 2	
	Coef.	t	Coef.	t
Climatic variables				
Temperature	-710.340**	6.08	-615.10*	4.96
Temperature squared	-10.022**	-3.15	-14.52**	-7.46
Precipitation	16.543***	6.72	17.83*	3.86
Precipitation squared	-0.893***	-7.25	-0.644**	-10.01
Socio-economic variables				
Area of holding	-7.201*	-3.44	-10.30**	-5.00
.log (Household	-8.343	-3.23	-3.56**	-2.89
size)	99.802*	5.75	78.72***	8.05
Irrigation (1/0)	41.71**	10.42	43.08**	16.32
Erosion	-41.305*	-8.230	-43.111**	-4.89
Use of hired work	-4012	-2.02	-3912	-5.32
(1/0) Constante				
Number of observations	2132		2132	
F	10.53		12.53	
R^2	0.3982		0.4256	

* Significatif au seuil de 10%; ** Significatif au seuil de 5%; *** Significatif au seuil de 1%.
Source: By us from ECAM 3, FAOSTAT and world bank data with STATA 12 software.

The explanatory power of the two models is excellent, according to values of correlation ratio. Correlation ratio for the first model indicates that farm income fluctuations are explained at 39.82 % by different climatic and socioeconomic variables while this ratio is 42.56% for the second model. This implies that quality of equation adjustment to dependant variable is also good. Fisher-Snedecor test shows, moreover, that the two models are globally significant. As for Student test, it shows that quadratic terms of temperature and precipitation are significant at 5% level and 1% respectively. Consequently relationship between climate and farm income is nonlinear.

The Signs of parameters relating to socio-economic characteristics are those theoretically expected except agricultural area. Indeed, we found that soil quality, market access, practice of irrigation and household size positively affects net farm income. This means that the more quality of soil is good and farmers have market access, the more net farm household income is high. The Positive influence of irrigation on farm net income is explained by the fact, during dry season, irrigation allows farmers to adapt their activity to climate variations. Practice of irrigation is an important need in Central Africa in general and Cameroon in particular since country's agriculture is mainly rain-fed agriculture.

For cons, effect of agricultural area on net income is negative. This can be explained by practice of extensive farming by in order to compensate low productivity of agricultural land. In the short run, this practice increases agricultural production without improving productivity of agricultural land. In the long run, this practice lowers crop yields due to insufficient resources to maintain activity on these large areas. As Ouedraogo (2012), we assessed sensitivity of farm incomes with respect to climatic variables. Thus, **Table 2** shows that an increasing of 1% in temperature leads to higher farm revenues by 32.4 % while an increasing of 1% in precipitation leads to lower farm revenues by 12.9 %.

Table 2: Elasticity of farm incomes.

	Elasticity	**R^2**	**F-statistic**	**t-statistic**	**DW**
Temperature	0.324	0.68	631.23	3.99	2.01
Precipitations	-0.129	0.56	57.59	13.03	1.55

Source : By us from MINAGRI, ECAM 3 and FAOSTAT data

Table 3: Marginal effect of climate variables on farm incomes.

	Marginal effect	**R^2**	**F-statistic**	**t-statistic**	**DW**
Temperature	-2200.2	0.68	631.23	1.99	2.01
precipitations	2322	0 .56	57.59	13.03	1.55

Source: By us from MINAGRI, ECAM 3 and FAOSTAT data

Looking at the marginal effects of climate change on agricultural income, Table 3 shows that increasing 1mm rainfall leads to an increase in net farm income of 2322 FCFA per hectare. While an increase of 1°C leads to decrease of 2200.20 FCFA per hectare.

6.2. Results on Dynamics of adjustments under uncertainty.

In this sub- section, we present and analyze results on dynamic adjustment of inputs and agricultural production in Cameroonian agricultural sector based on the coefficients of adjustment matrix $M_a = rI_4 - A$. Estimation results relate to 67 parameters in **Table 5** in appendix.

This second part of our study is to examine dynamics of adjustment in the agricultural sector in Cameroon. This objective is achieved performing quasi-fixity and interdependence tests. The first test is performed on agricultural production, labour, fertilizer and productive capital (approximated by machinery and equipment). The second test concerns independence of adjustments between these variables. In this study, these tests are used to assess if there is relationship between two variables, even when those variables are qualitative. It is whether, at the agricultural firm level, production adjustment affects inputs adjustment and vis-versa. Independence test, for example allows controlling of interdependence between production adjustment and amount of used quasi-fixed inputs on one hand; and interdependence between quasi-fixed inputs on the other hand. According to Monson and Taylor (1985), independent adjustment rate means that each quasi-fixed input adjusts to their long-run equilibrium level regardless of the other quasi-fixed inputs. According to Howard and Shumway (1988), independence reflects the fact that in the adjustment matrix, crossed adjustment coefficients are equal to zero.

$a_{ij} = a_{ji} = 0$, avec $i \neq j$. So, a quasi- fixed variable is adjusted to long-run equilibrium level independently of each other. For example, at a certain period, firm can hire new workers without needing to vary level of physical capital (amount of equipment and machinery) or it may decide to vary level of physical capital without needing to hire new workers.Null hypothesis is the lack of interdependence and therefore independence between adjustments. According to Warjiyo and Huffman (1995), univariate partial adjustment model is then appropriate to estimate adjustment coefficients. Consequently, change in relative price of input has no effect, even indirectly on the amount of other input. Alternative hypothesis reflects interdependence between adjustments of the various quasi-fixed factors: level change in amount of an input requires change in the amount of other input and vice-versa. In this case, flexible accelerator multivariate adjustment pattern appears to be a better representation of adjustment behaviour of quasi-fixed inputs by agricultural firms, instead of univariate partial adjustment model. The following table gives results of chi-square independence test.

Instantaneity implies that in the adjustment matrix, the own and crossed adjustment coefficients are equal to 1 and 0 respectively:

$\begin{cases} a_{ii}=1 \\ a_{ij}=a_{ji}=0 \end{cases}$. These restrictions reflect the fact that production and quasi- fixed inputs adjust instantaneously to their optimum level of long-run and are considered to be variable inputs in short and long-run. Therefore, the current amount of inputs $K(t)$ is always at the desired level or long-term equilibrium $\overline{K}$, variation in the amount of inputs $\dot{K}(t)$ is zero for all t and the adjustment matrix is an identity matrix of order 4. In this case, any adjustment of production, fertilizer, capital, labour is done smoothly and without costs. In other words, agricultural firm adjusts these variables in one period.

Quasi-fixity test is performed as follows:

$\begin{cases} H_0 : a_{ii} = 1, a_{ij} = 0 \\ H_1 : a_{ii} \prec 1, a_{ij} \neq 0 \end{cases}$. a_{ij} et a_{ji} are different from zero.

Null hypothesis reflects the fact that adjustments are instantaneous. Hence, firms adjust immediately and without costs in one period their level of output and production capacity to their optimum level. Thus, in the absence of adjustment costs, firms, facing change in relative prices adjust their output and theirs inputs freely without suffering production or revenue losses. As for alternative hypothesis, it represents the fact that changes in levels of quasi- fixed inputs are progressive: adjustment of amount of quasi-fixed inputs to their optimal level is done in several periods. Therefore, inputs are gradually adjusted to their l long run equilibrium level. In adjustment matrix, crossed and own adjustment coefficients are not only equal to zero but also strictly less than unity. They are then, in the short run , modeled as quasi-fixed inputs.
The Results of quasi- fixity test are shown in the following table:

Table 4. Tests of interdependence and instantaneity.

Hypothesis Tested	**Wald Test**	***df***	***p*-value**
Independent and instantaneous adjustment	32876.29	18	0.0000
Independent adjustment	112.03	14	0.0000
Quasi- fixity	301.10	18	0.0000
Independent and instantaneous adjustment *for*			
Crops	37.25	5	0.0000
Capital	967.39	5	0.0021
Labour	16.54	5	0.0301
Fertilizer	22.20	5	0.0100

Source: By us from MINAGRI, ECAM 3 and FAOSTAT data and with SAS software

The Wald test we use is particularly interesting in the sense that it is possible to perform simultaneously interdependence test and instantaneous adjustments test. So, according to the results, assumptions of independence and instantaneous adjustments are rejected since adjustment matrix M_a is different from unit matrix I_4. This confirms existence of adjustment costs in the process of adaptation and resilience to climate change and in market prices changes by farmers. Furthermore, independent adjustment test shows that production adjustment leads in capital adjustment, labour and fertilizer and vis-versa. Indeed, in Cameroon, farm households practise extensive agriculture in order to increase agricultural production affected by climate change. This practice also requires an increase in production capacity in terms of capital, labour and fertilizer. The results show that these adjustments to climate change and to changes in market prices do not happen instantly. Thus, at 10% level, quasi-fixity hypothesis is accepted for production, capital, fertilizer and labour. The fact that agricultural production is gradually adjusted can be explained by the limited adaptability of plant species. Capital which includes machinery, equipment and land, may be less flexible during certain periods (Sansi and Schumway, 2014). Since fertilizers are purchased, amount and also calendar of use are adjusted gradually. Results in the above table also show that workforce which includes paid self-employment and labour, do adjusts instantly.

The Adjustment matrix which provides information about speed of adjustment of quasi-fixed variables shows that all coefficients of this matrix are significantly different from -1 at 5% level for production, labour, and fertilizer and at 10 % for capital. This implies that in the short run and under climate change and market prices changes, production, capital, labour and fertilizer are actually quasi-fixed variables and their adjustment is not made in an annual period, but in several years. Own adjustment rate of production -0.4 implies that harvests adjust at 40% to their desired level every year in response to price shocks and climate change. While capital adjustment rate -0.0104 implies that this input is adjusted at 1.04% towards its equilibrium level in a year. In addition, labour adjustment rate -0.6666 means that workforce is adjusted at 66.66% annually. Finally, adjustment rate of fertilizers -0.9834 reflects the fact that this variable is set at 98.34% annually. It can be said that under climate change and prices shocks, Cameroonian farm households take about two and a half to adjust production at its optimum level (or desired level), about 24 years to fully adjust capital, one and a half to adjust workforce and about nine months to adjust fertilizers, each of them at their optimum level. These results show that in the Cameroonian agricultural sector, farmers are renewing more slowly their level of capital which includes machinery, equipment and agricultural land.

7. Conclusion

The first objective of this study is to understand and quantify the link between climate and agriculture in Cameroon. The second one is to examine how expectations of farmers on climate change affect investment and production decisions and inputs adjustment process. The first objective is achieved by applying two Ricardian models namely model **without adaptation** and **model with adaptation**. In the model without adaptation, irrigation and measures against erosion are not taken into account while in the model with adaptation, these measures are introduced in order to capture theirs effects on farm incomes. We found that soil quality, market access, irrigation and household size positively affect net farm income. This means that the higher the quality of soil is good, farmers have access to markets, the more the farm incomes are improved. With regard to irrigation, it permits to adapt to climate change, especially during dry seasons, since Cameroon's agriculture is mainly rain-fed agriculture. We also found that effect of agricultural area on farm income is negative. Then, estimates show that income of farm households are significantly sensitive to climate variations. Thus, a 1% increase in temperature leads to higher farm revenues by 32.4% while a 1% increase in rainfall causes a drop in farm income by 12.9%. As for climate marginal effects on incomes of farm households, we found that an increase in 1mm of rainfall led to an increase in net farm income per hectare of FCFA 2322. While an increase in 1°C of temperature leads to a decrease of FCFA 2200.20 per hectare. Finally, estimates of dynamic stochastic model show that, under uncertainty induced by climate change and in market prices changes, farmers gradually adjust production and inputs. These dynamic adjustments are justified by adaptation costs of measures implemented by farmers under uncertainty. Thus, in this uncertain environment, farmers take about two and a half years to fully adjust desired level of their crops, about 24 years to adjust capital to its desired level, one and a half to adjust work and about nine months to adjust fertilizer.

However, beyond all these results, although model allows to highlight adjustment costs induced by climate change and market prices change, it does not allow decomposition of these two effects. So in this study, changes in climate and relative price occur simultaneously.

This study contributes more to the validity of dynamic inputs demand models derived from dynamic duality approach in an uncertain environment, developed by Pietola and Myers (2000) and Krysiak (2006). In the same vein, this study shows that it is possible to model supply and demand for several quasi-fixed inputs and outputs through transformation of the value function of the firm in Hamilton-Jacobi-Bellman equations. Looking at the political contributions, interest of understanding and anticipating impacts of climate change on agriculture is very important for policy makers. It permits to implement appropriate measures to mitigate the socio-economic consequences.

Appendix

Table 5. Nonlinear Three-Stage Least squares Parameters Estimates Of Simultanous Equations

Parameter	Estimate	Standard Error	Parameter	Estimate	Standard Error
A_{11}	0.4501**	0.0272	I_{21}	0.0437**	0.0187
A_{12}	-0.1227**	0.0106	I_{22}	0.0543	0.0543
A_{13}	0.1039	0.0145	I_{24}	0.0741	0.0184
A_{14}	0.0210	0.0023	I_{31}	-0.0703	0.0349
A_{15}	-0.0027	0.0302	I_{32}	0.0267	0.0970
A_{21}	-0.6206**	0.4320	I_{34}	-0.0107	0.0111
A_{22}	0.1540*	0.1045	I_{41}	-0.0750**	0.0674
A_{23}	-0.0421	0.0376	I_{42}	-0.0201	0.0367
A_{24}	-0.0754	0.0603	I_{44}	-0.0704	0.0723
A_{25}	0.0661	0.2331	I_{51}	-0.0278	0.0403
A_{31}	0.1377*	0.0457	I_{52}	-0.0618	0.0823
A_{32}	-0.1834*	0.0324	I_{54}	-0.0343	0.0112
A_{33}	0.7166**	0.0765	C_{11}	12.1465	4.3572
A_{34}	-0.0102	0.0207	C_{12}	22.4390*	10.6563
A_{35}	-0.0732**	0.0750	C_{13}	-7.2126	11.4378
A_{41}	-0.0698	0.4509	C_{14}	-4.9347	5.1212
A_{42}	0.0310	0.3590	C_{15}	-9.2012	12.6717
A_{43}	-0.1048	0.0453	C_{22}	8.6077	8.2345
A_{44}	1.0331**	0.2370	C_{23}	-10.5123	19.1717
A_{45}	-0.4785	0.6432	C_{24}	-12.9453	7.0783
A_{51}	0.7534	0.4374	C_{25}	-17.0703*	9.9375
A_{52}	0.7903	0.4950	C_{33}	29.6520*	12.1362
A_{53}	-0.6209	0.2761	C_{34}	-8.2045	10.0028
A_{54}	0.0230	0.0532	C_{35}	-20.2304	13.2436
A_{55}	1.4351**	0.6732	C_{44}	11.3733	5.1056
H_{11}	0.0375	0.0657	C_{45}	6.7610	4.1273
H_{12}	0.1560	0.0439	C_{55}	42.4420**	31.4020
H_{21}	0.0645	0.2255			
H_{22}	0.0101	0.0448			
H_{31}	0.2014	0.2370			
H_{32}	-0.1769	0.0378			
H_{41}	0.1967	0.0265			
H_{42}	0.1345	0.0426			
H_{51}	-0.0532	0.4572			
H_{52}	-0.0730	0.0978			
I_{11}	0.0457	0.0157			
I_{12}	0.0579	0.0574			
I_{14}	0.0627	0.1122			

Sources : *By us form FAO STAT,MINAGRI 1961-2013 period, with SAS software.*

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FACTORS INFLUENCING CLIMATE CHANGE AWARENESS: THE CASE STUDY OF SMALL-SCALE MAIZE FARMERS IN MPUMALANGA PROVINCE OF SOUTH AFRICA.

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ABSTRACT

Climate change is possibly the greatest environmental challenge facing the world this century. The impact of climate change is a reality and it cuts across all climate - sensitive sectors including the Agriculture sector. It well documented by several scientists, Intergovernmental Panel on Climate Change and other experts that climate change threatens sustainable economic development and the totality of human existence. This study was conducted in Nkangala District, Mpumalanga province. Mpumalanga province remains the largest production region for forestry and the majority of the people living in Mpumalanga are farmers and they have contributed immensely to promote food security. However, due to the impacts and threaten by climate variability and change which resulted into shortage of food production and changes in the rainfall pattern. It was noted that there is a need for climate change awareness across the agriculture sector including farmers. Random sampling technique was used to select two hundred and fifty one farmers to be interviewed. The questionnaire was administrated to farmers and included matters relating to climate change awareness and agronomic practices including maize production. Data was captured and analysed using software package for social science (SPSS version 20). Descriptive analysis was used to describe data and Multivariate regression analysis was conducted to demonstrate the relationship and association of variables. It was noted that the majority of farmers in this province need capacity building and also climate change awareness initiatives which would assist these farmers to build the adaptive capacity, increase resilience and reduce vulnerability.

Keywords: Climate Change awareness, Nkangala District Mpumalanga Province South Africa, Small Scale maize farmers.

1. Introduction

According to (Hughton, D. 2002) climate change is possibly the greatest environmental challenge facing the world today. The impact of climate change varies globally; however, the problem and the challenges of climate change are becoming more threatening to sustainable economic development and the totality of human existence (Adejuwon, S.A, 2004). Small-scale farmers suffer the most because of their dependence on rain-fed agriculture, limited financial capacity, low adaptive capacity, high dependence on natural resources, inability to detect the occurrence of extreme hydrological and meteorological events due to low technology adoption, limited infrastructure, illiteracy, lack of skills, level of awareness and lack of capacity to diversify (Kurukulasuriya, P. and R. Mendelssohn, 2006a). Maize constitutes about 70 percent of grain production and covers about 60 percent of the cropping area in South Africa. It is a summer crop, mostly grown in semi - arid regions of the country, and is highly susceptible to changes in precipitation and temperature [Durand, W. 2006 & Benhin, J.K.A, 2006). In addition, maize is the main staple food in Southern Africa, and maize production in the country constitutes about 50 percent of the output within the Southern African Development Community (SADC) region (Durand, W. 2006). Consequently, maize is one of the key drivers of food inflation in South Africa BFAP (Bureau for Food and Agricultural Policy, 2007). A considerable number of studies have been done to investigate the impact of climate change on yields of grain crops such as maize under controlled experiments (Du Toit *et al;* 2002 & Durand, W. 2006). There is very little awareness on climate change in the developing countries (IPCC, 1996: Climate Change 1995). The overall objective of the paper is (i) to create awareness through which farmers can understand the impact and the threats that climate change pose within the agriculture sector. (ii) Build adaptive capacity and reduce vulnerability facing small scale farmers in Mpumalanga Province. This will enable small scale maize farmers in Mpumalanga province to have basic understanding about the impact of climate change in their areas.

2. Materials and Methods

This paper used quantitative design as a well detailed structured questionnaire written in English language as part of the data collection methods. The questionnaires consist of a logical flow of closed ended questions which address issues related to climate change, agricultural production, yields etc. Data was collected through face to face interviews with the farmers and also the help of the extension officer where 251 questionnaires were administered in the study area. The study was conducted in Emakhazeni local municipality within the Nkangala district municipality in the Mpumalanga province of South Africa. Stratified sampling technique was used to select two hundred and fifty one farmers to be interviewed. Data was captured and analysed using software package for social science (SPSS version 20). Descriptive analysis was used to describe data and Univariate regression analysis was conducted to demonstrate the relationship and association of variables. The following econometric model was used to determine association of variables:

Wi = _ + _Xi + _i (1)

Wi is the dependent variable value for person i (2)

Xi is the independent variable value for person i (3)

_ and _ are parameter values (4)

_i is the random error term (5)

The parameter _ is called the intercept or the value of W when X = 0 (6)

The parameter _ is called the slope or the change in W when X increases by one (7)

3. Results and Discussion

As shown in Table 1, there is association among the following variables: gender, age, occupation, education, source of income, information on climate change, extension service, importance of information on climate and quantity of harvest. This is supported by the fact that their estimate values are more than 1 at 95% confidence interval.

Gender (Female) had significant impact on the level of climate change awareness. According to Table 1, the odds of climate change awareness are 1.00 percent higher for female households than male households. It is widely recognised that climate change does not affect people equally (UNEP, 2011). It was reported that women and men perceive and experience climate change in diverse ways because of their distinct socially constructed gender roles, responsibilities, status and identities, which result in varied coping strategies and responses (Luseno *et al;* 2003 & , FAO, 2010). The situation observed in Mpumalanga province is not different from a research conducted in Limpopo province by (Maponya, P. and S. Mpandeli, 2012) that women play a vital role in supporting households and communities, thus, they are more aware and adapt to climate change through experience gained in agricultural production and the fact that the majority of these women spend most of their time in the field ploughing, removing weeds, monitoring the crops, harvesting etc. Often, women are more vulnerable to climate change than men.

Age is another significant variable which is associated to climate change awareness. According to Table 1 the odds of climate change awareness are 1.00 percent higher across all age categories. This is not surprising because climate change awareness is made across all age categories even in the schools and out of the school through the use of fliers, posters and many medium. According to (Bayard *et al;* 2005) age is positively related to some climate change adaptation measures that are related to agricultural activities. According to (Okoye, 1998) found that age is positively related to the awareness and adoption of conservation measures. The result of this research agrees with the findings of (Yusuf, 2005) that most farmers are within their active years and can make positive contribution to agricultural production, thus farmers' age had a significant impact on the awareness of climate change.

According to Table 1 the odds of climate change awareness are 1.10 percent higher across all occupations. The study shows that occupations of the respondents have significant impact on the level of climate change awareness. This could be from the fact that some farmers take farming as a full time and some farmers take farming as part time activity but in each case, they all come across awareness either through indigenous knowledge or at their various place of work through adverts. According to (Adebayo Tukur, 2003) occupation has a significant association with awareness of climate change. The more they carry out farming activities, the more the awareness and adoption to climate change.

According to Table 1 the odds of climate change awareness are 1.01 percent higher across all educational levels. Many research studies have shown that education increases ones's ability to receive, decode, and understand information relevant to perception and making innovative decisions (Wozniak, 1984). However, the result from the study area showed that education increases the probability of the level of climate change awareness. According to (Noor, 1981) and (Omolola,

2005) are of the view that education facilitates farmers' understanding and use of improved crop technologies. According to (Anley & Haile-Gabrile, 2007) improving education and employment is the key to stimulate local participation in various adaptation measures and natural resource management initiatives.

According to Table 1 the odds of climate change awareness are 1.00 percent higher across for households who rely on maize as source of income than households who don't rely on maize as source of income. From the study, farmers who rely on maize as a source of income have no other job or extra source of income, than farming activities, thus, they are involve and concern about their environment in relation to their faming activities because they need to provide for the household thereby tends to be more aware of the climate change as an environmental factor responsible for production, unlike farmers who have other source of income apart from farming.

According to Table 1 the odds of climate change awareness are 1.53 percent for households with climate change information. This shows that climate change information is significantly associated with awareness level of climate change. This is not surprising because a study reported by (Luseno *et al;* 2003) said the more the farmers had access to extension services and information about climate change, the more they adapt to climate change. From this study, the amount on climate change information at farmers' disposal determines the level of awareness of climate change. According to (Pender *et al;* 2004), it is hypothesized that farmers who have significant extension contacts have better chances to be aware of changing climatic conditions and as well as adaptation measures in response to climatic changes.

Access to extension services is another significant variable which is associated to climate change awareness. According to Table 1 the odds of climate change awareness are 1.50 percent for households with access to extension services. The study shows that access to extension services significantly affects awareness to climate change. Extension services provide an important source of information on climate change as well as agricultural production and management practices. Farmers who have significant extension contacts have better chances to be aware of changing climatic conditions and also of the various management practices that they can use to adapt to changes in climatic conditions. The role of extension service is to provide information to extension clients in order to allow them to use available resources by increasing technological options and organizational skills that in turn allow them to take greater advantage of production and market opportunities (GoK, Government of the Republic of Kenya 2001). According to (Nhemachena, 2008, & Apata *et al;* 2009 & Deressa *et al;* 2009 & Bryan *et al;* 2009) they have indicated that access to extension services had a strong positive influence on adapting to climate change and awareness.

According to Table 1 the odds of climate change awareness are 1.12 percent for households who recognise the importance of climate change information. According to (Hassan and Nhemachena, 2008) farmers that perceive change in climatic conditions and farmers who have access to climate change information have higher chances of taking adaptive measures in response to observable changes. Importance of climate change information brings about awareness on climate change and enhances farmer's knowledge on adaptation to climate change.

According to Table 1 the odds of climate change awareness are 1.01 percent for households who received good quantity of harvest. Good quantity of harvest is another significant variable which is associated to climate change awareness. Though the relationship between seasonal climate variables can be quite complex, we expected that farm revenues would have a significant relationship with climate change awareness (Kurukulasuriya and Mendelssohn, 2006a).

4. Summary and Conclusion

Due to prevailing problems associated with changes in weather patterns such as high temperatures, changes in rainfall patterns and effect of greenhouse gases (GHGs), which has resulted in low crop production, food insecurity, low income for farmers, there is a need to investigate whether small scale maize farmers are aware of climate change. So this study will enable small scale maize farmers and households in Mpumalanga province to understand the meaning of climate change, by creating awareness through which households and farmers can cope with climate change. This will improve climate change adaptation and thus increasing maize production as well as income for households and farmers.

Table 1: Univariate regression analysis of potential determinants of climate change awareness and maize production

Variable	Total	(%)	OR [95%CI]
Females	52	20.7	1.00[0.508 – 2.711] 1
Age	251	100	0.99 [0.440 – 2.567] 1
Occupation	251	100	1.10 [0.675 – 3000] 1
Education	251	100	1.01[0.599 – 2899] 1
Source of income (Yes)	179	71.3	0.97[0.127 – 2.112] 1
Climate change info	251	100	1.53[0.76 – 3.555] 1
Extension Service	251	100	1.50[0.68 – 3.44] 1
Importance of info	251	100	1.12[0.576 – 2.666] 1
Quantity of harvest	251	100	101[0.11- 2011] 1

OR= Odds ratio; 95%CI = 95% confidence intervals; 1< = no association; 1> = association

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Winners and losers from climate change in agriculture: food security issues in the Mediterranean basin

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ABSTRACT

The Mediterranean region has always shown a marked inter-annual variability in seasonal weather, creating uncertainty in decisional processes of cultivation and livestock breeding. This should not be neglected when assessing the impact of climate change (CC), which modifies the atmospheric variability and generates new uncertainty conditions, and is particularly relevant when modelling the adaptive responses of farmers to the CC itself. Our analysis examines precisely this aspect by reconstructing the effects of inter-annual climate variability in a diversified agricultural district that represents a wide range of rain and irrigated agricultural systems in the Mediterranean. We generated the atmospheric variability conditions of ten years representative of present climate (2000-2010) and as many of near future (2020-2030) by processing the results of a Regional Atmospheric Modelling System. Then, we implemented calibrated crop and livestock models to estimate the corresponding productive responses in the form of probability distribution functions (PDFs) under the two climatic conditions. We assumed these PDFs able to represent the expectations of farmers in a discrete stochastic programming model that reproduced the economic behaviour of the main farm types operating in the study area under uncertainty conditions. The comparison of the results in the two scenarios provided an assessment of the impact of CC, also taking into account the possibility of adjustment allowed by present technologies and price regimes. Major differences in the economic response emerged among farm typologies and sub-zones of the study area. As discussed in a previous paper, a crucial element of differentiation is water availability, since only irrigated C3 crops can take advantage from the fertilization effect of increasing future atmospheric CO_2 concentration. Instead, the reduction of spring rainfall associated to the higher temperatures depresses the rainfed crop production. A dualism emerges between the smaller impact on crop production in the irrigated plain sub-zone, equipped with collective water networks and abundant irrigation resources, and the major negative impact in the hilly area, where these facilities and resources are absent. Yet, increasing summer temperatures also negatively affected milk production and quality, and cattle mortality of intensive dairy farming. In this latter paper, after summarizing those impacts, we focus on some repercussions of the CC on the supply of agricultural products. Interesting aspects emerge about the link between CC and food security in the context of an advanced agriculture in the Mediterranean.

Keywords: CC adaptation, Mediterranean-farming systems, integrated assessment, modelling approaches

1. Introduction

The meteorological conditions of a climatic zone often presents a significant inter-annual variability: this is true even in periods in which people perceive the climate as in a stable condition. Many studies mention and explain the determinants and expressions of climate variability in the various sections of the Mediterranean area (Navarra and Tubiana, 2013). The atmospheric circulation in the Atlantic Ocean determines the variability of rainfall in the autumn period (Altava-Ortiz et al., 2011). Heat waves are a frequent feature of the Mediterranean summer (Gaetani et al., 2012). In addition, several anomalous warm summers have occurred in the Mediterranean and in southern Europe over the last 60 years, with hot events of different intensities and lengths (Segnalini et al., 2011).

Climate variability influences crop production and livestock as extensively treated in the scientific literature. The relationships between variability in the climatic conditions and livestock production have been investigated with specific mathematical and statistical models (Vitali et al., 2009; Bernabucci et al., 2014). Agronomical models have provided a rich characterization of optimal growth to represent the response of crops production under different climatic conditions (Liu and Tao, 2013; Dono et al., 2013a, 2013b, 2014). Various studies have used these models to assess the impact of CC by comparing crop yield or the requirement of inputs under conditions of current and future climate (Eckertsen et al., 2001; Semenov and Shewry, 2011; Rötter et al., 2012; Olesen et al., 2011; Palosuo et al., 2011; Reidsma et al., 2010; Iglesias et al., 2009). In addition, there is a growing recognition that the aggregate results can hide large amounts of variability, and is important to evaluate the effects of Climate Change (CC), and the possible adaptation strategies, to the level of farming systems, or agricultural households (Claessens et al., 2012). In this regard, it is important to considering that farmers base their annual planning on expectations about crop and livestock production that depend on inherent variability of climate and will prove correct, or less, only several months later. Therefore, when assessing the impact of CC on agriculture, and possible adaptation strategies, it must be considered how they can alter their production choices also responding to the changes in the climate variability.

A recent paper presented the main characteristics and results of an integrated study on the effects of climate variability on crop and livestock production, and farm management of a diversified Mediterranean agricultural district (Dono et al., 2016). The analysis assessed the productive and economic impact of CC at farm typology level, including the effect of changing the variability of atmospheric conditions. The study area is located in the Oristano province in the central-west Sardinia (Italy), and it is one of the Regional Pilot case studies conducted under the research activity of the FACCE MACSUR Knowledge hub[1]. This agricultural district extends for 54,000 hectares (Ha) and presents a variety of farming systems covering a wide range of conditions under both irrigated and rainfed Mediterranean conditions. Therefore, many issues generated by the interaction of CC seasonal impacts on different cropping and livestock systems were deeply explored and analysed. Data from the sixth Census of Agriculture, 2010, and records from the FADN and the local Water Users Association (WUA) show that irrigation is practiced on 36,000 Ha of that territory. The main crops of this sub-area are wheat, corn and forage, and cow's milk is the key product. In addition, vegetables are common, as also rice, citrus, olive trees and vineyards. Additional 18,000 Ha are instead rain-fed and used for pasture and rye grass, for sheep milk production, woods and set-aside. This latter sub-zone uses farm wells to irrigate very limited areas.

[1] http://macsur.eu/index.php/regional-case-studies

The problems due to the change of agro-climatic conditions in this area were analysed by integrating climatological, agronomic and livestock models, whose outputs, once treated with statistical methods, were included in an economic model that simulates the farm choices under present and then future climate context. Our hypothesis is that the represented farming systems were also relevant to many other areas of the Mediterranean, and the results obtained can provide a relevant support for the development of contextualized effective and strategic adaptive responses far beyond the analysed local context, in the transition to future climate. This also justifies the short-term time horizon chosen for the analysis, which addresses the changes in climate variability that can be immediately relevant for the development of strategic adaptation policies in the context of rural development.

Dono et al. (2016) provides a detailed description of the analysis; following a summary of its main steps and the description of some further results that we report in this paper, and regard the biomass production of the main agricultural activities. This aspect seems relevant in the context of food security given the changes in crop yields and in milk production generated by the CC.

2. Materials and method

A Regional Atmospheric Modelling System (RAMS) nested into an atmosphere-ocean model based on ECHAM 5.4, generated the current and future climate scenarios of the Oristano area (Scoccimarro et al., 2011). We defined these scenarios with reference to a decade, and not compared to one year, just to induce the model RAMS to consider the variability inherent in the climate, and generate a wide spectrum of conditions that may arise. Therefore, the greenhouse gas scenario A1B of 2000–2010 denotes the current climate; the scenario A1B of 2020–2030 denotes the future climate. A post-processing procedure based on observed data and reconstructed sea surface temperature reduced the errors due to poor geo-morphological description (mountains, land cover) from numerical models. The outcomes of RAMS for the current and future climates were furtherly processed with the weather generator WXGEN to obtaining data for 150 stochastic years under each of the two scenarios. These data defined the entire range of inter-annual climate variability in that territory under the two climates. Comparing the two scenarios emerges that the footprint of CC is the increase of the summer daily temperature, maximum, but mostly minimum. Temperature increases slightly during the spring, and markedly in fall–winter. Rain variability increases, coupled to a reduced annual average.

The EPIC (Environmental Policy Integrated Climate) model was used to estimate the impact of temperature, rainfall and atmospheric CO_2 in the two scenarios on yields of irrigated (silage maize, ryegrass, alfalfa) and rain-fed (grasslands, hay crop) crops (Balkovic et al., 2013). The model calibration utilized crop, soil and climate data from field experiments, and interviews to farmers. The impacts of the two climates on cattle breeding were evaluated using equations derived from the literature on the relationship between the index of temperature and humidity (THI), mortality (Vitali et al., 2009), milk yields and its somatic cell content (Bertocchi et al., 2014). These relationships were estimated with linear regression analyses in two phases in Italian areas where the Holstein Friesian is bred similarly to the study area.

Those results were processed with maximum likelihood methods to estimate the probability distribution functions (PDF) of the yields, current and future, of pastures and grasslands in the rainfed zone, and of irrigation needs, and relative yields, of maize, ryegrass and alfalfa in the irrigated zone. The irrigation needs of the other crops were estimated based on their present values and the percentage change in *net evapotranspiration* of the future climate with respect to the present. The range of each PDF was divided into 3 *states*, with 25% probability for low and high states, and 50% for intermediate, which constitute the vector of probability (P) of each uncertain variable. The representative value of the variables in the three *states* is the average of their values in the synthetic years falling in each *state*.

Those values were used to represent farmers' expectations on the course of weather in the incoming season in a model of discrete stochastic programming (DSP) that simulates their annual planning under uncertainty on atmospheric conditions (Hardaker et al., 2004). According to this modelling scheme, farmers plan their choices considering the probabilities of the various *states of nature* that may arise in the course of the season, and the possibility to correct the decisions taken if unexpected *states* should occur. Applying corrective actions minimizes the impact of those conditions, even if at a cost (the cost of uncertainty) that causes sub-optimal results. DSP has been used to represent the economic impact of many agricultural uncertainties: availability of irrigation water (Calatrava and Garrido, 2005), productive results of technologies (Coulibaly et al., 2011), on weather risks (Mosnier et al., 2009), change in climate variability (Dono and Mazzapicchio, 2010).

Our DSP model represents the territorial agricultural supply based on 13 farm types (Dono et al., 2016). The climatically driven variability accounted for in this study relates to summer water needs of crops, spring yields of pasture and hay from grasslands, autumnal yields of pastures and of grazed grasslands. The corrective actions regard the pumping of irrigation water from wells in case of higher temperatures and water requirements of the crops, and the buying of feed in case of lower yields of fodder. The mathematical representation of the model is compactly defined as follows:

$$\max_{X_1, XR_{n_s}} z = GI\,X_1 - \sum_{n=2}^{N}\sum_{s=1}^{S} P_s\,Cr\,XR_{n_s} + Pm\,Qm \qquad (1)$$

subject to:

$$A\,X_1 \leq B \qquad (2)$$

$$A_s\,X_1 \leq B + \sum_{n=2}^{N} XR_{n_s} \qquad \forall s \qquad (3)$$

$$N\,Y_s\,X_1 + \sum_{n=2}^{N} XR_{n_s} \geq R \qquad \forall s \qquad (4)$$

$$X_1 \geq 0 \text{ and } XR_{n_s} \geq 0 \qquad \forall s \qquad (5)$$

n is the number of stages of the decision making and s are the *states of nature* that uncertain variables can assume; X_1 is land, whose allocation occurs in the first stage; XR_{n_s} are corrective actions performed in the subsequent states (n= 2,..,N) on the actual occurrence of one of the *states*. These actions modify the available additional resources, at a cost (Cr). Equation (1) is the objective function (z) that sums different components: gross margins (GI) of the activities chosen in the first stage (X_1); costs (Cr) of the corrective actions XR_{n_s}. In this last case, the values of the uncertain activities in the *states of nature* are weighted with their probabilities (P_s), and summed over the N stages. Finally, the objective function sums the revenues of milk, based on the price (Pm) and the total quantity (Qm) obtained under present climate and future[2]. Constraints (2) refer to land and

[2] The model sections dedicated to the allocation of land do not account for the effects of climate on the revenues of cow milk, which are considered in the objective function, as for crops to sale (rice, wheat and barley). The effects of climate

labour resources: A is the matrix of technical constraints and B is the quantity of available resources. Constraints (3) refer to the water resource and show that uncertainty affects A_s, i.e. watering needs of irrigated crops, and that choices involve corrective actions, XR_{n_s}, in stages (n) for each states (s). Constraints (4) refer to animal feeding: N are the unitary contributions of nutritional elements, R are the nutritional needs of livestock categories. The uncertainty affects Y_s, i.e. yields of forage crops, and that choices involve corrective actions, XR_{n_s}, in stages (n) for each states (s).

We calibrated the model to the reference year 2010 with the PMP approach of Rohm and Dabbert (2003) that models the choice between technically similar crops, whose mutual substitution elasticity is greater than that relating to other crops[3]. The calibration involved land allocation among crops decided in the first stage.

3. Results of the DSP model

The values of the three *states of nature*, and the respective probabilities were included in the DSP model that generated the productive and economic results under the two scenarios. Table 1 reports the results on the *biomass production* of the main crops in the present scenario, and their percentage changes in the future for the total study area and its two subzones. The table also shows the impact on cow milk production.

Table 1: biomass production under present and future climatic scenarios [percentage changes of future over current (%Δ)]: total area, zone irrigated by the *WUA* and *rainfed* zone.

	Present climate (Mg)			Future climate (%Δ)		
	Total	*WUA*	*Rainfed*	*Total*	*WUA*	*Rainfed*
Grain cereals	57,544	49,695	7,849	18.0	8.1	80.6
Durum wheat	*23,580*	*18,604*	*4,976*	*2.3*	*2.5*	*1.6*
Rice	*24,894*	*24,894*	*0*	*7.2*	*7.2*	-
Barley	*6,192*	*4,200*	*1,992*	*-5.5*	*-5.5*	*-5.4*
Maize	*1,000*	*860*	*140*	*110.9*	*129.9*	*-6.0*
Forage crops	644,648	490,209	154,439	-2.2	0.1	-9.6
Grasslands	*149,653*	*17,876*	*131,777*	*-7.2*	*-7.2*	*-7.2*
Hay crops	*36,067*	*16,005*	*20,062*	*-18.3*	*-8.2*	*-26.3*
Silage maize	*384,916*	*384,916*	*0*	*0.7*	*0.7*	-
Italian ryegrass	*31,655*	*31,434*	*221*	*34.6*	*34.0*	*127.1*
Alfalfa	*32,207*	*29,828*	*2,379*	*-31.0*	*-32.6*	*-10.0*
Triticale	*10,150*	*10,150*	*0*	*-3.2*	*-3.2*	-
Field horticultural crops	234,189	227,021	7,168	-0.2	-0.2	-0.1
Processing tomato	*154,800*	*152,160*	*2,640*	*-0.3*	*-0.3*	*-0.2*
Melon and watermelon	*57,029*	*53,847*	*3,183*	*-0.3*	*-0.3*	*0.0*
Potato	*5,158*	*5,088*	*70*	*3.6*	*3.7*	*-0.8*
Carrot	*5,119*	*5,119*	*0*	*6.3*	*6.3*	-
Early potato	*2,166*	*1,748*	*418*	*-8.2*	*-10.2*	*0.0*
Greenhouse crops	7,008	6,175	833	-1.6	-1.9	0.0
Tree crops	19,985	16,644	3,341	0.0	0.0	0.0
Cow milk	173,619	173,619	0.0	-1.2	-1.2	-
summer period	*25,271*	*25,271*		*-8.4*	*-8.4*	

Source: our elaborations and analyses on (Dono et al., 2016)

on costs of milk production are considered in sections on production and the purchase of fodder, for which, inter alia, are also provided corrective actions in case of adverse conditions. Similar corrective actions concern the sheep sector. In this case, however, the summer production of milk is irrelevant; therefore, the model neglects climate impacts.

[3] For more details, see Cortignani and Dono (2015).

Cereal production grows significantly across the study area; the largest increases are in rice and corn production that, due to irrigation, may benefit from the fertilization effect of the increase in atmospheric CO_2 concentration. Instead, the production of fodder reduces, with sharp falls mainly in the non-irrigated sub-area, where the decrease of the spring rains causes a drop in the yields of hay crops. On the contrary, water availability allows an appreciable increase of the productivity of the Italian ryegrass in the irrigated sub-area, thereby increasing the production of that crop in the beef and dairy farms, and in the sheep farms that manage some farmland in that sub-region. Also, the production of corn silage increases, due to the notable expansion of the late hybrid at shorter circle, which compensates the considerable drop of the variety that is currently widely cultivated. Minor changes affect vegetable crops: the appreciable contraction of early potatoes also depends on the choices of the dairy farms to expanding the acreage of the irrigated late hybrid of silage maize and of Italian ryegrass. The last lines of the table show the reduction in bovine milk: this is only due to the decrease in the unitary production, given that the simulation keeps fixed the number of bred cows. A relatively small reduction of the annual production emerges; the drop is instead quite impressive in the summer months.

These production variations contribute to generating the changes in net income (NI) in the two sub-areas that the table 2 identifies for various groups of farm types and their aggregates. Data show that the negative impacts in the irrigated sub-zone affect almost exclusively the dairy cattle farms that suffer a -5.3% average drop of NI. The decrease of revenues is mainly due to the reduction of cow's milk production; however, this is partly offset by the decrease in the purchase of livestock feed due to the expected increase in farm fodder yields. Other types in this sub-zone benefited by increases of NI, due to the increased cereal yields from the CO_2 fertilization effect. In the rice-growing farms, the effect on the rice crop yield is notable, and the same applies to their NI.

Table 2: net income (NI) per group of representative farms in the present and future climate (000 €); percentage changes of future NI over present (% Δ NI)

	Present NI	Future NI	% Δ NI
Rice	4,317	4,718	9.3
Trees and arable crops	3,874	3,874	0.0
Dairy farms	33,180	31,433	-5.3
Mixed crops	23,500	23,459	-0.2
Irrigated zone	66,102	64,721	-2.1
Greenhouses	1,231	1,236	0.4
Mixed crops	3,733	3,730	-0.1
Sheep	7,903	7,230	-8.5
Rain-fed zone	11,636	10,961	-5.8
Total area	77,738	75,681	-2.6

Source: our elaborations and analyses on (Dono et al., 2016)

A larger reduction occurs for the NI of the rainfed area, due to an increase in variable costs that is more than proportional to the increase in revenues caused by higher grain yields and sales of arable crops. In particular, there are significant consequences of the reduction in the fodder production from grasslands and hay-crops: sheep farms had to notably increase purchases of feed and hay, which greatly compressed NI of these types and of the entire zone.

4. Discussion

The results showed that in the next 2020-30 decade the CC can generate different types of alterations of atmospheric conditions that are all relevant for the annual planning of agricultural activities under Mediterranean conditions. Those changes can be beneficial to some farm activities but unfavourable for others, thus leading to winners and losers under the same area and climatic pressures. Even within the same farm type, CC can generate impacts of different sign and intensity among different agricultural activities. For example, the decrease of spring hay yields offsets the increase in yield of grass meadows and pastures of sheep farms. Similarly, the decrease in milk production due to heat stress elides the potentially positive effects on income generated by the increase in irrigated fodder yields of dairy farms. However, magnitude and sign of the productive and economic impacts depend on the resource endowment of farms in the specific context, and the way access to them is regulated. For example, in rainfed areas the increased probability of high temperatures and low rainfall in the spring, has a negative impact on the fodder production and, therefore, increases the costs for purchasing fodder. On the contrary, the current, non-limiting availability of water resources in the WUA sub-zone, allows irrigated farms to escape the negative effects of spring drought on fodder production, and to take full advantage of the potential yield increase of C3 crop species due to the expected increased concentration of atmospheric CO_2. This results into higher yields, consistently with the results of other studies in Europe (Schönhart et al., 2014), and lower cost for fodder supply. This advantage at least partially compensates for other negative economic impacts of CC in dairy farms, due to the reduction of production and quality of milk in the summer months and increased mortality of livestock. This confirms the close relationship between the capability of adaptation to CC and farms' resource endowment, as evidenced by Antle et al. (2004) for northern USA farming systems. Similarly, Reidsma et al. (2010) conclude that the heterogeneity of the income impacts of the CC on EU agriculture, at both regional and farm levels, and the adaptation capacity largely depends on the characteristics of the farms (size, intensity and kind of land use) in the same region. We found this evidence particularly true for the Mediterranean context.

Our results show that in some cases available technologies provide considerable opportunities for adaptation, as already found in other studies (Shrestha et al, 2013). For example, the availability of a wide range of silage maize hybrids with different degree of earliness can contribute to mitigate the impact of higher temperatures prolonging the duration of the crop production cycle, and thus maintaining substantially unchanged the current crop yield level. The criteria used to manage the resources influence this flexibility. The peculiar water payment system "hectare-culture" (i.e. the cost of water depends on the type of crop and not the actual use water) implies that only the variation in the irrigated area, and not also in the amount of water used, affects the cost of using the resource (and the payments to WUA) (Dono and Giraldo, 2012).

On some important aspects these results only give helpful hints, but no clear indications. In fact, the structure of the model we used, which is a local agricultural supply model, does not allow defining the productive implications due to CC on market prices, along the food chain, as well as the relationships with buyers of agricultural products and suppliers of agricultural raw materials. For instance, the 8.4% reduction in the production of milk in the summer months may generate problems in the cheese-making, which also suffers because of a reduction in the quality of milk[4]. This is important for the study area because the summer sales of fresh dairy products are financially very relevant to the cooperative cheesemaking company that uses the totality of the milk produced in the area, and is the leading producer of these foods in Sardinia. The problem will have wider repercussions if the decline in milk summer production will be generalized to the north of the Mediterranean area: this might affect the summer production of many cheeses with protected

[4] Another impact of the CC reported in Dono et al. (2016)

designation of origin in those territories. Conversely, a generalized increase in the supply of cereals from other, more important, areas of production may reduce market prices, reducing the positive effects indicated by our model for the farms involved in those productions. Similarly, the reduction in the production of some fodder and the increase of their demand may increase prices, as well as the demand for land rented for their production, with further negative effects on the budget of livestock farms.

5. Conclusions

The interdisciplinary modelling approach adopted for this study allowed an integrated assessment of the expected impacts of CC over a wide range of farming systems under Mediterranean conditions. This approach assessed the sensitivity to CC by identifying the crucial phases of the cropping systems, and by framing the agricultural management issues from the farmers' perspective. Under rainfed conditions, the expected increase in summer temperatures might only slightly affect farming systems that are already designed considering a summer drought condition. This is the case of the sheep farming in rainfed conditions, which is often already managed for minimizing the requirements of feed of the flocks in the summer. Instead, other changes, sometimes neglected, might be particularly relevant. This is the case of the increased temperatures and reduced rainfall in spring, which reduce the hay-crop yields, hence increasing the vulnerability of rainfed livestock farming systems.

The need to focus on specific aspects of CC that are most worth to consider as they may reveal gaps in the adaptive capacity of the different farming systems, is an important conclusion of this study.

In contrast, a limitation of this study is the absence of connection with the CC effects on market balance, and on the productive relationships between agriculture and other segments of the supply chain of agricultural production. The local supply model used for this analysis assumes, in fact, that the prices of inputs and outputs remain unchanged, and this hypothesis can be restrictive if we assume that the model can represent the CC agricultural effects in a wider area. Of course, for some industries, even a large area such as the Mediterranean has little influence on the market balances; for others, changes in local agricultural productivity and supply may however influence prices. At this time within the MACSUR project, we are just trying to consider the set of these market effects, integrating the results of local models like this with the results of the CAPRI model (www.capri-model.org), which can simulate the change of market balances and the more general climate impacts.

Overall, however, the outcomes of this study suggest that the challenges posed by CC in the near future require more than just a more efficient management of resources at local scales. Effective adaptation pathways may emerge from a strategic long-term contextualized visionary perspective of the future of agriculture, emerging from the integration of scientific and lay knowledge (Nguyen et al, 2014). This is particularly important in the vulnerable areas of the world such as the Mediterranean basin.

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Addressing Italian Official Statistics to the measurement of Climate Change impacts and adaptation options on Agriculture

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ABSTRACT

The accelerating pace of Climate Change (CC) is having significant consequences on Italian agriculture in terms of impacts and adaptation options. Weather heavily affects crop production trends, yields and quality variability with impacts that can vary by region. Measuring and enhancing the relationship between Agriculture and CC is complex. To develop the analysis of CC effects on agriculture in a comprehensive way, an urgent need of CC related statistics (CCRS) has been recommended by international institutions (UNECE, IPCC, Eurostat, OECD) in recent years. National Statistical Offices are called for actions aimed to improve the usefulness of existing statistics and to develop new statistics, filling information gaps. To appropriately address official statistics to the measurement of CC impacts on agriculture new methodologies need to be adopted, enhancing multidisciplinary approach and expertise, linking datasets across domains, reviewing existing classification systems, geo-referencing data, developing partnerships among different producers. This work mainly aims i) to present current official statistics production in Italy, highlighting data gaps in CC analysis; ii) to describe operating actions needed to better measure CC impacts on agriculture; iii) to integrate results provided by the Istat surveys on agricultural and meteo-climatic phenomena. Statistical innovations are addressed to enhance the availability of new relevant data, necessary for the analysis of CC impacts on agriculture at the national and local scale. In this study the relationship among meteorological factors, crop yields, water resources used in agriculture compared to water used in other sectors have been presented. Our work highlights the need to strengthen collection and use of several data sources by integrating data from surveys with administrative data. To this aim, the cooperation and the awareness of all agencies and institutions operating in the National Statistical System are essential to exploit the existing information assets and to develop new statistics coherent and consistent with the statistical international framework.

Keywords: Climate Change, Impacts and Adaptations, Official Statistics, Agriculture and Water statistics.

1. Introduction

After Paris agreement and other international initiatives, the demand for high quality statistics related to CC keeps growing. CC is a global multidimensional phenomenon that affects almost every aspect of human life and interactions between human and natural systems. National Statistical System (NSS) and National Statistical Offices (NSO) are called to enhance their contribution in the production of official statistics related to climate change to best satisfy user needs.

In 2014, the Conference of European Statisticians (CES) published a set of Recommendations on Climate Change-Related Statistics[1] (CCRS) to help ensure that information needs are effectively met. The work is an important step towards taking data needs related to CC more fully into account in NSSs, improving the contribution and involvement of official statistics in measuring CCRS. The CES recommendations define CCRS as "environmental, social, economic data that measure the human causes of CC, the impacts of CC on human and natural systems, the efforts of humans to avoid the consequences as well as their efforts to adapt to the consequences". They are organized into five conceptual areas: drivers, emissions, impacts, mitigation and adaptation.

The primary drivers of CC are anthropogenic emissions of greenhouse gases (GHG) from production and use of fossil fuels, agricultural and forestry practices and manufacturing processes. The efforts to mitigate CC are aimed at changing production and consumption patterns. To the extent that mitigation fails, the ensuing impacts and human efforts to adapt to CC will be heavily felt by the economy and society. It's clear that CCRS involve a wide range of interlinked statistical domains.

In this contest, agriculture plays a dual critical role, on one side as a cause of CC as producer of GHG emissions, on the other agriculture is threatened by CC impacts, by the increasing demand rising from population; by the increasing pressure of natural resources; by extreme events and disasters impacts. Improving sustainable agricultural productivity has become a global challenge.

The UN's new Sustainable Development Goals (SDG)[2] include a series of targets related to CC and agriculture. Goal 2 of SDG addresses to "End hunger, achieve food security and improved nutrition and promote sustainable agriculture". In particular the target 2.4 declaims: "By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality". Goal 13 addresses to "Take urgent action to combat climate change and its impacts". In particular the target 13.1: "Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries". Climate-related hazards and natural disasters can threat agriculture. They can be caused by CC, as extreme weather events such as floods, landslide, extreme temperatures, cyclones and other natural consequences that provoke environmental degradation (desertification, salinization, acidification, insect infestation) or they can be caused by other natural or man-made hazards, that provoke direct or indirect damages (pollution, contaminations, etc).

In 2015, an UNECE Task Force (TF) on Measuring Extreme Events and Disasters[3] has been defined to clarify the role of official statistics in providing data related to extreme events and disasters and to identify practical steps how NSOs, in coordination with national agencies responsible for disaster management, can support disaster management and risk reduction. The work takes into account the relevant issues raised in the context of SDGs and Sendai Framework[4]

[1] http://www.unece.org/stats/publications/ces_climatechange.html
http://www.unece.org/fileadmin/DAM/stats/documents/sustainable_development/Growing_need_for_official_statistics_in_measuring_climate_change.pdf
[2] https://sustainabledevelopment.un.org/?menu=1300
[3] http://www.unece.org/statistics/statstos/task-force-on-measuring-extreme-events-and-disasters.html
[4] https://sustainabledevelopment.un.org/frameworks/sendaiframework

for Disaster Risk Reduction 2015-2030. A first objective of the TF is the international harmonization of terminology in connection with the Open-ended Intergovernmental Expert Working Group on Indicators and Terminology Relating to Disaster Risk Reduction[5].

The demand for high quality statistics to measure and describe all this interlinked dimensions is evidently expanded. Global and local analysis are needed, as well as statistics at national and sub regional level. There's a huge amount of data already available from several producers (inside and outside NSS) that suffer lack of standardization and quality standard. The role of official statistics in this contest is to guarantee the production of statistics meeting user's needs and to ensure high quality levels standards, in order to obtain relevant, consistent and comparable statistics and indicators. Referenced frameworks among the several national and international initiatives have the advantage of structuring the over whelming amount of information produced providing standardization of definitions, methods, classifications and ensuring homogeneity and comparability. UNSD-FDES[6], 2013 and its methodological 2014-2016 developments, is based on a multi-purpose conceptual and statistical approach, defining standardized concepts, definitions and methodologies. The System of Environmental Economic Accounting 2012 – Central Framework (SEEA-CF[7]) provides the first international statistical standard for environmental-economic accounting.

The work of the UNECE task force highlights how NSOs already produce data potentially relevant to CC, but that have been collected and produced with other purposes. This data should become usable for CC analysis. To do so, NSOs are recommended to facilitate access to data that already exists; improve geo-spatial analysis; improve linking between socio-economic and environmental data. Furthermore NSOs should develop new statistics based on a review of key data needs.

The aim of this work is to describe the current production of data potentially useful for measuring CC impacts ad adaptation options in agriculture, through a review of the main data sources available in Italian national institute of statistics (Istat). Then, the work will present a critical analysis of the data gaps in which the NSOs should improve the efforts, in order to fill the statistical information required.

2. Climate Change and Agriculture

CC variability has effects on socio-economic and natural environment. Agriculture and water resources are expected to be the most sensitive. Global warming and changes in rainfall and temperature patterns affect water resources availability and crop water requirements. As CC will alter water cycle, the pressure on water resources will increase. Being water resources one of the major inputs for a sustainable agricultural development, CC may have adverse impacts on crop production systems. Increasing pressures impose a sustainable use of irrigation water supported by specific policy actions. In particular, measuring the relationship between water resources used for irrigation and meteo-climatic and hydrological variables is crucial.

In this context, official statistics may provide a solid basis to know quantitative aspects referring to multi-dimensional phenomena related to the analysis of CC impacts on agriculture such as: weather conditions variability, out of season events, water resources availability, trend of different crops yields, quality of agricultural products, water resources required by crops, pressure exerted on irrigation water by crop and by area, abandonment of less-favored farming areas.

[5] http://www.preventionweb.net/drr-framework/open-ended-working-group/
[6] http://unstats.un.org/unsd/environment/fdes.htm
[7] http://unstats.un.org/unsd/envaccounting/seea.asp

To develop empirical CC impacts analysis, data adequately spatialized, provided at a high degree of disaggregation and on yearly basis, are needed. In a context characterized by uncertainty inherent in climate variability, the role of policy is crucial in managing the water resources efficiently across space and time to prevent agricultural yield fluctuations causing welfare loss. For this purpose, policy makers need standardized tools to define optimal policies and measures for a sustainable agricultural development and water resources management and to monitor objective achievement.

In Italy, country located in the heart of Mediterranean basin, CC is in place in the last decades (as confirmed by meteo-climatic and hydrological official statistics) and affects either water resources demand and many crop products through decreasing yields and quality and livestock management. On the basis of Istat statistics, the data collected by meteorological stations located in the region capital municipalities have recorded a "warming" during the last fifteen years, because in the period 2001-2014, the average annual temperature was equal to 15.1°C, with an increase of about 1°C with respect to the long-term average for the 30-year period 1971-2000[8]. In the same period the meteorological stations located in the Italian regional capital municipalities registered a change in rainfall pattern, because the average annual precipitation was equal to 740.8 mm, with a reduction of about 1.1% compared to 1971-2000 mean value.

Negative impacts of CC are more common than positive ones in our country where irrigated agriculture is the major water user accounting for more than 47 % of total use.

Italian agricultural production is characterized by a wide range of high quality products, typical Mediterranean crops and IGP-DOP products. Many agricultural products need suitable microclimatic conditions otherwise decreasing yields and quality mainly due to changes in rainfalls and in minimum temperatures patterns. Not only quantity and quality of such crops, but also the choice of species and varieties that will be possible to grow and the location of the production, can be seriously compromised by CC effects. The increasing likelihood and severity of extreme weather events will considerably increase the risk of crop failure in Italy. Italian crop production system faces and will cope deep changes of weather conditions and water resources availability, intensifying problems of water scarcity and irrigation requirements especially in the South of Italy and increasing drought risk and heat stress. Moreover, CC effects could lead to inefficiency in the agricultural production also linked to the sector structure including many small firms, with a low capability to adapt themselves to a new situation.

As CC affects many dimensions, official statistics on different thematic issues need to be integrated and harmonized to provide a solid and consistent basis for empirical analysis on CC impacts. A poor integration between regulations relating to specific subject areas of environmental and agricultural statistics have been carried out in recent years. The role of official statistics is to produce and disseminate statistical information needed for any type of study for modelling, making scenarios and elaborating adaptation policies, related to all relevant dimensions, such as: crop yields, water availability and use, irrigated areas, areas under organic farming, use of fertilizer, seeds and pesticides, temperatures and precipitation patterns, extreme weather events (heat waves, drought, floods , storms, fire forest, etc.).

As a substantial delay with respect to the information needs emerges, strengthening production of CCRS, hydrological and meteo-climatic statistics, agricultural and water statistics is essential to ameliorate the analysis of CC impacts on water resources and agriculture in order to provide official data, useful also to policy decisions. By evaluating the adaptive capacity of the Italian agricultural system to deal with external influences, implementing optimal CC mitigation-adaptation strategies by policy makers is needed.

[8] http://www.istat.it/it/archivio/giornata+mondiale+acqua

Considering official statistics currently issued on these dimensions, short or medium run CC effects empirical analysis are bounded by the availability of some variables at an adequate level of disaggregation and of long time series for all the variables considered, as it would be appropriate for modelling. Official statistics show several data gaps and some points of weakness summarized in the following points:

- *volumes of irrigation water* would be crucial in the analysis (as input in the production function) to evaluate CC effects on crop production. The scarce availability of official statistics on irrigation water has forced to use over the years the variable *irrigated areas* as proxy. For the first time, statistics on irrigation water in Italy were issued by VI Agricultural Census 2010. Strengthening the production of official statistics on irrigation water means improving the analysis on the demand of water resources and water use efficiency in presence of CC;
- *meteo-climatic variables* are a measure of CC, the need emerges updating on regularly basis time series of *all meteo-climatic and hydrological statistics* both for recent years and at a high degree of spatialization, thus being suitable to study the connections between climate and agriculture at local scale too;
- *agricultural statistics* need to be strengthened also homogenizing the scale (temporal and spatial) and the disaggregation level at which data are provided to develop analyses on CC effects on agriculture at the national and local level. For example, it would be necessary to strengthen statistics on harvested production disaggregated by type of crops, inputs used disaggregated by crop meteo-climatic statistics spatialized and suitable updated for a medium-term CC effects analysis;
- *data on mitigation policies* undertaken by Italy, in accordance with EU Policy related with CC would be useful in the analysis.

To this aim, in recent years, some methodological innovations have been developed and introduced in the national structural sampling survey on agriculture (*Farm structure Survey*) and new domains have been detected in the 2013 and 2016 edition such as: volumes of irrigation water by crop, technique of irrigation, water resources used by source of abstraction of, organic farming production, use of plant protection, use of energy products for current production, production of energy from renewable sources.

Goals to achieve are represented by strengthening administrative archives, integration of different data sources, enhancing the production of statistics and new data crucial in this type of analysis, expanding temporal and spatial scale and disaggregation level at which data are provided, update all meteo-climatic statistics suitably spatialized.

3. Climate change, agriculture and water statistics in Istat

Warmer temperatures, changes in precipitation levels and patterns, extreme weather events are already impacting all human and economic activities. Agriculture, in particular, is extremely dependent on weather and climate events in order to produce the food necessary to sustain human life. CC is here and now. CC is expected to negatively condition both crop and livestock production in most part of the world, although some regions may actually take advantages from the changing conditions. The natural ecosystems are responding to change. So, for example, some fruits grow faster, others slower, changing so the normal length of their life cycle. The biological (phenological) responses to CC are very often unpredictable and their management becomes then increasingly difficult.

Overall, productivity levels may changes as CC consequences, for example increase of actual evapotranspiration and crop water requirements, decrease of water availability and quality. Substantial reductions in the impact that CC could generate on global agricultural production, and therefore food security, could be obtained thanks to a better understanding of the dynamics of the phenomenon.

Quantifiable indicators of the environmental sustainability of agriculture are a fundamental tool for monitoring current conditions, identifying trends, setting goals, evaluating progress and comparing performances among different regions and countries. This set of indicators is useful for policymakers, farmers, businesses, and civil society to better understand the state of the art.

The current statistical production, based on both official and non-official sources, even if already consistent, does not always allow at the moment the construction of timely, solid, comparable agri-environmental indicators that can respond to the needs of those who monitor CC in all its declinations and its essential relationships with the agriculture. There is doubtless a lack of integration of the various regulations, also at European level, relating to the different subject areas of the environment and agricultural statistics. The presence of missing data, the difficulty of integrating different data sources, the lack of long time series, make it extremely difficult to produce a connecting framework between the CC and Agriculture statistics.

Although many efforts have been initiated for a better performance of the official statistical production, the challenge is to continue to evolve the core suite of official statistics. Internally and externally, NSOs have to explore increased linkage of datasets, creating value from data, with the aim to give the society a plausible and consistent point of view, and more importantly, as the counterfactual for scenario analysis.

Agriculture and Water statistics will be deepened in the following paragraphs.

Considering the important role that agriculture has always played in the Italian economy, Istat regularly collects, checks, analyses and disseminates statistical data on agriculture. Istat production covers a wide range of subjects and several surveys are organized by the Institute in this matter, to comply with European regulations and to satisfy needs expressed at the national and local level.

Even if the information collected are periodically enriched, following the emerging information demand, the current production is not always prepared to adequately meet the requirements coming from the CC analysis needed.

In the next we will identify, analyse and profile the landscape of existing data sources, indicators, and datasets relevant to verify the environmental sustainability of agriculture.

The list of the main Istat activities, with features that could be used in an integrated approach directed at climate change and agriculture perspective in Italy, includes:

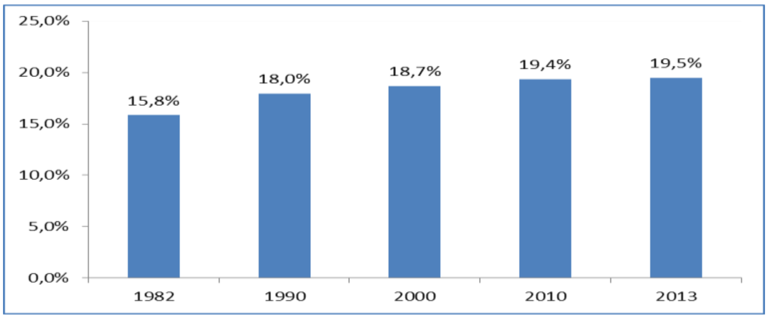
- **Agriculture Census[9],** periodically conducted in an European framework, provides in Italy since 1961, and every ten years, a statistical portrait of agricultural and livestock system at national, regional and local level. The data emerging from the Census have impact on the development of national and Community agricultural policies. The Census also absolve the disclosure obligations established by the Regulations on structural agricultural statistics, with the aim to homogenize the data collection and to disseminate comparable indicators. Census information useful for a CC lecture refer to crops, area cultivated, irrigable and irrigated area, organic farm, livestock, number of working days, volume of water of irrigation use (only for the 2010 edition).
- **Estimate of crops, flower and pot plant production and area,** that is a survey that allows currently to estimate cultivated area, harvested production, yields.
- **Farm structure survey[10]**, a sampling survey that every three years allows to identify the main transformations of the agricultural world and that disseminates data on irrigated

[9] http://www.istat.it/it/archivio/138962

[10] http://www.istat.it/it/archivio/167401

area, number of working day, irrigation by crop and system, production of energy from renewable sources, water supply sources, use of energy products for current production, organic farming, techniques of application of livestock effluents.

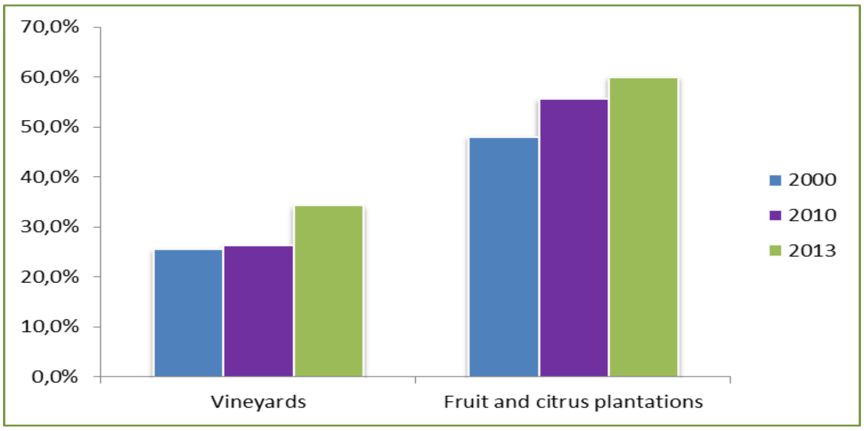
- **Survey on the fertilizers supply for agricultural use (chemical fertilizers, soil conditioners and improvers)**, that allows to observe the fertilizers supply distribution and the nutrients in fertilizers.



Source: Istat - Agriculture Census

Figure 1: *Share of irrigated area on the total utilized agricultural area (percentage values)*

Figure 1 shows about the share of total utilized agricultural area that has been irrigated in the period 1982-2013, more than thirty years. This indicator assumes always more importance due to the strong variation of water availability, that in some period of the year determines a condition of water scarcity.



Source: Istat - Agriculture Census (2000, 2010), Farm structure survey (2013)

Figure 2: *Share of irrigated area for some typical crops (percentage values)*

Figure 2 shows the share of irrigated area for some crops particularly representative of the Italian agriculture and typical of the Mediterranean area: vineyards, fruit and citrus plantations. In the period 2000-2013 the presence of the irrigation practice has increased for both crops especially during the warmest season.

Water is the main element through which CC influences the ecosystem and subsequently the livelihood and well-being of societies. Higher temperatures and changes in extreme weather conditions affect the availability and distribution of rainfall, snowmelt, river flows, groundwater and further damage water quality.

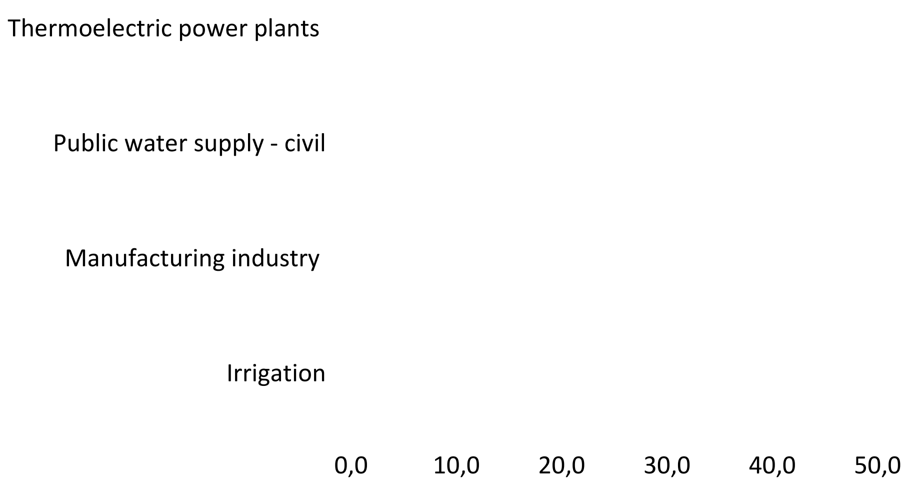
Water statistics represent, then, a fundamental card in the construction of our mosaic, playing a pivotal role in the adaptation process to CC.

In Italy there is a lack of uniform estimates on the amount of water abstracted, supplied, discharged and treated for different uses. Available data suffer from a large fragmentation of information, data heterogeneity and lack of standardization. To improve national knowledge on Water Statistics, several activities have been carried out following the guidelines of the EU relating to the Water Framework Directive (WFD, 2000/60/EC) and Eurostat initiatives on Water Statistics and Water Accounts.

The main activities carried out by Istat are:

- **Meteo-climatic and hydrological survey**: implementation of a geographical data-warehouse with meteorological, agro-meteorological and hydrological daily values measured since 1951. The thermo-pluviometric monitoring network has about 6,200 stations and the hydrometric one about 950 stations.
- **Urban water census:** since 1951 Istat has been periodically collected information on water resources for domestic use through a specific census. Data collected are referred to water abstraction and transmission, public water supply network, public sewerage and urban wastewater treatment plants.
- **Use of water resources**: estimation of water used in manufacturing industry, production and distribution of electricity, agriculture.

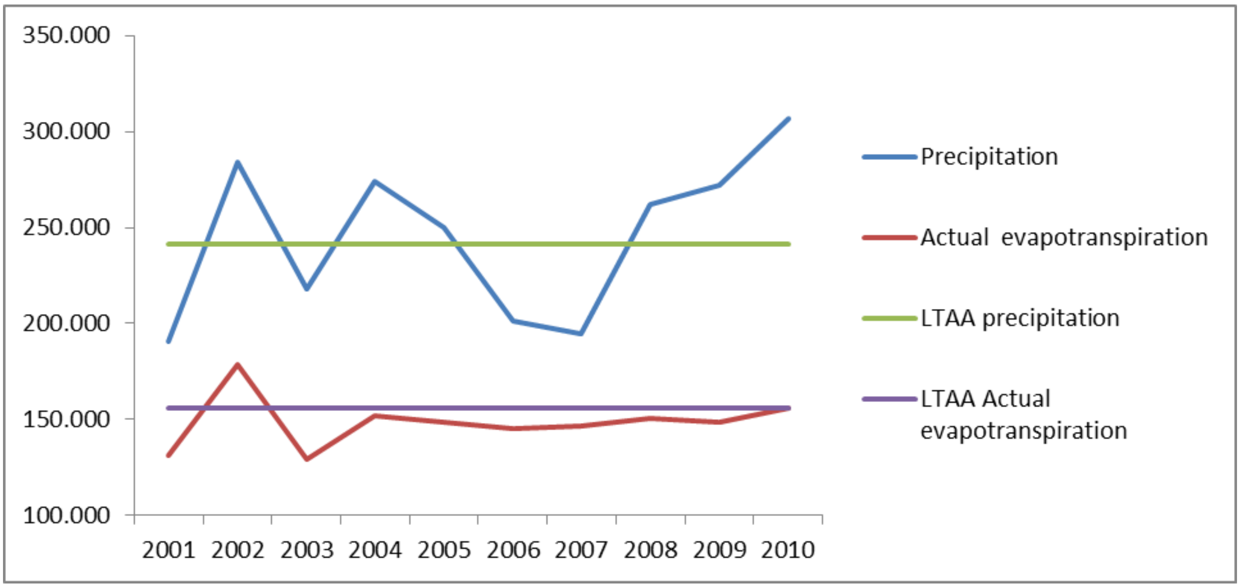
The integration of data coming from these sources allows to compare the use of water by sector: irrigation water, public water supply, manufacturing industry, thermoelectric power plants cooling (for process and cooling of inland water, without sea water). At the national level, in the crop year 2009-2010 the total volume of irrigation water amounted to about 11.6 billion of cubic meters. In 2012, water supplied by the public water supply system amounted to 5.2 billion of cubic meters; the total volume of water used as input by Italian manufacturing industry amounted to 5.5 billion of cubic meters; the volume of inland water used for cooling and process of thermoelectric power plants amounted to 2.2 billion of cubic meters (Figure 3). Summing the four values, the estimation of water used for the sectors included in the equation is equal to 24.5 billions of cubic meters. But this value does not represent the entire volume of water used, as for example the estimation of water used for livestock.



Sources: Istat - Meteo-climatic and hydrological survey, Urban water census, Use of water resources

Figure 3: *Water used by sector. Year 2012, crop year 2009-2010* (billion of cubic meters)

Water use represents the demand of water from the "environment to economy", where renewable freshwater resources statistics are fundamental to evaluate the stocks of water availability[11]. The Istat Meteo-climatic and hydrological survey has disseminated information at national, regional and river basin level, from 1971 to 2010; this has allowed the estimation of the indicators needed for the assessment of water balance.



Source: Istat, Meteo-climatic and hydrological data

Figure 4: *Trend of annual precipitation and actual evapotranspiration (2001-2010) compared to the value of Long-Term Annual Average (1971-2000). Values in billion of cubic meters*

Table 2: *Temperatures and precipitations, Year 2014 (average Celsius grade, average mm)*

	Gen	Feb	Mar	Apr	May	Jun	Jul	Ago	Sep	Oct	Nov	Dic
Temperature maximum (average 1981-2010)	7,7	8,7	11,9	15,0	20,1	24,1	27,2	27,1	22,7	17,9	12,2	8,5
Temperature maximum 2014	9,2	10,4	13,1	16,5	19,4	25,1	25,0	25,8	22,8	20,2	14,5	10,0
Temperature minimum (average 1981-2010)	1,2	1,2	3,7	6,5	10,9	14,5	17,1	17,2	13,8	10,2	5,5	2,2
Temperature minimum 2014	3,3	3,9	4,5	7,9	10,0	15,3	16,3	16,6	14,3	12,6	8,4	3,8
Precipitation (average 1981-2010)	57,3	50,1	56,8	71,0	64,0	52,5	40,0	48,6	76,5	89,8	95,5	77,2
Precipitation 2014	133,0	121,3	75,0	76,3	56,4	62,6	89,6	50,7	64,5	47,0	157,0	75,0

Source: Istat, Meteo-climatic and Hydrological *survey*

Data availability on an annual basis provides a first assessment; but to fully understand the vulnerability of the resource, the temporal and spatial variability is essential. Precipitation and temperatures (minimum, average, maximum) on a monthly basis, allow an evaluation of the yearly oscillations (Table 2). Furthermore, specific climate extremes indexes[12] such us the number of frost,

[11] 2014 Eurostat Regional Environmental Questionnaire (REQ 2014)
[12] http://etccdi.pacificclimate.org/

summer or icing days, the number of tropical nights or the precipitation intensity index, could highlight changes in climate that can affect agriculture. Climate extremes indexes have been processed currently only for the thermo-pluviometric stations of region capital municipalities, while the analysis should be extended to the rural areas for the purposes of agriculture.

4. Conclusions

This work highlights how there is still a strong need of multidisciplinary statistical information for the study and analysis of interactions of all dimensions of CC impacts, to conceive adaptation strategies and to evaluate their effectiveness. Several international initiatives promote to enhance the production of high quality consistent, robust, relevant and international comparable statistics. The role of official statistics in the contest of NSS is recognized as crucial.

Existing statistics should become more usable for the analysis, investing in building and implementing harmonized methods and definitions, adequately transforming the overwhelming amount of statistical data available from several sources into comparable statistics; new statistics should be developed ensuring a coherent system at national and international level, suitable to meet the statistical information demand. NSOs have an important role in this contest; improving knowledge and awareness on emerging themes, providing internationally agreed guidelines and frameworks.

NSOs should strengthen their efforts to meet information needs. Proceeding step by step NSOs should make a review of their relevant data available adopting an integrated approach, considering all their sources of data both from surveys and registers. This relevant data should be organized in an combined mode. Istat already produces relevant data for the analysis of CC impacts and adaptation option in agriculture. Data are produced by the agricultural Census and by several surveys belonging to different statistical domains. It needs, immediately, an enlarged view of information, which no longer considers the various aspects individually, but that integrates information collected for different purposes. A global and integrated perspective is essential to approach multidimensional phenomena such as CC impacts and adaptation in agriculture. The most relevant areas refer to agricultural, hydrological, meteo-climatic statistics, but additional statistical domains could be relevant to explain all dimensions of the phenomenon. Besides the global and national scale, regional scale and georeferenced data are essential for the comprehension of the dynamics of the phenomena. Upstream planning of data collection, a review of the surveys, an exploration of the content of administrative archives, a joint activity between the various institutions that in various ways will have an active part in the construction and implementation of a CC Strategy, are certainly necessary activities so that - in the long run - the statistical offer could be considered robust, with an high social value.

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Giovanna Tagliacozzo, Simona Ramberti, Stefano Tersigni, Donatella Vignani (Istat)

A cross-reading of official statistics production to improve the analysis of Climate Change related phenomena

Rome 2015 – Science Symposium on Climate

http://www.rome2015.it/

Giovanna Tagliacozzo, Simona Ramberti, Stefano Tersigni, Donatella Vignani (Istat)

Il Censimento delle acque per uso civile in Italia (Anno 2012)

Il rapporto generale sulle acque: obiettivo 2020

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THEMATIC SET

F29

BIG DATA FOR AGRICULTURAL STATISTICS

Session Organizer
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ABSTRACT

Growing information needs and the tendency to reduce the response burden to businesses and households stimulate the search for alternative data sources which may supplement traditional sources like surveys, censuses, and administrative sources. During the last ten years, big data became the subject of quite a number of projects which experiment with substituting traditional data. This statement is probably understood although no clear and commonly accepted definition of the notion big data has been established so far. In the context of the session "Big data for agricultural statistics", reports on the use of data from the following data sources are welcome and of interest:

- e-commerce, e.g., portals of retailers, service providers, price comparison services
- commercial transactions, e.g., credit card transactions, scanners in supermarkets
- sensors, e.g., satellite imaging, environmental sensors, road sensors
- tracking devices, e.g., tracking data from mobile telephones, GPS
- administrative sources, e.g., insurance records, bank records, medical records
- tracks of human behaviour, e.g., online searches, online page viewing

The presentations may report on projects where the derivation of agricultural statistics is based on or supported by data from one of the mentioned data sources. Of interest are also presentations which report on innovative methods that allow for results which cannot be derived from traditional data.

The presentations should inform as much as possible on the following points:

- he used statistical method,
- the quality of the alternative data,
- the representativeness and
- other quality-aspects of the resulting statistics.

Having the general theme of the ICAS-7 in mind, statistics which allow the monitoring of sustainable development goals are especially welcome.

LIST OF PAPERS

Application of data warehouse and big data technology in agriculture in India
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B. Rater | USDA National Agricultural Statistics Service | Washington, DC | USA
M. Hyman | USDA National Agricultural Statistics Service | Washington, DC | USA
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Istat Farm Register: data collection by using web scraping for agritourism farms

G. Barcaroli | Istat | Rome | Italy
D. Fusco | Istat | Rome | Italy
P. Giordano | Istat | Rome | Italy
M. Greco | Istat | Rome | Italy
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Application of Data Warehouse and Big Data Technology in Agriculture in India

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ABSTRACT

In the recent years, it is observed that the scientist, planners, executives across the globe are using data collected from traditional record keeping by government agencies, data collected using sensors and satellite imagery technologies and combining it with predictive weather modelling. It is being done to help farmers to make better decisions with respect to optimal time of sowing/planting of the crops, optima time for application of pesticides, insecticides, and fertilizers starting with sowing, and time for harvesting crops in general and especially in a given region of the country at a given point in time. The technologies such as data warehouse/ big data are also being implemented to improve the quality of data since data provided by different arms of the government such as organizations of central government and state government varies a lot on many parameters and create problem in making right decisions. This is being done as part of digitization India program of central government. Keeping in view, the importance of quality and accuracy of data for planners, researchers, political leadership and farmers in particular, this paper presents various aspects of the data warehouse/ big data technology application in agriculture in the context of India. These aspects are (i) Identification of major domain of implementation of data warehouse/ big data technology in agriculture in India, (ii) identification of present status of application of data warehouse /big data technology and harvesting the benefits of the technology in India, (iii) identification and quantification of the benefits of the data warehouse/ big data technology application in increasing agriculture production or reducing losses to farmers (iv) identification of most popular data warehouse / big data technologies to be implemented in India (v) identification of targeted components of crop life cycle for data warehouse/ big data technology in agriculture in India, and (vi) impact of usage of technology and role of technologies such as data warehouse /big data in eradicating hunger or poverty from earth by way of helping farmers in increasing production and in maintaining ecosystem of the crops. The analysis being carried out by keeping in view irrigated and rain fed areas under cultivation in India and also changing climatic conditions which are impacting agriculture production in India.

Introduction

India's total area is 3.287 million km². The area under agriculture was 60.6% during 2013-14. Agriculture sector (Agriculture proper & Live stock, Forestry & logging, Fishing and related activities) accounted for 17.8%[1] of the GDP (gross domestic product) in 2013-14. It was more that 51% during 1950-51. The total production of agriculture sector was US$ 366.92 billion. Indian share in world agriculture output is 7.68%. About 50% of the workforce is employed in agriculture in India. Though the contribution of agriculture to GDP is steadily declining but still agriculture is demographically the broadest economic sector and plays a significant role in the overall socio-economic fabric of India. As per FAO 2010 reports, India was the world's largest producer of many fresh fruits and vegetables, milk, major spices, select fibrous crops such as jute, staples such as millets and castor oil seed. India is the second largest producer of wheat and rice.

Food security of India depends mainly on production of cereals crops. However, it needs to increase production of fruits, vegetables, pulses, and milk to meet the demands of growing population with rising income. India's priority areas in the context of agriculture are (i) higher productivity with optimal usage of water and other resources, (ii) poverty alleviation and management of natural resources, (iii) sustaining the cultivated land for future productivity and environment, (iv) reducing the waste of food grains and other agriculture produce, and (v) keeping the balance of prices of agriculture produces between producer and consumers, and many more.

The key to success depend on availability of quality data. The quality data can be captured / created, stored in times series manner, and analysed with technologies such as data warehouse, big data, data analytics, and reporting tools. To mention here as an example, Big data in agriculture refers to the Electronic Farm Records (EFR) which includes soil temperatures maps and data, precipitation maps and data, electrical conductivity maps and data, moisture content data, air permeability maps and data, nutrient contents and pH level data, past cultivation records, past losses, insurance and yield related information. It also includes social media data including tweets, blogs, new feeds, agriculture research reports and research articles in agriculture and other related journal. The technology will also help in mining the big data and discover the associations, understand patterns and past & future trends to improve the agricultural systems, accurate estimation of large number of input and output parameters, increase crop productivity in relation to changing input parameters, and reduction in input costs by accurate diagnoses and analysis of large numbers of factors effecting it.

Keeping in view the importance of quality data as suggested by Addison (2015), the present research paper is an attempt to (i) identify major domain of implementation of data warehouse/ big data technology in agriculture in India, (ii) identify present status of application of data warehouse /big data technology and harvesting the benefits of the technology in India, (iii) identification and quantification of the benefits of the data warehouse/ big data technology application in increasing agriculture production or reducing losses to farmers (iv) identification of most popular data warehouse / big data technologies to be implemented in India (v) identification of targeted components of crop life cycle for data warehouse/ big data technology in agriculture in India, and (vi) impact of usage of technology such as data warehouse /big data in eradicating hunger or poverty from earth by way of helping farmers in increasing production and in maintaining ecosystem of the crops.

[1] http://data.worldbank.org/indicator/NV.AGR.TOTL.ZS

The analysis being carried out by keeping in view irrigated and rain fed areas under cultivation in India and also changing climatic conditions which are impacting agriculture production in India.

Research Methodology

The present study can be termed as exploratory cum descriptive in nature. Research article is based on secondary as well as primary data. Secondary data is about application of data warehouse and big data technologies in agriculture and primary data collected from 20 villages of Aligarh District of State of Uttar Pradesh through group discussion method from farmers. This data was mainly about usage of machinery by the farmers, challenges of supply chain of agriculture produce, government initiatives, and their awareness about data collection by different agencies with respect to soil fertility, applications of fertilizers & pesticides and other inputs, existing practices adopted by farmers etc. The data is analyzed mainly in the form of frequency distribution.

Result & Discussion

Identification major segment of data warehouse/big data technologies in agriculture in India (1).

Big data / data warehouses technologies along with mobile technologies can be used in sourcing large set of data of agriculture sector activities, processing of this data, and generating valuable information for farmers, consumers, and government agencies from large set data. To be specific, Big data farming (or precision farming) is going to help farmers by offering to farmers (i) highly accurate weather forecasts and real time field data to optimize the resources & to reduce losses to farmers specifically in rainfed regions, (ii) real-time optimization of farming machinery, irrigation schedules, and other inputs, (iii) cloud-hosted cost effective information resources for farmers, (iv) automated irrigation and other farm practices recommendations, (v) monitoring the attack of insects, pest & diseases on crop with changing climatic conditions, (vi) monitoring of prices of agriculture produce before sowing and after harvesting, (vii) management of inventories of public distribution and its large & complex supply chains, (viii) monitoring of temperature, humidity, oxygen levels, and other needed parameters of food storage containers and shipment containers to maintain quality of agriculture produce before it is consumed, (ix) collection and analysis of post harvest field data for suggesting the activities with respect to maintaining the fertility of soil and making agriculture environmental friendly.

Identification of present status of application of data warehouse /big data technology and harvesting the benefits of the technology in India (2).

Four set of technologies are implemented in an organization to harvest the real benefit of information technologies. These are (i) technologies to source data/capture data/automate business processes, (ii) technologies to transport data from one place to another, i.e., from source to destination (Sylvester (2013)) (iii) technologies to integrate and store data, and (iv) technologies to analyse and report the data / information to consumer of information. Due to large size of the country as well number of organizations, implementation of all four set of technologies is not yet completed in India. In addition, implementation of technologies is easy in government owned organization but difficult in a segment which is not so organized. For example, meteorological department is collecting, analysing, and reporting information to users about meteorological parameters in general but not in relation to the cultivation of a particular crop in a particular region and its impact. Secondly, basic data of 105, 64,74, 292 citizens (80+% of population) is captured as part of Unique Identification Authority of India (UIDAI) project using data warehouse technology *(*https://portal.**uidai**.gov.in/). Thirdly, major procurement and distribution agencies such as Food Corporation of India and others are computerised for monitoring the inventory of food stocks on day to day basis (http://fci.gov.in/). There is a need to integrate various data bases in order to derive values to farmers out of this data.

Identification and quantification of the benefits of the data warehouse/ big data technology application in increasing agriculture production or reducing losses to farmers (3)

Many studies are conducted for identification and quantification of benefits of data warehouse / big data technologies. Madgavkar and Krishnamurthy (2014) estimated that technology based applications in agriculture in India will have US$ 45-80 billion impact annually as given in table 1. These estimates are not comprehensive.

Table 1: Impact of Technology based application on Indian agriculture (US$ Billion)

Sized Applications	Economic impact	Potential reach	Potential productivity or value gains
Hybrid and GM crops	1-4	10% of total of 92 million tones of farm produce under GM crops	5-10% productivity improvement
Precision Farming	8-30	20% of total arable land under precision agriculture	15-60% yield improvement 2ill help 22 million farmers.
Real-time market information	10-15	90 million farmers (60% of total) using real-time market information	3% productivity increase, 2.5% increase in price realization, input cost reduced by 3%.
Reduced leakage and Waste	27-32	$19 billion leakage in (PDS), $28 billion of non-PDS food waste	Up to 90% reduction in PDS leakage. 50% lower wastage in distribution of other produce.

Yield is a function of genetical characteristics of crops, environmental conditions & farm practices. The input variables are not independent. One need to develop predictive/ prescriptive models to optimize yield for a specific environment by optimizing farm practices for genetically different crops. This is possible only by conducted experiments, collecting and analysing data of these experiments. This will need in turn data warehouse/ big data technologies to store and analyse large set of data. It will result into many useful finding to boost agriculture at low cost. To mention, farmers in India usually burn residues of the rice crop after harvest in winter and of wheat in March-April. However, it is observed in adopted villages under Consultative Group for International Agricultural Research (CGIAR) project on Climate Change, Agriculture and Food Security (CCAFS) that zero tillage along with residue management and diversification of crops reduce the fertilizer requirement by a fifth after three years. Experimental data revealed that a tonne of rice and wheat residues, about 40% of which is carbon, contain 5-8 kg of nitrogen, 1-2 kg of phosphorus and 11-13 kg of potassium.
Further empirical studies confirmed an increase in yield by 10-15% with zero tillage and line sowing of wheat. Zero tillage reduces diesel cost by 80-85% (Seetharaman (2016)). This is not propagated in other part of the country due to non-availability of data in electronic form.

Identification of most popular data warehouse / big data technologies to be implemented in India (4)

Big data started with precision farming. Further, it can store data on fertilizer consumption (from production in factories and imports if any), planting (data are collated from different sources), crop protection (data are collated from different sources), harvesting and yield of crops (large number of crop cutting experiments & imaginary data). In addition data of 3rd parties on weather, data from satellite / aerial imagery (large amount of granular data is collected), data of soil fertility (not much data is collected), topographic data (large amount data is available with many companies), research & development data (data from academics & industry), land records and fertility data (data are collated from different sources), and data of machinery and equipments of manufacturers, data of commodity markets (local, regional and global), weather data can be integrated with big data technologies. Scope of these technologies is unlimited but major initiatives are needed (i) in storing data of all farm produces, (ii) data of live stock & fisheries etc, (iii) data of complete supply chain of farm produce, (iii) marketing and procurement, distribution policies and systems. It will help in reducing losses. Once it is achieved in a comprehensive way more initiatives should be taken to input side of supply chain.

To achieve these objectives government scientific organizations have taken initiatives in identifying utility and segments of agriculture sector for implementing these technologies. To mention, (i) Council of Scientific & Industrial Research (CSIR) has approached scientific community to work on research projects to prepare roadmap for big data technologies in India (http://www.dst.gov.in/big-data-initiative-1), (ii) National Agricultural Bioinformatics Grid (NABG) project at Indian Agricultural Statistics Research Institute (IASRI) launched in 2010, (iii) Advanced Supercomputing Hub for OMICS Knowledge in Agriculture – ASHOKA established during 2014. Peisker and Dalai (2015) suggested a frame work for agriculture sector once connectivity with households, villages, elected village level institutions, government departments is established. They reported that present sources of data are (i) kisan SMS portalsystem, (ii) Community information Center, (iii) AGMARKNET (http://agmarknet.dac.gov.in), (iv) e-choupal, (v) agriwatch.com. These sources may be further integrated and augmented. Channe et al (2015) proposed an approach based on five key technologies: Internet of Things, Sensors, Cloud Computing, Mobile Computing and Big-Data Analysis.

Precision Farming Development Centres (PFDCs) been established in India to promote "Precision Farming & Plasticulture Applications for high-tech horticulture" and located in State Agricultural Universities (SAUs); ICAR Institutes such as IARI, New Delhi; CIAE, Bhopal & CISH, Lucknow and IIT, Kharagpur. These centers have been operating as hub-centers of plasticulture and precision farming in respective states. National Committee on Plasticulture Applications in Horticulture (NCPAH) during the year 2008-09 established five new Precision Farming Development Centres located at Bhopal, Imphal, Leh, Ludhiana & Ranchi under the centrally sponsored scheme Micro Irrigation (http://www.ncpahindia.com/pfdc-mandate).

Identification of targeted components of crop life cycle for data warehouse/ big data technology in agriculture in India (5)

Data warehouse/ big data technology is needed during the complete life cycle of the crop but capturing data on all factors impacting yield is not possible with existing resources available with developed economies and specifically in India. With the existing data on rainfall, seed, farm practices, fertilizer, pesticides, insecticides production & imports, these technologies can target data on inputs and its analysis to extend full advantage of moisture content of soil as well as life in days of the crop. Second, life cycle to be targeted for data collection and analysis is post harvest period. Initial cycle will help in reducing cost of cultivation and post harvest will reduce losses of supply chain.

Impact of usage of technology such as data warehouse /big data in eradicating hunger or poverty (6)

This section presents problems of supply chain of agricultural produce and other related problems and the technologies used by farmers not necessarily data warehouse and big data technologies. These findings are based on primary data collected from Aligrah District (Northern part of India) mainly on three themes. The findings on these themes are listed in the following:

(i) Usage of farm machinery: Indian farmers have started using machinery at their fields. The popular ones are tractors, walking tractors, combine, laser levellers, and other farm farm equipment to open furrows in the ground, shredding, spraying and fertilizing the soil. In many cases machinery is replaced by services provided by farmers from State of Punjab. In the recent years due to increase in cost of diesel, almost all farmers have applied laser levellers and auto start switches for water pump sets. They are also using tractors, combine but not much is employed for data collection. Data collection is either manual or through imaginaries.

(ii) Supply chain of Agri-produce and challenges: Indian agriculture supply chain is spread in large geographical area. The agriculture produce are grown in specific geographical areas and sold by farmers either to government agencies, whole seller or retailers in other parts of the country. Road transport is major mechanism to transport agriculture produce for shorter distance and rail for longer distance. The agriculture markets are not yet developed in smaller towns, & district headquarters. Major movements are between large markets.

Based on analysis of data collected form 20 villages from Aligarh district (State of Uttar Pradesh) it was inferred that (i) every farmer brings its produce specifically grains, fruits & vegetables, milk etc to the centers listed in fig 1 (Khair, Atrauli, Khurja, Iglas, Manai, and Aligarh) with no advance information about demand-supply and price variations. Another group of consumers (farmers & non-farmers) come to these centers to buy the same produce from these towns at a high cost due to market taxes, and transportation costs etc at other time (ii) all storage facilities are located in these towns which in turn increases transportation costs and also loss of work at home, (iii) in many cases the farmers bring their produce to nearby state of Delhi which operates a larger markets and small traders buy the same produce from Delhi markets & do retailing in the small towns which are much nearer to producer farmers. It results in to higher transportation cost to traders & farmers, (iv) most cases return to the farmers are not linked to quality of the produce in many cases, as they cannot pack or certify their produce as organic and inorganic (v) farmers are guided by resources available, and advise of local traders or peers with respect to usage of fertilizers or pesticides rather than scientific methods, (vi) their knowledge about residual effect is very low, (vii) crop rotation is limited to wheat & paddy and in other segments potato & paddy, (viii) all farmers burn residues of wheat, sugarcane, paddy, maize with no interference from experts, (ix) farmers are not much aware of data collection activities by any agencies for the purpose of new research initiatives, and (ix) invest lots of resources in tillage which is not needed specifically in paddy.

Fig 1: Map of Aligarh District (Uttar Pradesh)

(iii) Making government initiatives more effective & beneficial to farmers.

Indian government protects the farmers by fixing minimum support price for major crops every year. Government agencies (Food Corporation of India, State corporations etc.) procure major food grains directly from farmers every year as part of its food security program to provide major food grain to the weaker sections of the societies though public distribution systems. Government has implemented information technology based systems for capturing data of the activities of these organizations but integration of data among these agencies is still needed. As mentioned, earlier all data of benefits of government schemes is linked to Aadhaar card (UIAI) and also to the bank account of farmers. It has reduced leakage of government monetary help to the farmers.

Concluding Remark:

It is beyond doubt that application of data warehouse / big data technologies will help all members of eco-systems. Quality data is vital for growth of agriculture in India. Government has taken many initiatives for capturing data and making use of it. The success is achieved in relation to collection and analysis of (i) weather data, (ii) forecasting area under different crops & yield using remote sensing application, data of crop cutting experiments, and data collected by state irrigation departments etc, (iii) data of procurement of food grains & vegetables, storage centers, public distribution systems etc, (iv) data generated academic/research institutions, (v) information about shelf life of the produce and many more segments of eco-system.

What is needed? Integration of all these data sets using data warehouse and big data technology for the purpose of analysis to make concept such as precision farming realty. Most of data used in research is generated from big agricultural universities and institutions farms where resources are available in developing new varieties etc but this is not the case with farmers. Experiment must incorporate some constraints to see the potential of new varieties or new practices. This will be possible in a country like India with private sector development in developing such technologies, public and private collaboration in implementation, and government support and investment as in case of some other sectors (World Economic Forum (2012)).

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Exploring a Big Data Approach to List Building

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ABSTRACT

The US Department of Agriculture's National Agricultural Statistics Service (NASS) has the responsibility of quantifying the nation's agricultural production. Historically it has focused on large, production agriculture. With increased interest and activity in the urban areas, NASS has begun exploring how to better quantify urban agriculture. This segment of agriculture is particularly challenging to enumerate because the agricultural holdings tend to be small, widely dispersed, and more transient than the predominantly large farms in rural areas. In collaboration with the Multi-Agency Collaboration Environment (MACE), a new approach to list building was explored in a pilot study conducted in the City of Baltimore, Maryland. Using a big data approach, areas of potential agricultural activity were identified by gathering information (state and local permits, facebook and twitter feeds, interest groups, *etc.*) via the web. A sample was drawn from the list, and an in-person survey was conducted to assess whether or not the identified areas were producing agriculture. Here the lessons learned from the study and next steps are discussed.

Keywords: urban agriculture, list building, web scraping

1. Introduction

Urban agriculture has been of increasing interest at the local, state, and national levels. Some cities, such as Detroit, Michigan, have goals of increasing their food resiliency by growing a large portion of the fruits and vegetables used by their citizens within the city limits (Colasanti, *et al*. 2010). Cities have also promoted urban agriculture to ensure that the vacant lots, abandoned buildings, and other under-utilized land are used productively (Goldsmith 2014, Santo, *et al.* 2016). Urban agriculture takes a variety of forms including backyard gardens, school or community gardens, urban farms, greenhouses, hoop houses, converted warehouses, and vertical gardens. At the local level, policies favourable to urban agriculture have been developed, access to land has been facilitated, and sometimes funding can be obtained to initiate agricultural activity. Federal funding programs for urban agriculture, such as The New Farmers and People's Garden Initiatives, have been established. The US Department of Agriculture (USDA) has developed a website with a wealth of information, including more funding opportunities, for urban farmers (USDA 2016). Organizations focused on urban agriculture have also been developed. These efforts have naturally led policy makers at the local and national levels to ask whether or not the programs are effective in increasing urban agriculture.

Although USDA's National Agricultural Statistics Service (NASS) has always included urban farms in its counts of farms and farm production, the estimates have not been as precise as those for other sectors of the agricultural economy. Because urban agriculture is responsible for a small portion of the total farm production, NASS has not devoted the resources—and has not had the resources—needed to provide better estimates. Policy makers at all levels are increasingly interested in the efficacy of programs designed to increase urban agriculture. Thus, the Under Secretary for USDA's Research, Education and Economics asked NASS to explore ways to better quantify the extent and food production of urban agriculture.

Urban farms tend to be smaller, more diverse, more transient, and more widely dispersed than the more traditional farms in rural areas of the U.S. This makes these farms challenging to identify and thus to quantify. The NASS list frame is thought to have substantial under-coverage of urban farms. During the 2012 Census of Agriculture, capture-recapture methods were employed to adjust for under-coverage, non-response, and misclassification, using the NASS Census mailing list and a sample from the NASS area frame, as the two independent samples (Young, *et al.* 2012). For a survey of urban agriculture, a sample from the NASS list frame, which is a list of all known confirmed or potential farms in the US, could serve as one sample in a capture-recapture analysis. However, it is cost prohibitive to obtain sufficient numbers of urban farms in a sample drawn from the NASS area frame because these farms tend to be dispersed (not concentrated) within the urban areas. Thus, NASS began to explore alternative ways to build a list of urban farms that would be independent of the NASS list frame, provide good coverage, and be relatively inexpensive, as a foundation for a second sample.

Taylor and Lovell (2014) identified potential areas of urban agricultural activity in Chicago, Illinois, from high-resolution aerial images in Google Earth in conjunction with ArcGIS. First, lists from several non-governmental organizations were combined to identify 1236 potential community gardens in Chicago. The sites were visited in 2010, and 12.9% were found to be food gardens with the others being ornamental garden/parks, a streetscaping projects, or no garden. The confirmed food and non-food gardens were analysed to develop a visual classification approach to classifying urban agriculture. Then the Google Earth images of Chicago were analysed visually, and 4493 potential areas of agricultural activity that were not included in the 1236 areas on the lists were identified. In a follow-up survey of 194 of the sites, 166 (89.6%) were found to have agriculture on them.

Although the methods used by Taylor and Lovell (2014) were effective for identifying urban agricultural sites, the approach was labor intensive, and it would be cost prohibitive when scaled to the national level. Thus, NASS began to consider ways in which to automate the approach. The results of that effort are presented in this paper. In Section 2, the target population for a national urban agricultural study is defined. A pilot study of a new approach to identifying urban agriculture in the City of Baltimore, with considerations for national implementation, is described in Section 3. The final section reviews the lessons learned and future directions.

2. Urban Agriculture

Historically, urban agriculture has not been reported separately; it has been combined with all other types of agriculture. To report on it separately, urban agriculture had to be defined so that an operation can be unambiguously identified as either being or not being urban agriculture. After consulting with the USDA's Economic Research Service, agriculture within the urbanized areas, as defined by the US Census Bureau, was defined to be within the target population (see Figure 1).

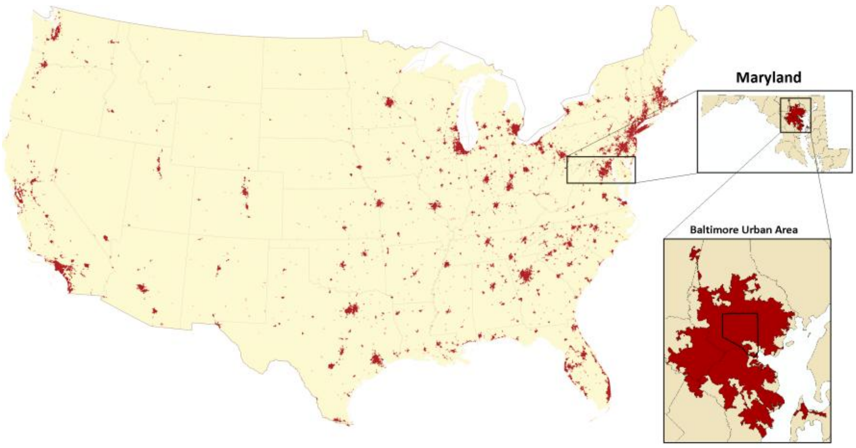

Figure 1: *Urbanized areas within the US (left), area of pilot study within US (upper right), and Baltimore City boundaries contrasted with Baltimore urbanized area (lower right)*

Then consideration turned to what should be included as agriculture within these urbanized areas. In the US, the definition of a farm is any operation that produces and sells or has the potential to sell $1000 or more of agricultural products in a year. Thus, an individual with a large backyard garden who sells the excess produce at a farmers market is a farmer if the produce sells for at least $1000 over the course of a year.

Community gardens are a common form of agriculture occurring in urbanized areas. For these types of operations, NASS has traditionally considered each plot as an operation, which either qualifies as a farm and is counted or found to not qualify as a farm and is not counted. Often none of the plots produces enough to qualify as a farm even though the total production of the community garden could well be enough to be classified as a farm. This could contribute to the perception that NASS is not fully reporting agricultural activity in urban areas. Thus, for the purposes of the pilot study, all agriculture was considered, but the entities meeting the definition of a farm were to be reported separately from those that did not qualify as a farm, such as ones that produced food only for home consumption.

What types of urban agriculture were within the target population? Community and school gardens were included as well as animal production, such as bees and chickens. In many urban areas, abandoned warehouses have been converted for agricultural production, which were part of the target population. Greenhouses on the top of buildings, production in hoop houses, and aquaponics were also determined to be within the scope of urban agriculture.

What types of entities were not included in the target population of urban agriculture? Gardens on the top of buildings for enjoyment and not for production were excluded. Plants grown in window boxes or in pots on the porch were excluded. Also, mobile gardens, such as those on the top of a bus or in the bed of a pickup, were not in the target population.

3. City of Baltimore Pilot Study

A pilot study was conducted in the city of Baltimore. Recent city urban agricultural initiatives include the Baltimore Office of Sustainability's Land Leasing Initiative, the Urban Agriculture Tax Credit, and the Urban Agriculture Training Program (Baltimore Office of Sustainability 2016). With a plethora of vacant buildings and vacant lots, Baltimore City is focused on redevelopment strategies for the city's land use policies and on greening initiatives, such as urban agriculture. Based on available funds, the study area did not include the full urbanized area of Baltimore but was restricted to the City of Baltimore (see Figure 1).

To build a list of agricultural areas within Baltimore, NASS collaborated with the Multi-Agency Collaboration Environment (MACE). MACE is a consortium of Government agencies and contractors that solves complex data problems. In collaboration with the Air Force Research Laboratory, they explored the use of text and image analytics to create a list of urban farms within the City of Baltimore.

Traditional imagery analysis techniques were found to not be useful for automatically identifying the small areas of agriculture common in urban farms. The satellite imagery available had a 0.5-m resolution. An example of that imagery is provided on the left side of Figure 2. On the right is a 15-cm aerial imagery of the same area. (The green dots are at the same point in space on each.) The human eye is more effective than algorithms in detecting items within imagery. The agricultural activity evident in the 15-cm imagery is not visible in the 0.5 satellite imagery. Thus, satellite imagery was found to not be useful for this purpose. With the aerial imagery, the presence of agriculture is evident, and automatic identification is potentially possible. However, the aerial imagery was prohibitively expensive for NASS, so NASS was unable to take advantage of either satellite or aerial imagery. Therefore, the MACE list was based on the web-scraping techniques associated with the text analytics.

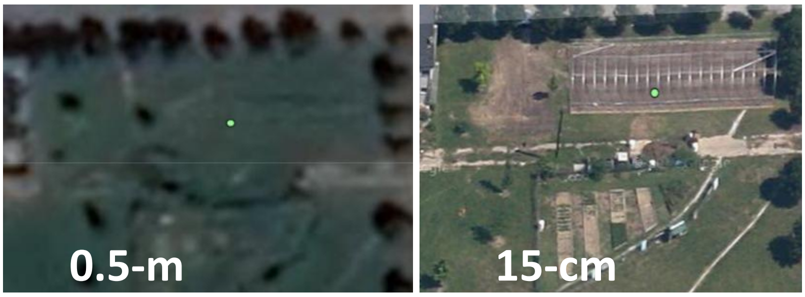

Figure 2: *Comparison of visibility of agricultural area using 0.5-m satellite imagery (left) compared to 15-cm aerial imagery (right). The green dots are at the same point in space.*

MACE identified 505 areas of potential agriculture. The City of Baltimore had a 2013 list of areas of agricultural activity that was not available for the development of either the NASS list frame or the MACE list. Of the 159 non-school garden areas on the list, one was on the NASS list frame, and 89 were on the MACE list. The NASS list frame has only farms and potential farms while the MACE list is broader, including agricultural activity of any size. This could explain some of the difference. However, Baltimore's list included 13 urban farms; one of those was on the NASS list frame; the MACE list included all 13 farms.

To further evaluate the MACE list, an in-person survey was conducted to assess whether or not the identified areas had agricultural activity. A random sample of 266 of the potential areas were selected. For the community gardens, efforts were made to sample the plots within the community garden. Only 12 of the plot surveys were completed in six community gardens. It was extremely difficult to identify the plot operators for an interview; finding the manager or coordinator of the community garden was much easier. It became clear that interviewing the operators of the individual plots would be cost prohibitive. Of the 266 sites, 71% (188) of the interviews were completed. In 21% (73) of the cases, the operator could not be found, and there was a 2% (5) non-response rate.

If the operator could not be contacted, the interviewer was asked to make an effort to observe whether or not agriculture was present. In 5% of the cases, the presence or absence of agriculture could not be ascertained from either an interview or observation. For about half (52%) of the sites, agriculture was present. During the 2012 census, half of the operations on the list frame were identified as farms; the other half were non-farms. Of course, some of those on the MACE list identified as having agricultural activity were not farms.

From the 188 completed interviews, 108 unique operations were identified with agricultural activity. Backyard or home gardens (34), school gardens (29), and community gardens (20) were the most common types of operations. Urban farms, vacant lot gardens, roof top gardens, aquaponics, hydroponics, and a commercial enterprise were also present.

People grew a variety of produce on urban agricultural sites, with fruits and vegetables being most common, but a sizeable proportion raised or kept farm animals and produced animal products. As one would expect, the areas dedicated to agriculture tended to be small, with about 2/3 having an area of less than 1000 square feet.

3. Results and Discussion

Several lessons were learned from the pilot study. Only areas of at least 36 square feet were considered during the pilot study because it was anticipated that satellite imagery would be used to identify agricultural sites in urban areas. Since satellite imagery did not prove to be useful at the 0.5-m resolution available, the minimum area requirement has been dropped for future work.

Although people could generally report the total area available for agricultural activity, they had difficulty specifying the land devoted to each purpose, such as tomatoes, peppers, bees, *etc*. Many were unable to quantify the amount of agricultural products produced, either in terms of weight or in value. This was particularly true for those who sold no produce. Thus, if the full range of agricultural activity is to be reported, it would be best to separately quantify those agricultural operations that qualify as a farm and those that do not. In addition, the questionnaire should undergo extensive testing and perhaps revision so that the respondents can provide more accurate data.

Community gardens are challenging. Whereas few, if any, plots qualify as a farm, the total output of the community garden may qualify as a farm. Although each individual plot may be correctly classified as a non-farm for all community gardens within an area, it may be perceived that the contribution of community gardens is under-estimated. Reporting the activity for the community gardens instead of the plots within the gardens would result in another set of challenges. In particular, reporting the demographics of those engaged in urban agriculture would be difficult. The manager of the community garden may not have the demographic details of the plot operators, such as age, sex, race, and ethnicity of the individual plot operators.

Although the list building approach has good potential for providing the foundation for improved estimates of urban agriculture, funding will not be available for an enhanced urban agriculture effort during the 2017 Census of Agriculture.

The web scraping approach to list building is being used for the NASS 2015 Local Foods Marketing Study, and local foods producers tend to live in or near urban areas. The MACE list is used to draw a second sample in a capture-recapture framework with the first sample coming from the NASS list frame. The data from the local foods study will provide good insights into the viability of this approach to list building.

A pilot study in the state of Washington is being conducted to explore the use of web scraping to build a list of small farms. Three NASS staff are working with MACE personnel for this project in an effort to build capacity for web scraping within NASS. In general, identifying all types of small farms continues to be a challenge. For the 2012 US Census of Agriculture, capture-recapture was used to adjust for coverage, non-response, and misclassification. Two independent samples were the Census mail list and the June area frame. Could web scraping be the foundation for a third sample? Finally, some challenging methodological issues need to be addressed if this listing building approach is to be used, along with a capture-recapture approach. For example, it is likely that the probability of capture varies with list.

With constant pressure to provide statistics on emerging sectors of agriculture in short time frames, it is important to identify new, cost-effective approaches to addressing the questions of interest to policy makers and other stakeholders. Web scraping, technology, and secondary data sources for this purpose may be tools that are used increasingly.

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Big Data for the National Agricultural Census,Colombia2014

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ABSTRACT

National Statistics Offices (NSO) are including new information sources, as Big Data, specifically Earth Observation (EO) data into their production processes, in order to improve official statistics for different subjects. Under this approach, DANE, the NSO of Colombia, carried out a pilot project to complement the information on land cover for the agricultural statistical framework of Colombia in three municipalities of the Atlántico department and their multi-temporal analysis. Processing was carried out with available Landsat satellite images for the years 2005, 2010 and 2014 usingErdas, InterIMAGE and ArcGIS software. As a result, the variable land cover was imputed for the 20% of the agricultural statistical framework units without information. It is concluded that, in order to get more disaggregated coverages, further research must be done including higher resolution images and multi-temporal analysis in periods shorter than one year.

Keywords: Satellite images, land cover, object-basedimage analysis, data imputation.

1. Introduction

43 years after the realization of the last agricultural census in Colombia, and with the aim to know the present situation of agriculture and livestock in the country, during 2013 and 2014 DANE carried out the third National Agricultural Census (CNA for its acronym in Spanish).During the country-wide field collection process more than 113 million hectares were covered, in the 1101 municipalities distributed across the 32 departments that integrate the country.It is important to highlight that besides the administrative division of the territory, 181Afro-descendant communities' lands, 773 indigenous territories and 56 national natural parks were included in the census operational design.

Nevertheless, census coverage was under 70% in some municipalities because of:

- Inability tocontact producers orsuitable informants.
- Uninhabited properties.
- Inaccessibilitydue to geographical and public order conditions
- Rejection to census enumerators.

Following these shortcomings and for the construction of the National Agricultural Framework, DANE carried out a pilot project to complement the information about land cover using Big Data specifically remote sensing data.

Big Data is defined as "*any large and complex collection of data sets that becomes difficult to process using traditional data processing applications", and therefore includes data from Earth Observations satellites. In many cases Big Data is considered to be unstructured data or data that is used for another aim than the original creator of the data intended. In the case of Earth Observation it is actually purposefully created to be highly structured and to measure specific aspects of the earth. The complexity of EO data is to extract a meaningful form of information about a real object, value, state or condition from an electromagnetic signal measured in space"*(Task Team Satellite Imagery, Remote Sensing and Geo-spatial data, 2016).

Through the extraction of land cover data from satellite images, the goal is to impute the variable "land cover" for the analysis units of the National Agricultural Framework. This will provide detailed and high quality agricultural statistical information for policies formulation and implementation, as those currently is being implemented in Colombia, for example the Land Law and Rural Development.

2. Background

National Agricultural Census - CNA

CNA was conducted during 2013 and 2014, to collect information about agriculture, forest, aquaculture and fisheries;as well as socio-demographic information fromagricultural producers and rural inhabitants. This was a declarative census, in which information was provided by suitable respondent, who knowsabout the activities undertaken at each observation unit. The census analyticalunit is the Agricultural Production Unit (UPA for its acronym in Spanish)which is defined as the area in which a single producer[1] makes decisions and takes responsibility over the productive activity. The UPA has no size limits, and it can be formed by part of a rural property, a complete rural property, or a group of continuous rural properties.

The National Agricultural Framework is a spatial representation of the UPAs and non-agricultural units (UPNA) located in rural area; and therefore, it is the basis for sampling design in agricultural surveys and any statistical operation with rural domain.The Framework includes information about thelocation (X, Y coordinates), identification (property code and politic-administrative information), and agriculturespecificdata from each unit.Given the importance of the framework for DANE regular statistical production, the information of the 3rd National Agricultural Census is fundamental for updating this tool.

Based on the information from the 3rd CNA, ten classes for land use and land cover were stablished, which are grouped into six categories (Table 1). For each UPA was assigned a predominant land coverage defined by the coverage whose participation percentage is equal or greater than70% of the UPA total area. If the condition was not fulfilled, 'mixed' predominant coveragewas assigned.

[1]The concept of agricultural producer includes individuals (natural person), as well as companies or formal partnerships (legal person)

GENERAL CATEGORY	CLASS	DESCRIPTION
Temporary	Temporary crops	"Temporary crops are those which are both sown and harvested during the same agricultural year, sometimes more than once." (FAOSTAT, 2015)
	Fallow land	Area that had crops during the last 12 months, but had no crops the day of the interview.
	Roosting area	Area that had crops in the last 3 years, but had no crops in the 12 months prior the interview.
Permanent	Permanent crops	"Permanent crops are sown or planted once, and then occupy the land for some years and need not be replanted after each annual harvest." (FAOSTAT, 2015)
Grassland	Grassland	Land on which the vegetation is dominated by grasses, glasslike plants and herbaceous.
Non-agricultural	Non-agricultural	Land where the properties are dedicated to develop non-agricultural activities, such as industry, commerce and services.
Forest land	Forest plantation	"Forest stands established by planting or/and seeding in the process of afforestation or reforestation" (FAO, 2016).
Other land cover and uses	Other land cover	Soils covered by natural waters, *páramo* vegetation, bare soil, rocky outcrops, opencast mines, etc.
	Stubble	Land area where more than three years have passed since last crop and is covered by shrubby vegetation. Census day had no crops.
	Natural forest	Land with different classes and associations of trees, shrub, herbaceous, and other plants which are not classified as a forest plantation.

Table 1. Land use and land cover categories for the National Agricultural Framework.

Related works

Remote sensing in agriculture has been applied since the seventies, covering a wide variety of fields (Carfagna, 1999), (Hanuschak & Delincé, 2004) and (Gallego, 2006); among them, vegetation monitoring and land cover mapping is highlighted.

Other remote sensing applications are related to the survey design (sampling frame and stratification), crop identification, planted areas estimation, crop status in large areas and production estimation. Remote sensing complemented with GIS exhibits great potential for creating information layers on crops that may include location at a centimeter scale for precision agriculture (Craig & Atkinson, 2013).

Furthermore, United Nations Statistics Division has recognized the need for further investigating the benefits and challenges of using Big Data for official statistics. To address this matter, the Working Group on Satellite Images and Geospatial Data was established in 2014; in this context,several pilot projects were developed, including the application of remote sensing for agricultural statistics production, presented by the Australian Bureau of Statistics (ABS).

3. Methodology

In order to impute the information on land use and land cover to the UPA that lacked of this information,a remote sensing methodology was implemented. In this case, the steps were as follows:

Step 1. Defining the area of study. Three main considerations were taken into account:

- Municipalities that include at least three general categories of land cover defined by the CNA.
- Municipalities with slope less than 20° (to avoid topographic correction on the images)
- Municipalities that show natural and/or anthropic precedents of changes on land cover that could be of interest for a multi-temporal analysis.

Three municipalities metthese criteria:*Campo de la Cruz, Santa Lucía and Suan*, located on the Caribbean coast, northern Colombia (Figure 1).

During 2010 - 2011 an intensive rainy season generated floods and landslides in different zones of Colombia. One of the biggest effects was generated by the rupture of the *Canal del Dique*dike, which caused flooding in several towns, including the ones chosen for the study.(CEPAL, 2012).

Figure 1. Study areais 852 km^2 (828 km^2 rural area).

Step 2. Satellite data selection. The imagery acquisition was done under these criteria:

- Total coverage of the study area, to avoid the need to generate a satellite mosaic[2].
- Similar sensors for the years 2005, 2010, and 2014.
- Images taken over the same area and the epoch of census field work(2014, first trimester) for 2005, 2010, and 2014.

The Landsat images met those criteria and they were downloaded free of charge from the Earth Explorer website[3] (United States Geological Survey, USGS)see Table 2.However, Landsat 7 images captured since May/2003 have gaps generated by a failure in the SLC sensor. Therefore, a filling procedure was done by using two images from the same sensor.

[2]A mosaic is one image created by merging several individual images of adjacent areas.

[3]http://earthexplorer.usgs.gov/

Program/Sensor	Path-Row	Date
Landsat7ETM+	9-53	23January2005
Landsat7ETM+	9-53	24February 2005
Landsat5TM	9-53	29January2010
Landsat8OLI	9-53	9February2014

Table 2.Landsat imagery chosen for the project

Step 3. Satellite images pre-processing.This procedure included the following activities:

- Filling the gaps for the 2005 images.The Phase 2 Gap-Fillalgorithm proposed by the USGS and NASA was used. This algorithm fills the gaps of one primary image using another image with valid data in the gap zone.A pixel with no data from the primary image is replaced by the adjusted value of same pixel of the secundary image.The pixel is adjusted using the value of the standard deviation and mean of neighboring pixels (valid pixels in both images). Every spectral band was processed separately.

- Layerstacking. This procedureconsistsof the combination of multiple separate bands in a single image. As the number of bands of the Landsat sensors (ETM+, TM and OLI) is different, only the bands common to all images were used. In this project, this process was made with the *"Layer Stack"*Erdas's tool.

- Defining LANDSAT image subset.A portion of a larger image was generated covering the study area.

- Radiometric resolution scaling:The Landsat image for 2014 has a radiometric resolution of 10 bits, and the 2005 and 2010 images have an 8 bits value. Since it is desirable to have all the images in the same rank of digital levels, a scaling radiometric resolution procedure was applied to the 2014 image to ensure the same radiometric resolution, i. e. 8 bits.

Step 4. Satellite images classification

Digital image classification involves grouping pixels to represent land cover features. There are several image classification methods and for the purposes of this project, object-based imageanalysis was chosen.

This methodis carried outthroughtwo general procedures:

- Image segmentation: This process creates objects by grouping similar pixels. It starts with each pixel forming one image object, which is sequentially merged to formbigger ones.For this process, the TA_Baatzsegmenter algorithm, which creates objects based on colour and shape (Baatz& Schäpe, 2000), was used, along with the InterIMAGE free software.

- Classification: In this process, each image object is allocated to a particular class, according to the criteria and rules defined.

Step 5. Global accuracy assessment.

To evaluate how well the classification represents the real world, the following taskswere executed:

- Estimation of the sample size (n) by using the binomial distribution formula.(Rossiter, 2014).

$$n = \frac{Np(1-p)}{(N-1)\frac{d^2}{Z^2_{(1-\alpha/2)}} + p(1-p}$$

Where:

n s mple size.
N universe (total image objects)
D sampling error (5%)
A confidence level (95%), and
p *apriori* precision (90%)

- Distribution of the random sample with the "create random points" ArcGIS tool.
- Visual classification of the sample, using Google Earth and orthophotos, taken as close to the date of the satellite images as possible.
- Comparison between visualand automatic classifications (InterIMAGE results) for sample points.
- Estimation of the coincidence percentage between the visual and automatic classification.

Step 6. Data Imputation.

To impute land cover information to the UPAs with no data, a model was implemented using ArcGIS tools. The model takes the land cover map obtained from the image automatic classification, and split the map into UPAs. As a result, every UPA without land cover information was allocated a predominant land cover.

Step 7.Change detection

In order to quantify the changes in land cover during the period of study, a pixel by pixelcomparison was conducted between the 2005 -2010, and 2010 -2014land cover maps. As a result, a change detection matrixwas created; which is a table that allows to measure changes among different land-cover/land-use classes over a time period (Jensen, 2005).

4. Results and discussion

The classeswere defined considering the CNAgeneral categories (Table 1). Nevertheless,the categories "permanent crops" and "forest" were excluded due to their small area size and quantity. The non-agricultural land category cannot be identified by satellite images, since it is mainly related to industry and services uses.

Table 3 shows the decision rules defined to classify each objects into the land cover categories. The objects which did not meet any decision rule were assigned to the Temporary category.

General category		**Decision rule**		
		2014	**2010**	**2005**
Oher land	Water	ratio(band5)<0.21	mean(band4)≤ 50.4	mean(band4)≤ 53.5
cover and	Bare	bandMeanDiv(band5,band2)<2.3	mean(band1)> 83.5	mean(band1) ≥89
uses	soil	ratio(band5)≥ 0.21		ratio(band5)<0.228
	Stubble/ Natural Forest	ratio(band5) ≥0.32	mean(band2) ≤ 37 mean(band4)> 50.4	mean(band2)≤ 80 ratio(band2)<0.2
Grassland		ratio(band3)>0.11 ratio(band5)≥ 0.21	ratio(band5) ≥0.285	ratio(band5) ≥ 0.228

Table 3. Decision Rules used in each year.

The global accuracy of the classification for each yearis presented in Table 4. The highest accuracy was obtained for the year 2014.

Year	Samples	Coincidence percentage
2005	135	57%
2010	135	70%
2014	136	84%

Table 4. Global accuracy of the classification.

Figures 2, 3 and 4show the land cover distribution for the years 2005, 2010 and 2014.

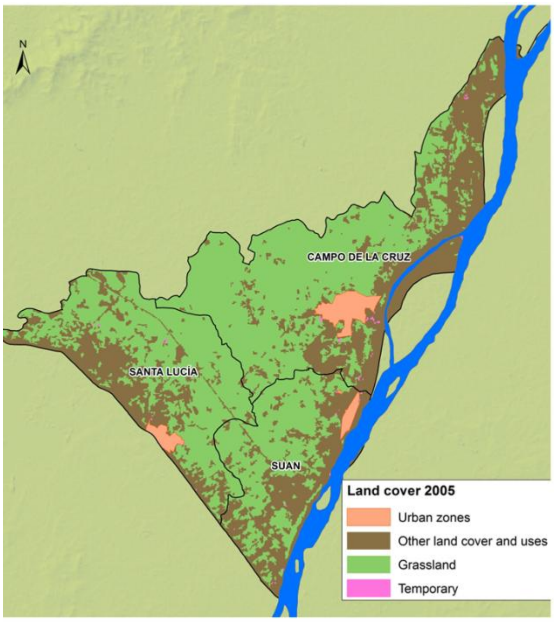

Figure 2. Land cover year 2005

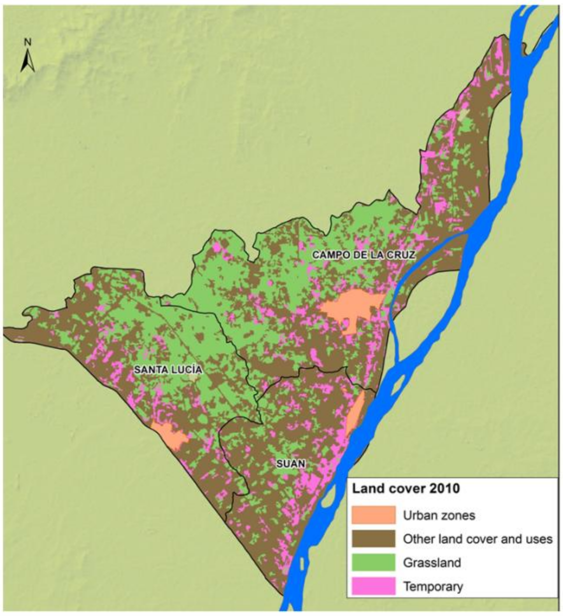

Figure 3. Land cover year 2010

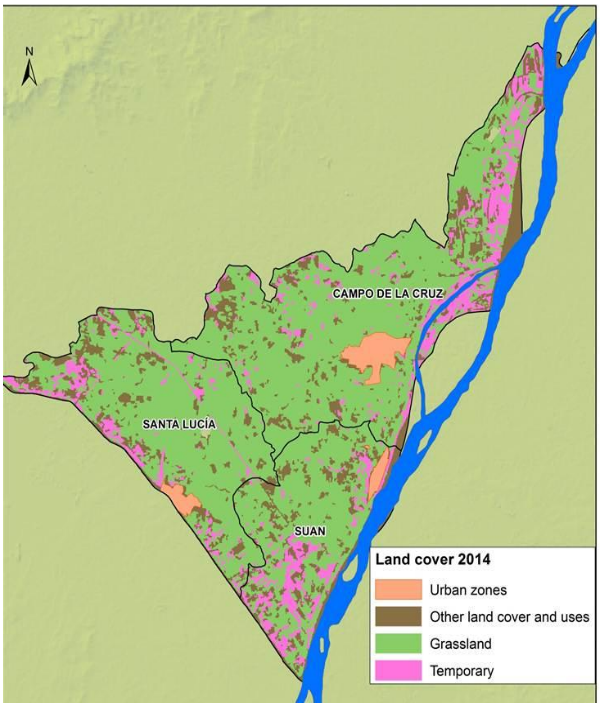

Figure 4. Land Cover 2014

With the 2014land cover map obtained from classification,it was possible to impute the predominant land cover to598 UPAs without census information (out of 2.975). Figure 5 shows the land cover map obtained from census results and imputation. Grassland areas are prevailing in the three municipalities;temporary and permanent cropsareas are located mainly in Suan and the riverbank.

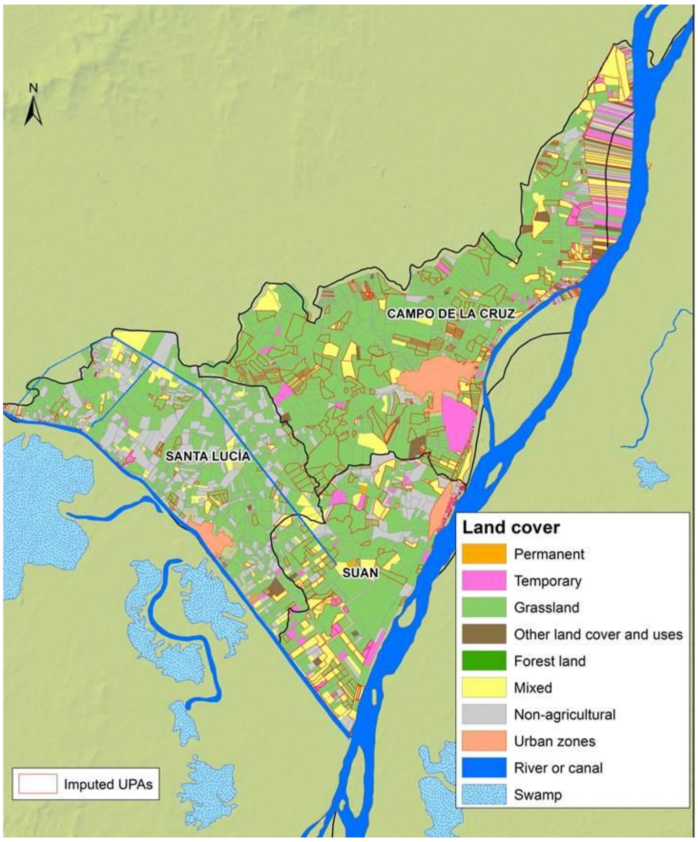

Figure 5. Predominantcoverage by UPAs. 2014

Once the post-classification and comparison methods were applied, changes were detected asreportedin Table5. From 2005 to 2010, there was an increase in land classified as 'Other land cover and uses', which includes Stubble and Natural forest. However, the most significant land cover changes are identified during the period 2010-2014, asit shows an important increase in grassland, and decrease in Oher land cover and uses.

2005-2010	Temporary	Grassland	Oher land cover and uses
Temporary	22%	17%	61%
Grassland	9%	46%	45%
Other land cover and uses	13%	11%	76%

2010-2014	Temporary	Grassland	Oher land cover and uses
Temporary	8%	79%	12%
Grassland	6%	86%	8%
Other land cover and uses	16%	58%	25%

Table 5. Change detection matrix.

A possible explanation to the 2005-2010 phenomenon is that during this time, the more common crops were scattered mango and guava trees. Due to the characteristics of these crops, they were classified as Stubble and Natural forest. It concludes that patterns of fruit trees and Other land cover and uses are similar. The increase in this category can be related to the rise of fruit trees.On the other hand, for the 2010-2014 changes, they might have been caused by the 2010 -2011 floods, as this climate phenomenon and the subsequent increase in soil moisture, may have induced a faster degradation of agricultural and productive soils.

5. Conclusions

Satellite images are a valuable source of information on land cover and they provide suitable complementary information for areas where field data are not available.More detailed results require satellite images with higher resolution (spatial and spectral) preferably collected at different months during the same year. This could be useful to make decisions based on productive cycles (temporary or permanent), crop areas, sowing and harvest periods, and to improve the results of the CNA.

The study results prove the change detection matrix to be an useful tool to measure changes in land cover; however its precision depends on the classification accuracy. In addition, it is important to highlight that an adequate use of image classification methods requires knowing the study area, in order to correctly define land cover classes and decision rules. Also, although the classification software InterIMAGE is of free access and easy to use, documentation on it use is limited.

In addition, it is important to explore remote sensing automatic techniques that allow replicate the process in other areas of the country. This could lead to face new challenges as dealing with images and algorithms for cloudy areas, development of topographic correction methods and assessment of computational efficiency for Big Data.

Finally, it was prove that Big Data from satellite imagery is considered a powerful tool to overcome lack information, and with greatpotential for the usein National Statistics Offices.

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ISTAT Farm Register: Data Collection by Using Web Scraping for Agritourism Farms

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Abstract

The Farm Register is a key element for the Agricultural Statistical System. Agritourism Farms (AFs) represent a small sub-population of the units included in the Farm Register (around 20,000 out of 1.7 million in 2013), but their number is increasing along the time and acquiring importance from an economic point of view. Given the tendency of using the World Wide Web to substitute the traditional way of acquiring information, ISTAT is now experimenting the possibility to collect such information directly from the sparse and unstructured information in the Internet, belonging to the vast category of Big Data, by means of a web scraping technique. A specific scraping application is developed for one of the most important hubs (TripAdvisor) and an another one for scraping individual websites. The text collected in this way requires a specific processing step finalised to extract and structure the information of interest. At the end of the process, the obtained information is used not only to update the existing information available on the Farm Register, but also to enrich it, permitting the production and the periodical dissemination of statistics related to the activities and to the services offered by the AFs, at a minimum cost. This strategy permits also to check the information (regarding newly born farms or ceased ones) stored in the Register, pertaining to the coverage of the frame. From a statistical point of view, such derived information represent a new methodological framework, that requires the evaluation of specific quality indicators.

Keywords: Farm Register, Agritourism, Web Scraping, Internet as a Data source, Big Data

1. Introduction

Agritourism Farms (AFs) are farms where the agricultural activities are integrated with the touristic ones. They are in a growing trend in Europe at least since the 1970s, particularly in Italy. Now they are more and more popular in other parts of the world as well, especially Australia, Asia and North America. A reason of such increase could be identified by observing the decline in agricultural and other forms of rural employment in many countries, that created a need for a diversified range of rural businesses. In most cases, agritourism has become an important element of development in rural areas. The initial concentration of agritourism in Italy was in small mountains and hill farms. Today the offer is more sparse, and is characterized by structures ranging from simple family farms to luxurious estates. In 2010, with 19,973 operators and about 200,000 beds available, there were more than two million guests, out of which 50% foreigners, who spent in the farm an average of 4.5 nights (Santucci, 2013).

The Farm Register maintained by the Italian National Institute of Statistics (ISTAT) is a key element for the Agricultural Statistical System. Moreover, it represents the frame for selecting samples for any survey in this sector. Such frame is built by integrating ten different administrative and statistical sources. Agritourism farms (AFs) represent a small sub-population of the units included in the Farm Register (around 20,000 out of 1.7 million in 2013), but their number is increasing along the time and acquiring importance from an economic point of view. The main source of information for these farms is represented by the administrative data of the authorised Agritourism. A dedicated survey is carried out by ISTAT, on a yearly basis and with standard questionnaires, to collect some useful information about their characteristics. Given the tendency of using the World Wide Web to substitute the traditional way of acquiring information, ISTAT decided to experiment the possibility to collect such information through the Internet, accordingly to a strategy typical of the most recent Big Data paradigm. It has to be noted that, despite the objects of the analysis (the AFs) are limited, the quantity of information that can be derived for them from the web is huge and changes rapidly over the time. This is in line with the Gartner's definition of Big Data, that considers "*high-volume, high-velocity and/or high-variety information assets that demand cost-effective, innovative forms of information processing*"[1]. Moreover, it has to be observed that the information obtained under such paradigm is sparse and unstructured, but its proper use could permit the pursuing of the following objectives:

- improve the quality and the completeness of the administrative information already existing, that consists of *identification* (ID fiscal code of the holder, name, address, telephone, etc.), *agricultural production* (Total Area, Utilized Agricultural Area, main crops, livestock, labor force, geo-localization) and *touristic* (rooms, places, food service, other activities) data.
- collect new data in the topic as prices, wi-fi facilities, swimming-pool, organic and quality production, email address, website, horse riding, etc..
- implement a statistical system that can be updated more frequently and at a minimum cost.

The general idea of such work is to obtain structured information useful to update and enrich the Farm Register. From a statistical point of view, the use of the Big Data paradigm in this context represents a new methodological framework that should be evaluated in order to verify its efficiency and its quality. To this purpose, the administrative database (the *master dataset*) represents the benchmark according to which it will be possible to introduce specific indicators able to verify the coherence of the derived information.

Such paradigm implies the use of a new technique to collect the information: the "web scraping". But, also, it is necessary to define an integrated strategy in order to correctly link each AF referenced in the *master dat set* to the information collected on the web.

[1] http://www.gartner.com/it-glossary/big-data/

2. Web scraping and the integrated strategy

Web scraping is a computer software technique for extracting information from the web. Its objective is the collection and transformation of unstructured data (typically represented by a document written in HTML language) in more structured data. It is implemented by automatic procedures that permit to access the whole content of one or more websites, or that can select specific parts from these, by simulating a human behaviour when browsing for a specific purpose (Barcaroli *et al*, 2015a).

The use of this technique is more and more considered in the official statistics community: see Hoekstra *et al* (2012) and Ten Bosh and Windmeijer (2014).

In general, each website is characterized by a specific, and often unique, structure; an automatic approach can hardly be conceived to ensure the correct recognition of the relevant information in correspondence with all this diversity. Some facilities in this sense could derive if a special schema is applied to mark up the elements in the web pages; such approach is often used by the major search engines (that could be intended as special scrapers) to help them in identifying the target information. It has to be noted that specific standards are already defined (for instance, the definitions introduced by the Schema.org community), though not commonly used by the webmasters.

When the structure of the website is not known a priori, a phase of post-processing of the scraped texts is required, in order to gather the desired information, possibly by making use of text mining and machine learning techniques (Barcaroli *et al*, 2015b). But there are also situations (usually limited to a small number of websites) in which the structure is well defined and the information can be easily extracted with personalised applications; in such cases the results are usually more reliable (Polidoro *et al*, 2015).

In this study the two approaches have been integrated, by considering, from one side, all websites pertaining to AFs in the *master dataset* (each other different in structure and content) and, from the other side, a specific "hub" website (TripAdvisor), i.e. an aggregator of information for travellers that have large collections of pages generated dynamically from an underlying structure, like a database. This last reference gave us the possibility to retrieve data encoded into pages characterized by a common structure from which the content can be translated into the original relational form.

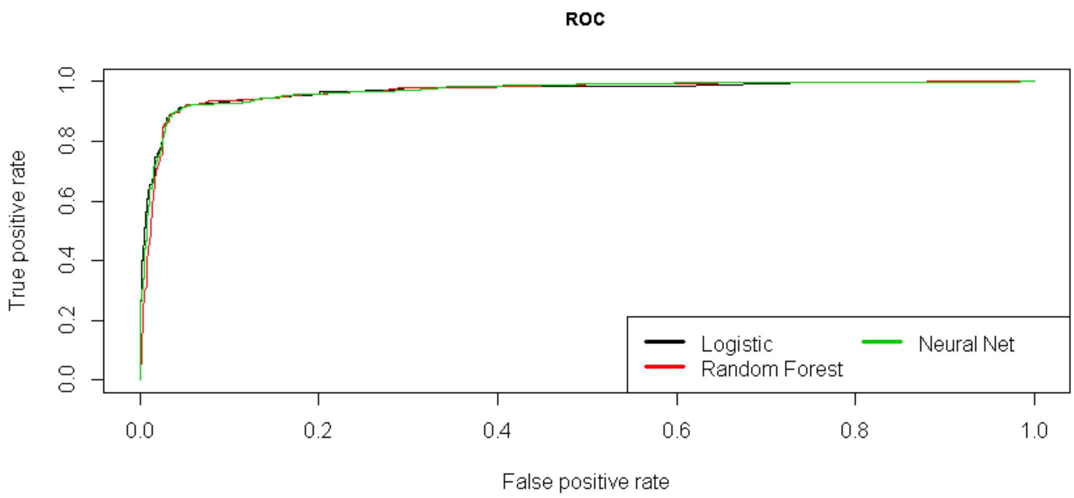
The main issue in this study refers to the proper identification of the links between the AFs as in the master frame (i.e. the database of all Agritourism Farms, originated by the legal obligation to register this activity) and their web sites or their reference in the hub website. To this purpose, the only information that can be used is the denomination and the address; unfortunately, these are often not correctly or uniquely indicated. For instance, the owner's personal information could be used in one source and the denomination of the farm in another source; the address could be different or differently written (by means of abbreviations). Moreover, there could be an implicit difference in the two sources, because in the master frame the information depends on the peculiar administrative purposes, while in the other the aim is purely informative and promotional.

To solve such issue, we used a "natural linker", able to treat also incomplete information. The perfect candidate for this scope was a "web search engine", to which specific queries (each one having in input the denomination and the address of a given AF) were submitted. The result of each query consists of different URLs, from which we should identify those referred to the specific website or those pointing to the hub. This second situation was easier to be solved, due to the fact that the presence of the text "tripadvisor.com" in one of the URLs represents the pointer to the information of the AF collected in the hub itself.

In order to identify the correct website for each AF (if existing and included in those rsulting from the query), a specific procedure was developed in which both the URL text and its content are examined: for the first the similarity between the URL and the denomination of the AF is evaluated,

while as for the content, the presence of the phone number and of the address in one of the page of the related website is verified.
This led us to obtain a vector of variables containing different values resulting from the above comparisons for each one of the 10 URLs obtained by the search engine for a given AF.. A set of models (logistic, random forests, neural networks) have been fitted in order to determine for each AF the most probable corresponding URL among those found by the search engine. The training set is the one of those AFs for which the URL is known as it is indicated in the *master dataset*. The three models perform nearly the same (as illustrated in Figure 1), and the logistic was chosen because the computed score obtained by applying this model can be interpreted as a probability.

Figure 1 – *Performance of the models in determining the true URL for each AF*



Once obtained in this way the list of the URLs pertaining to the AFs contained in the *master dataset*, the contained texts were collected and analysed. In particular, we looked for specific terms in the pages of the website (single or combinations) to verify if the AF has a "restaurant", a "swimming pool", a "wifi" and if it sells products derived from the proper activities.
Obviously, the correct determination of the presence of one of the above characteristics is not precise because it could be affected by the use of different terms, by terms written in different languages or with different lemmas, etc. More precise could be, instead, the results deriving from the characteristics extracted from the hub; in this case, in fact, the structure of the page permits to better recognize the different terms that are located in some "standard position".
Referring to the hub website (TripAdvisor), we were able to look for more additional information, like the possibility to host pets, to play specific sports (golf, tennis), to have a baby sitter service, to be near the sea, etc. Moreover from this hub it is possible to obtain information on the number of rooms and of the prices of each AF.
To implement this strategy we used the software ADaMSoft[2], an Open Source general-purpose software written in Java for data management, data analysis, ETL, etc., that integrates, between others, methods and libraries to parse HTML pages or to interpret the results of queries submitted to a web search engine. The results of these scraping procedures consist of a dataset in which the elements of the web pages are stored in its rows, while their different characteristics in proper columns. Such representation permits to preserve the logical structure of the page and to identify the hierarchy of the elements (i.e. the Document Object Model). As an example, it is possible to consider that a column in the output data set contains the reference URL of the page; then, for each

[2] http://adamsoft.sourceforge.net/

element of the page a record is created, characterized by a column that specifies its type (for instance BODY, INPUT, DIV, TEXT, IMG, etc.), a column with the associated text. It has to be noted that the procedures are executed in a multithread approach: this means that more than one website can be scraped in parallel. The number of threads depends on the amount of available memory: obviously, this has an impact on the time needed to scrape all the websites, while the final performance depends on their complexity (i.e. the number of pages and their response time). The limit to the full scrape of a website derives from the possibility to be blocked by the server due to a "high traffic" concentrated in a small amount of time. In some cases (for instance when referring to TripAdvisor) we divided the queries in blocks of one hundred and we set the maximum waiting time to 30 minutes.

The administrative database of the authorized AFs (the *master dataset*) includes 18,818 farms. As explained above, the first step of our selected strategy was the execution of a query in specific web search engine (Microsoft Bing). Through the query, 17,081 AFs (92%) have been identified in the web (namely with at least one URL found). The reason of the 1,737 AFs not found are various: different reference time, different farm denomination in the two sources, not existence of the AF in the web, errors in the denominations and addresses, etc

For those for which the query was successful, by applying the logistic model we were able to determine 3,289 websites (20%) specific of the AF; 5,525 (32%), instead, were those AFs for which a link in the TripAdvisor hub. The number of AFs for which were found both an entry in TripAdvisor and a specific website were 1,935.

Table 1 summarizes these results.

Table 1 – *main results obtained after the execution of the query related to the search of each AF*

Result of the query	**Frequency**
Not found by the search engine	1,737
Found by the search engine but the retrieved URLs are not referred neither to Tripadvisor nor as a correct link to the AF specific website	10,202
URLs recognized as correct specific websites of AFs not found in TripAdvisor	1,354
AF found in Tripadvisor, without a recognized specific website	3,590
AFs with both recognized specific websites and found in TripAdvisor	1,935
Total	**18,818**

The total number of AFs for which it is possible to gather information by the Internet is therefore 6,879 (36.6% of the total).

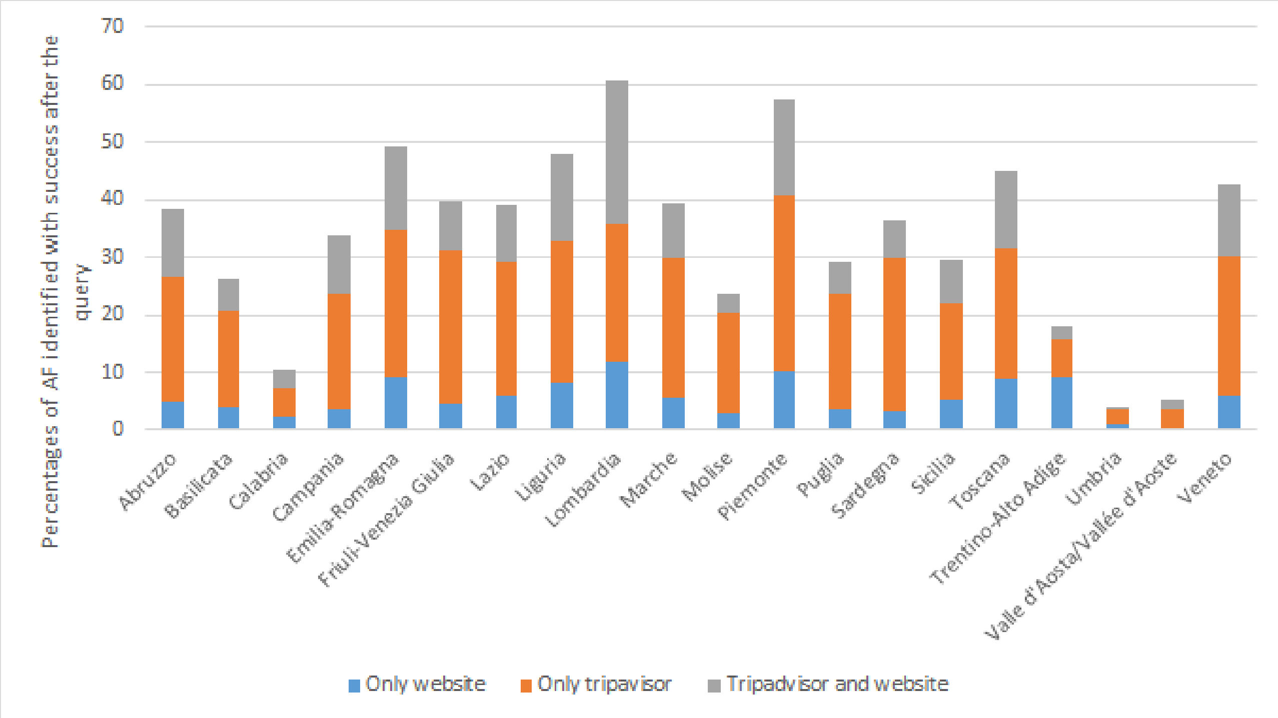
3. Analysis of the results

It is of the utmost importance to assess the representativeness of the subset of AFs whose information can be obtained after the execution of the query illustrated in the previous paragraph.

At geographical level, the coverage rates show a high variability among the Italian Nuts2 areas (Figure 2).

Figure 2 shows that the AFs identified by our strategy are not equally distributed among the Nuts2; the higher percentages (more than the 40%) are in the biggest Regions of the North and Center of Italy (Lombardia, Piemonte, Emilia Romagna, Liguria, Toscana and Veneto, while in other regions (Calabria, Umbria, Valle d'Aosta) it falls under 10%: it is therefore not possible to consider the subset of AFs found as representative by a geographical point of view.

Figure 2 - *Coverage Rate of AFs by Region*



To make proper inference we assume that the identification probabilities achieved by the retrieval procedure are uniform conditionally to the region and change among regions (that is, each AF has the same probability to be found on web given the region). If this assumption holds at least approximately we could solve the coverage issue by making use of proper weights to be assigned to each AF. Such calibration factors can be obtained by the inverse of the coverage rate in each region. This is possible because the number of AFs in the regions is known and certain.
Let us consider some important variables contained in the master DB, as the *availability of restaurant (yes/no)*. This information is contained in the *master dataset*: it is possible to verify its coherence with reference with the corresponding information found (i) only in the hub, (ii) only in specific websites, (iii) in both hub and specific websites. To this purpose let us consider the "confusion matrix" (Table 2), that cross-classifies the presence/absence of such facility with respect to the different sources. It is possible to evaluate the effectiveness of the method by considering the "accuracy rate", i.e. the ratio between the concordances (frequencies on the main diagonal) and the total number of units involved .

Table 2 – *Confusion matrix related to the availability of restaurant as in the master data set and as recognized by referring to the AFs identified only in the hub, only by considering their web sites or jointly*

Presence of restaurant as in the master dataset	**Information derived only from y the hub**		**Information derived from the specific websites**		**Information derived both from the hub and from specific websites**	
	No	**Yes**	**No**	**Yes**	**No**	**Yes**
No	1667	640	537	475	325	812
Yes	741	542	148	194	141	657
Rate of success	*61.5% (100*2209/3590)*		*50.6% (100*685/1354)*		*50.7% (100*982/1935)*	

Table 2 shows the concordances and discordances between administrative data and web data and it opens questions on the quality both the master dataset and the database obtained by the web-scraping procedure. Hereinafter, we assume the discordances between web and administrative data depend on real discrepancies between the information (and not depending on errors due to the data collection process). So how to explain these differences? In this phase of the study we give some plausible justifications that agree with the evidences given in Table 3:

i) the *master dataset* is likely to suffer of a general problem of information updating. Some structural information (as the *availability of rooms*) is correctly indicated at the moment of registration of a new AF, while some other characteristics (as the *availability of restaurant*, or the *sales of products*, or others), that may be offered at a later period, are not added in the *master dataset*, but only in the hubs and/or in the AF websites. This can explain why the differences for *availability of rooms* are small in the four columns, while are relevant for *availability of restaurant*, and highly relevant for *sales of products*;

ii) the difference among columns (2), (3) and (4) should be given by the coverage effect on the master dataset. For *availability of rooms*, the frequencies are quite stable and the performance of the weighting procedure could indicate to better investigate the procedure;

iii) the discrepancy related to the coverage is more relevant for *availability of restaurant*. The difference between 27.1% and 33.9% depends on the coverage. The remaining differences depend on the values of the variables;

iv) for *sales of products* the coverage effect is well defined by the difference between column (1) and (2) even though the frequencies of columns (3) and (4) show a relevant problem related to the quality of the variable, presumably in the master dataset.

Table 3 – *Percentages of AFs with a restaurant, that sell products and that have rooms, as in the master or as identified after the web scraping*

Variables	**Percentages of positive values (=yes)**			
	(1) Total in the master	**(2) In the common subset with value given by the master**	**(3) In the common subset with value obtained by web scraping**	**(4) In the common subset with obtained by the web scraping and after weighting**
Availability of restaurant	27.1%	33.9%	38.5%	35.9%
Sales of products	7.1%	4.4%	21.8%	18.6%
Availability of rooms	34.1%	35.1%	33.5%	32.3%

This analysis suggests the importance to collect information from the web even though it is already available in the *master dataset*. This information can be used for validating or updating it, for imputing missing values and for identifying outliers.

But one of the objectives of the strategy here proposed is also to collect additional information. Considering only the population of agritourisms identified by our strategy (6,879), *presence of swimming pools* is in 18% of cases (unweighted) and 17.1% (weighted). It is also possible to note that *wifi facilities* are in 20.6% (unweighted) and in 19.4% (weighted).

The implemented strategy would permit also to identify the prices of offered services, as related information is available in 41% of cases. Other information can be obtained with respect to the *possibility to host animals*, to offer some *sports facilities*, to *accept credit cards*, etc.

4. Conclusions and future work

This study proposes an approach based on collecting data directly from the Internet with the aim of improving the quality and the completeness of the administrative information on the Italian Agritourism Farms already available, and to produce statistics regarding structural data.

Up to 36.6% of the official AFs can be accessed in the Internet because of the availability of their websites and this number is likely to increase in the time with the spread of Internet and its potentiality in the touristic field.
Information collected from the Internet can be used in different ways, in order to:

- provide final estimations for some structural variables;
- identify outliers with respect to existing variables of the master frame;
- impute missing values in the existing variables of the master frame;
- add new variables to the master frame.

In order to assess the quality of the information obtained with this new strategy, a further step will be to provide a direct comparison of the different values obtained by the different sources, individuating also the true values: to this purpose, a sample of AFs will be selected, the corresponding websites will be manually accessed and inspected.
This manual procedure will allow to discard or confirm two strong assumptions we made when analysing the results: the adopted procedure (i) leads to identify the real value of the variable of interest on the web without error and (ii) the information on the web is updated.
Finally, new developments will regard:

- the improvement of the web scraping technique for increasing the coverage of AFs;
- the possibility to produce prices indices concerning agritourism.

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THEMATIC SET

F30

USE OF REMOTE SENSING AND DRONES IN OFFICIAL AGRICULTURAL STATISTICS

Session Organizer
M. Ballin | Istat | Rome | Italy
M. Miller | USDA National Agricultural Statistics Service |Washington, DC | USA

ABSTRACT

This session will focus on technology development and utilization, as well as the survey design, of remotely sensed data for agricultural monitoring in the establishment of official agricultural statistics. This includes remotely sensed data at the macro, country level, from satellite imagery, down to micro, field level data, from drones or Unmanned Aircraft Systems (UAS). Uses of remotely sensed data include cropland stratification for sampling frame development, early warning analysis, disaster assessment, vegetation condition and soil moisture monitoring, and crop area and yield indications

LIST OF PAPERS

Use of remote sensing and satellite imagery in estimating crop production: Malawi's experience

E. J. Mwanaleza | Ministry of Agriculture, Irrigation and Water Development | Lilongwe | Malawi

DOI: 10.1481/icasVII.2016.f30

The use of satellite pictures and data provided by drones for the purposes of identification of crops and assessment of plant production

T. Milewski | Central Statistical Office of Poland | Warsaw | Poland

DOI: 10.1481/icasVII.2016.f30b

Nationwide demonstration cases of Sentinel-2 satellite exploitation towards early crop area indicator

P. Defourny | Earth and Life Institute | Université Catholique de Louvain | Louvain-la-Neuve | Belgium
S. Bontemps | Earth and Life Institute | Université Catholique de Louvain | Louvain-la-Neuve | Belgium
N. Bellemans | Earth and Life Institute | Université Catholique de Louvain | Louvain-la-Neuve | Belgium
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E. Guzzonato | CS, Systèmes d'information | Le Plessis Robinson | France
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Grassland biomass assessment with remote sensing tools and open source software

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USE OF REMOTE SENSING AND SATELLITE IMAGERY IN ESTIMATING CROP PRODUCTION: MALAWI'S EXPERIENCE

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ABSTRACT

Malawi through the Ministry of Agriculture, Irrigation and Water Development (MoAIWD) conducted two studies on the use of remote sensing and satellite imagery to estimate crop production. The objective of the studies was to explore a statistically sound methodology for estimating crop production in order to improve the quality and reliability of agricultural statistics to ensure effective policy formulation and strengthen monitoring of Malawi's agriculture sector performance.

The Ministry piloted two methodologies simultaneously. The two studies were successfully implemented and provided useful lessons to the Ministry in terms of producing credible crop production statistics. The two methodologies had the same general technical principles but different statistical methodologies which had strong implications especially in terms of costs and statistical accuracy and validity.

Malawi currently uses a household sample survey known as Agricultural Production Estimates Survey (APES) to estimate agricultural production. APES has three modules namely crops, livestock and fisheries.

Great lessons were learnt from the pilot studies. Remote sensing and satellite imagery provide a statistically sound approach for estimating crop production. It can be used as a stand-alone methodology for estimation crop production or integrated with the household sample survey to develop a more robust methodology for estimating crop production. The use of remote sensing and satellite imagery requires less human resource and period for data collection as compared to the household sample survey. It has also uncovered an opportunity for early objective yield estimation for crops, more precise hactarege estimation, provision of tangible land use distribution criteria to use for the rural road rehabilitation programmimg and generation of crop production maps which can be used for strategic establishment of grain storage facilities in the country.

Based on the results of the pilots and an evaluation of the two pilot methodologies, Malawi has three options for incorporating the use of remote sensing and satellite imagery in its programmes for crop production estimation to improve accuracy of crop production statistics. The first option is complete adoption of the remote sensing and satellite imagery approach for substitution. This involves combining the two methodologies to make one strong methodology and replace it with crop production module of the traditional household survey. The farm household data which is generated through crops module should be collected through the livestock module. The second option is partial adoption of the use of the technology. This involves integrating some modules of the remote sensing and satellite imagery methodologies into the household survey. The last option is to completely adopt the use of remote sensing and satellite imagery for complementarily. This involves using the combined remote sensing and satellite imagery methodology on a regular period to be providing benchmark data for crop estimates.

Key words: crop production estimates, agricultural statistics

1.0 BACKGROUND

The Ministry of Agriculture, Irrigation and Water Development (MoAIWD) annually conducts the annual sample survey of agricultural popularly known as Agricultural Production Estimates Survey (APES). APES also referred to as *list frame methodology* in this paper is a household sample survey conducted to provide important information to the Government of Malawi and its stakeholders for formulating policies and planning of various activities in the agriculture sector. The survey covers three main agricultural sub-sectors, namely: crops, livestock and fisheries. Data collection for the survey is done by extension officers located in various areas across the country.

The survey is conducted in three rounds every year. The first round is conducted from September of the preceding year to January of the current year. Figures from the first round estimates are based on farmers' intentions on crops to be grown and related hectarage. The results from the first round may not conclusively inform the ultimate agricultural production as farmers' intentions can change in the course of implementing respective farm activities. Weather conditions and related parameters may also change in the course of the agricultural season. However, results of the first round provide early warning signals on national food security so that policy makers in the public, private and non state sectors can make sound strategies regarding impending food situation. The first round also involves collection of livestock and fisheries data.

The second round is conducted from February to March and focuses on verification and adjustment of area measurement of crops grown by the sampled agricultural households and results obtained are used to determine crop area for the season.

The third round of the survey which is normally considered as the final round is undertaken during harvesting period from April to May. The third round mainly involves weighing of the harvest to obtain actual yield for crops based on the sampled households. This round includes collection of livestock data as well.

Despite successful implementation of the methodology, it has been observed that there is need to improve certain critical weak areas of the methodology or review the whole methodology to response to the current situation; and adopt and employ innovative and emerging technologies in the production of agricultural statistics. The list frame methodology was designed over twenty years ago. Since then a lot of things have changed. For instance, the number of farm households has more than doubled which requires an adjustment of the sample size. The area under cultivation has also tremendously increased. On the other hand, the number of extension officers responsible for field data collection has greatly decreased due to high labour turn-over.

In a bid to improve crop production statistics, Malawi initiated the use of remote sensing and satellite imagery in the estimation of crop production in 2010. The initial step of the initiative was to conduct a nationwide survey on land cover and use. In 2012 the country piloted a project on crop area in few districts by using point frame approach. The key outcomes of the pilot were that the point frame based methodology proved to be technically feasible for the country and statistically very valuable given the precision of the crop area estimates attained. In 2013 another methodology which used area frame based approach was identified and piloted in few selected areas of the country.

In 2014/15 agricultural season the country simultaneously piloted the two methodologies national wide. The two methodologies had the same general technical principles but different statistical methodologies which had strong implications especially in terms of costs, statistical accuracy and validity. Results of the two pilot methodologies were compared with results from the list frame methodology.

The point frame methodology was developed by a consortium of ITA and EFTAS from Italy and Germany respectively while area frame methodology by Airbus from France. Both methodologies were implemented in collaboration with the Ministry of Agriculture, Irrigation and Water Development

2.0 OBJECTIVES OF THE PILOT PROJECTS

The objective of the studies was to explore a statistically sound methodology for estimating crop production in order to improve the quality and reliability of agricultural statistics to ensure effective policy formulation and strengthen monitoring of Malawi's agriculture sector performance.

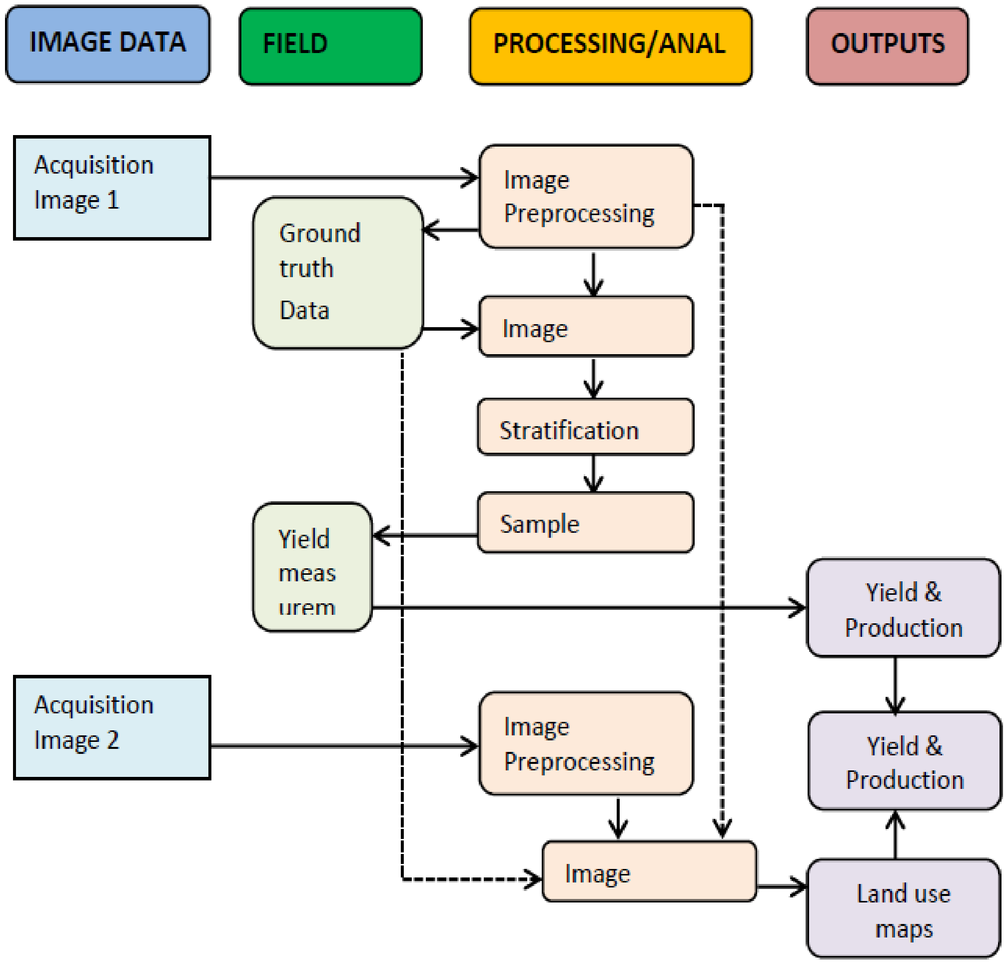
3.0 BRIEF DESCRIPTION OF THE METHODOLOGIES

3.1 Area Frame Methodology

The project used an area frame design. An area frame provides a very efficient tool to survey a territory for various purposes (precise acreage estimation of small crops, yield surveys, production practices, etc.). In the case of Malawi project it was used to estimate maize yields by use of crop cutting. Hectarage estimation was done by the use remote sensing.

Prior to the field data collection, land-use mapping was done using a classification of pairs of satellite images. The classification technique was implemented in three major steps: acquisition of the images, ground truth data collection and classification at the pixel level (Figure 1). To produce the land-use mapping, at least two SPOT 6/7 images at 6m resolution were acquired by district at different times. The first images were acquired from February 19 to April 30, 2015 and the second images were acquired from April 11 and June 9, 2015.

Figure 1: Flow Diagram of the Process



The timeframes for image acquisition were defined with regards to the known local crop calendars. Field surveys were carried out during the first mission in the 15 districts to collect ground truth information required for the calibration of the image classification process and then commonly available Geographical Information System (GIS) and Remote Sensing software (IDRISI, Quantum GIS/GRASS and ArcGIS) were used to perform all data preparation, image integration and classifications. A total of 1551 out of the targeted 1,705 cells were surveyed in all the targeted 27 districts. In each cell two fields were sampled for crop cutting. Data on yield estimate and related information were collected and sent by email to the supervisor on daily basis who after data quality control transmitted the final data to the Ministry headquarters.

Figure 2: GIS Survey Interface Showing Sampled Cells

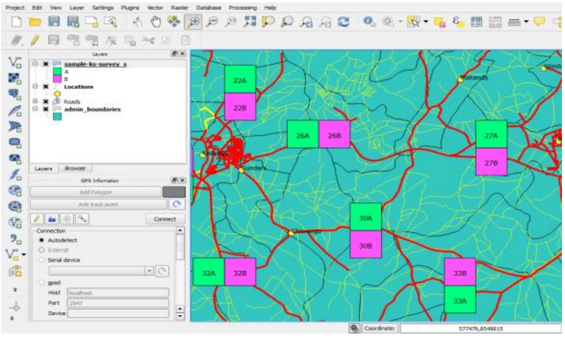
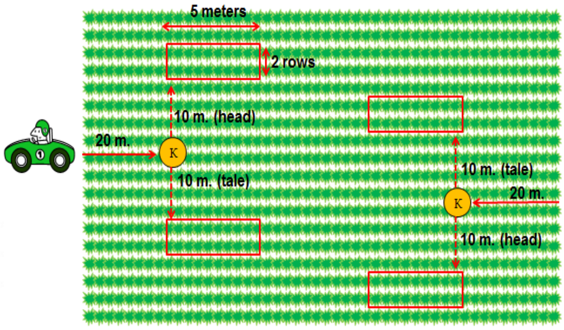


Figure 3: Sample Field with Positions for Crop Cutting



3.2 Point Frame Methodology

The methodology is point frame based whereby the surveyors were required to visit the sampled points, observe within a 3m radius the crop grown at that particular point and record the data. A total of 24000 points were sampled for the survey. Sampled points were classified into clusters of 16 points each with a distance of 250m from one point to the other. For yield estimation, farmer interviews and crop cutting were conducted to assess productivity.

Figure 4: Sample of a Cluster

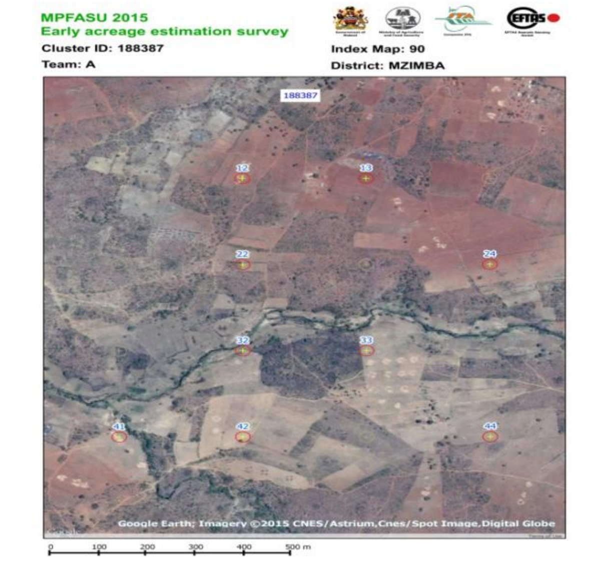
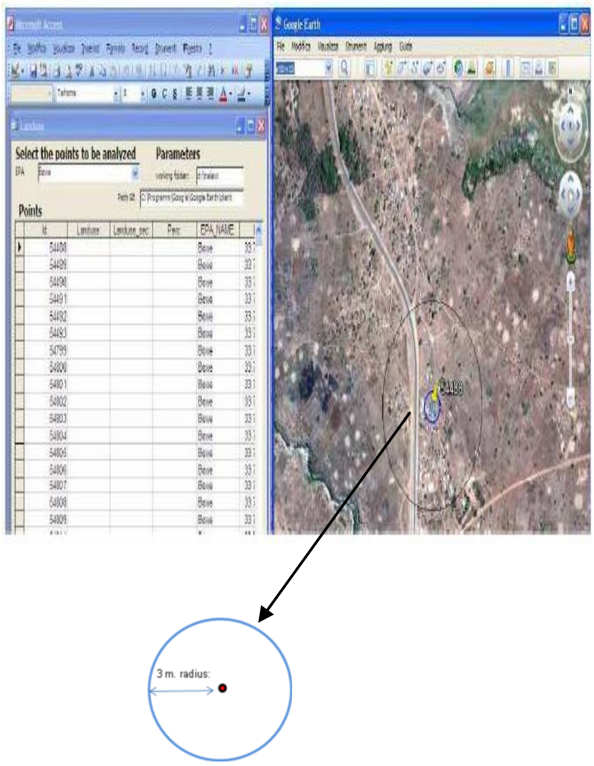


Figure 5: Sample of a Point



NOTE: a point is a geo-location of the area surveyed. The crop is observed within 3 meters of the point. With the guidance of the Global Positioning System (GPS), upon reaching the point the enumerator observes and records on the type of crop within the radius of the point. For mixed cropping the enumerator has to judge the percentage of each crop in the point

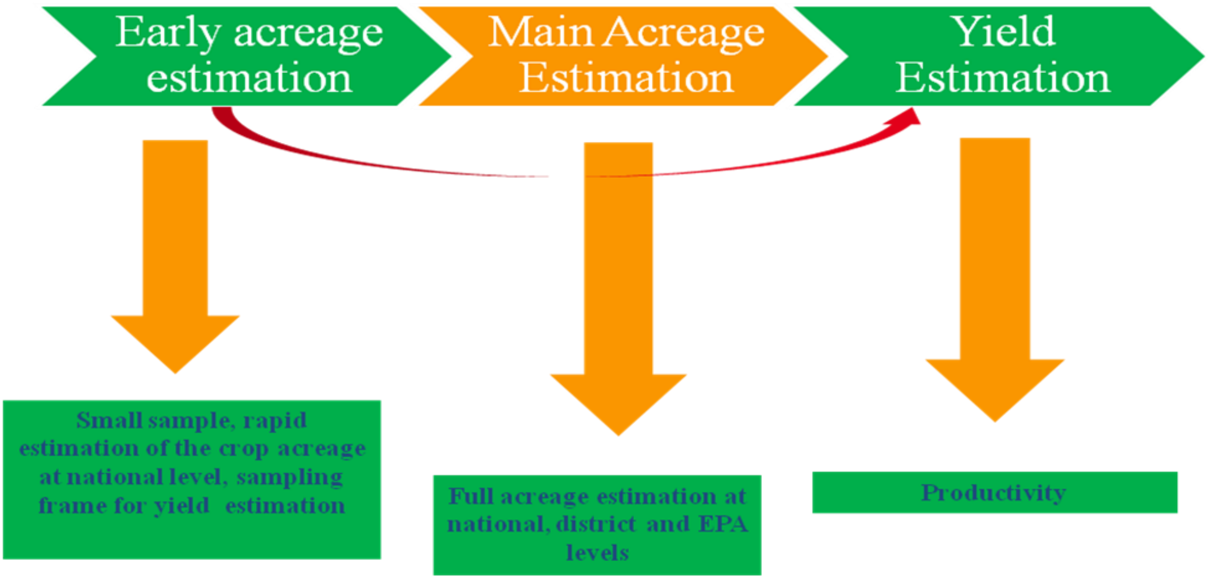
The project had three main modules:

Module1: **Early Crop Acreage Estimation:** the objective of the module was to provide a forecast of crop area at national level. The module also provided a sampling frame for selection of points for yield estimation using crop cutting method**.** The module objectives was achieved by using a sample of 300 clusters on the agricultural land with 16 sampling units (points) inside a square grid spaced 250 x 250 m.

Module 2: **Full Crop Acreage Estimation**: the second project component was designed in order to obtain crop acreage estimation across the country and for the crops of the country with a Coefficient of Variation (CV) of 4-5% for maize. The ground survey was planned to be carried out on 25,000-27,000 sampling units (points) grouped in 1500 clusters and randomly allocated separately across the country.

Module 3: **Yield Estimation**: the objective of this module was attained by interviewing 1,200 farmers located within the 300 clusters. The farm interviews collected among others data on quantity the farmer had harvest from the garden, socio-economic information and sizes of the garden. In addition crop cutting was done in selected 20 gardens within the same clusters to complement farm interviews data.

Figure 6: Main Modules of the Project



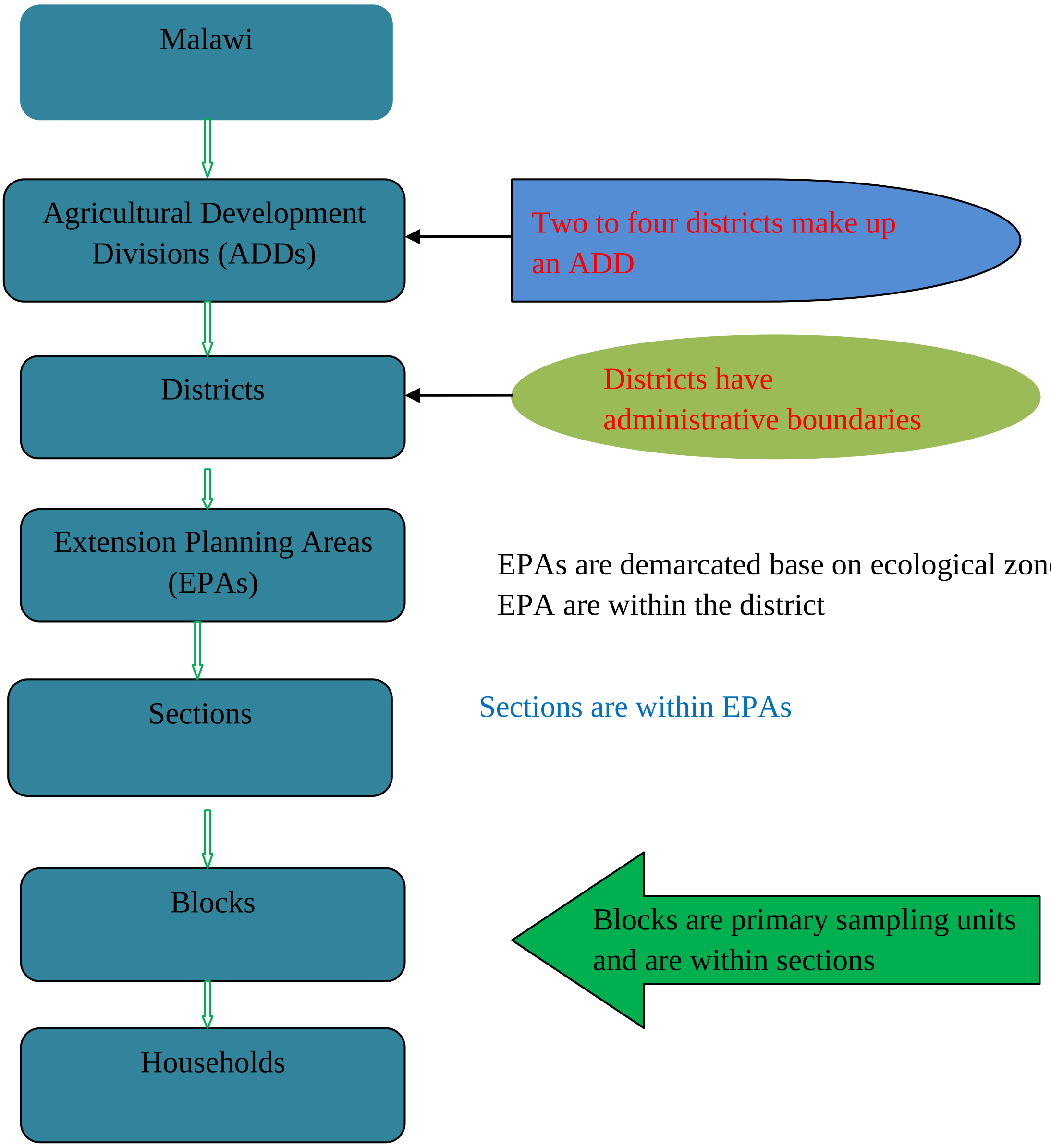
Field data collection was done by forty surveyors for a period of four weeks. Data collection and data entry was done at the same time using tablets. Data was submitted to a cloud archive server and centrally downloaded for monitoring of data flow and quality control.

3.3 List Frame Methodology

The survey begins in September every year up to April in the preceding year. The survey uses a stratified two-stage systematic sampling. Extension Planning Areas (EPAs) making up a district constitute the strata. Each EPA consists of Sections and individual Sections comprise Blocks. The Block is the Primary Sampling Unit (PSU) used in the survey (Figure 6).

The first step in sample identification involves the selection of 25 percent of the Blocks in each EPA using a systematic random method. The second step requires the identification of a Secondary Sampling Unit (SSU) of agricultural households drawn from the selected Blocks. In each selected Block, all households are listed. From the list, agricultural households are serially listed and a survey sample of 20 percent, but in any case not more than 15 households, is identified again using systematic random sampling.

Figure 7: Sampling Structure



Extension officers, who are data collectors for the survey, are required to list all households in the selected Blocks and identify agricultural households. The officer indicates if the household grows field and/or horticultural crops, keeps livestock and do any fish farming activities. For crop module, extension officers are required to conduct garden measurement exercise using the GPS in the sampled households.

For yield assessment, the estimation for the first and second rounds are subjective based on extension officer's judgment on crop development. Based on the crop stand, the extension officer is required to make a judgment whether the yield will remain the same, go up or down and by what percentage. In the third round the actual yield is estimated using crop cutting. Livestock data is collected by actual counting of the livestock from the household. Fisheries data is collected from both fish farming/aquaculture from the sampled households and capture fisheries from natural water bodies. Data processing and analysis is done at the EPA level, and then data aggregation processes are done at the district, Agricultural Development Divisions (ADDs) and national levels.

4.0 RESULTS

Results of the two projects compared with the results from the list frame approach are shown in Tables 1,2 and 3. The comparisons are made for maize only because area frame methodology focused on maize crop only. Maize is the major staple food in Malawi. The comparisons are from rainfed production only for both results as the pilot projects did not take into account winter cropping as done in the list frame methodology.

Table 1 provides results on hectarage estimation from all the three methodologies. From point frame methodology, hectarage was estimated at 1,396,477 hectares lower by 7 percent as compared to 1,499,340 hectares from the list frame. The area frame estimated hectarage at 1,812,908 hactares giving a difference of 21 percent as compared to the list fame approach. Generally, results from point frame estimation are lower across the ADDs while figures from area frame are higher as compared to the results from list frame methodology. Comparisons further show that results are close at national level with great variations at ADDs.

Table 1: Results of the hectarage estimation

		List frame Vs Point frame			List frame Vs Area frame			
ADD	List frame	Point frame	Diff	% Diff	List frame	Area frame	Diff	% Diff
Blantyre	260,999	197,610	63,389	24	260,999	266,646	-5,647	-2
Kasungu	341,783	330,423	11,360	3	341,783	402,368	-60,585	-18
Karonga	52,962	30,843	22,119	42	52,962	57,481	-4,519	-9
Lilongwe	334,212	397,450	-63,238	-19	334,212	473,174	-138,962	-42
Machinga	266,301	226,538	39,763	15	266,301	322,229	-55,928	-21
Mzuzu	144,210	145,200	-990	-1	144,210	172,340	-28,130	-20
Salima	61,588	50,486	11,102	18	61,588	59,665	1,923	3
Shire Valley	37,285	17,928	19,357	52	37,285	59,005	-21,720	-58
National	1,499,340	1,396,477	102,863	7	1,499,340	1,812,908	-313,568	-21

In terms of productivity, the point frame estimated a national maize yield of 1430 kgs lower by 129kgs representing 5 percent difference as compared to the list frame. The area frame estimated national maize yield of 1470kgs versas 1508kgs from list frame, giving a difference of 3 percent (Table 2). In both cases national maize yield from list frame is slightly higher as compared to the two pilot methodologies.

Table 2: Results of the Yield Estimation

	List frame Vs Point frame				List frame Vs Area frame			
ADD	List frame	Point frame	Diff	% Diff	List frame	Area frame	Diff	% Diff
Blantyre	1,484	612	1,163	66	1,484	1,512	263	15
Kasungu	1,790	1,543	247	14	1,790	1,825	-35	-2
Karonga	2,261	1,586	675	30	2,261	2,228	33	1
Lilongwe	1,748	1,975	-227	-13	1,748	1,259	489	28
Machinga	774	1,160	-386	-50	774	1,050	-276	-36
Mzuzu	1,452	1,014	438	30	1,452	1,676	-224	-15
Salima	1,828	1,137	691	38	1,828	1,770	58	3
Shire Valley	816	446	370	45	816	1,210	-394	-48
National	1,508	1,430	129	5	1,508	1,470	89	3

Results on national maize production are presented in Table 3. The point frame methodology estimated national maize production at 1,996,428 metric tons while the list frame estimated 2,261,581 metric tons. The area frame methodology estimated the production at 2,665,492. The results show that figures are close at national level with great variations at lower levels. Possible reasons for such differences are small sample sizes for the pilot methodologies, hence, there is need to increase the sample size to achieve good precision at lower levels. However, an investigation is required to establish factual causes for the differences. As the case with hacterage figures, generally results from point frame estimation are lower across the ADDs while figures from area frame are higher as compared to results from the list frame.

Table 3: Results of the Production Estimation

	List frame Vs Point frame				List frame Vs Area frame			
ADD	List frame	Point frame	Diff	% Diff	List frame	Area frame	Diff	% Diff
Blantyre	387,239	136,639	326,536	70	387,239	403,045	60,130	13
Kasungu	611,955	498,230	113,725	19	611,955	734,314	-122,359	-20
Karonga	119,772	46,608	73,164	61	119,772	128,043	-8,271	-7
Lilongwe	584,066	778,083	-194,017	-33	584,066	595,830	-11,764	-2
Machinga	206,120	270,997	-64,877	-31	206,120	338,408	-132,288	-64
Mzuzu	209,432	178,067	31,365	15	209,432	288,823	-79,391	-38
Salima	112,565	76,210	36,355	32	112,565	105,606	6,959	6
Shire Valley	30,432	11,593	18,839	62	30,432	71,423	-40,991	-135
National	2,261,581	1,996,428	341,089	12	2,261,581	2,665,492	-327,975	-18

5.0 LESSONS LEARNT AND RECOMMENDATIONS

A number of important lessons were learnt from the pilot studies. Remote sensing and satellite imagery provide a statistically sound approach for estimating crop production. It can be used as a stand-alone methodology for estimation crop production or integrated with the household sample survey to develop a more robust methodology for estimating crop production. The use of remote sensing and satellite imagery requires less human resources and period for data collection as compared to the household sample survey.

From the results of the pilots and lessons learnt from the pilot methodologies, Malawi had three options for incorporating the use of remote sensing and satellite imagery in its programmes for crop production estimation to improve accuracy of crop production statistics. The first option was complete adoption of the remote sensing and satellite imagery approach for substitution. This involves combining the two methodologies to make one strong methodology and replace it with crop production module of the traditional household survey. The farm household data which is generated through crops module should be collected through the livestock module. The second option was partial adoption of the use of the technology. This involves integrating some modules of the remote sensing and satellite imagery methodologies into the household survey. The last option is to completely adopt the use of remote sensing and satellite imagery for complementarily. This involves using the combined remote sensing and satellite imagery methodology on a regular period to be providing benchmark data for crop estimates.

Based on the evaluation of the two methodologies Malawi opted for partial adoption of the use of the technology by integrating some modules of the point and area frame methodologies into the list frame methodology. To maintain livestock and fisheries components of the list frame methodology, there is need to go for multi-frame approach. This means livestock and fisheries data should be collected from the list frame and crop production data from combined point frame and list frame methodologies.

The evaluation also recommended adoption of number of lessons learnt from the projects aiming at improving agricultural production statistics. The recommendations were categorized into short and long terms.

5.1 Short Term Recommendations

i) Use of Information, Communication and Technology (ICT) in Data Collection and Transmission: There is need to introduce electronic data transmission system for agricultura surveys. This is one of the important lessons learnt from both methodologies. Electronic data acquisition and transmission has proven to promote quick and error free data submission. There is need to use the existing central server located in the Ministry headquarters for data submission. Daily data transmission by data collectors should be made possible by distributing tablets (i.e., with GPS and internet access) to each of the data collector

ii) Development of electronic database: There is need to develop an electronic database for agricultural production survey. All data should be centrally stored and managed. By having micro-data, the Ministry will be able to derive estimates with coefficient of variations to determine precision of estimates for each crop at all levels. The database should be programmed so that estimates are calculated automatically as data is being transmitted to the database. The data collection program should be designed in such a way that errors are detected automatically as data is being transmitted hence reducing period for data cleaning.

iii) Introduction of moisture content measurement for crops: The current methodology does not measure moisture content for crops. It is recommended that weighing of crops should be done when the crop is completely dry. However, it is not certain whether this protocol is strictly followed by the extension officers. If it is not followed, this gives a chance for overestimation. Even if it is followed, this means that the extension officers have to wait for the crop to dry in cases of early harvesting, hence, delay in submission of the data. It is strongly recommended that moisture content measurement as learnt from the area frame methodology be introduced to improve data quality and facilitate early submission of the data.

5.2 Long-Term Recommendations

i) Use of point frame approach for hectarage estimation: The point frame methodology should be adopted for hectarage estimation. However, to achieve good estimates at all levels, there is need to increase the sample size for points. The point frame hectarage estimation has proven to be more accurate, quick, easy, less time consuming and requires less human resource.

ii) aintain yield estimation method from the list frame: Crop cutting method from list frame methodology has proven to produce credible results. The method is applicable to all crops. Yield estimation methods from the pilot methodologies either require some adjustments (point frame methodology) or separate methods for non-cereal crops (area frame methodology).

iii) Revision of sampling frame for the list frame: The current methodology samples 15 households in each block. This means that all blocks are treated as homogeneous entities. This may result in oversampling in areas where there are less agricultural households and under sampling in areas with more households. The sampling plan should be revised. The sampling plan should be based on agricultural land use, meaning, a sample of households should be allocated according to the agricultural land in that particular area. Stratification taking advantage of differences in agricultural land use intensity will provide a significant increase in precision. Therefore, from the area frame methodology, revising the sampling methodology under list frame based on actual agricultural land use density rather than population estimates is recommended.

iv) Development of strong capacity building programme: If the recommendations are approved, there will be need for strong capacity building in the Ministry mainly through short and medium-term training. Arrangements should be made with the Development Partners such as Food and Agricultural organization (FAO) of the United Nations for local technical support in sampling, GIS and image analysis.

6.0 CONCLUSION

Great lessons have been learnt from the pilot studies which can improve crop area and production statistics. Application of remote sensing and satellite imagery technologies in crop production estimation has proven to provide quick, reliable and timely statistics. It has also uncovered an opportunity for early objective yield estimation for crops, more precise hactarege estimation, provision of tangible land use distribution criteria to use for the rural road rehabilitation programmimg and generation of crop production maps which can be used for strategic establishment of grain storage facilities in the country. However, to ensure successful implementation of the lessons leant, there is great need for strong capacity building programme in the area of GIS and remote sensing.

The use of satellite pictures and data provided by drones for the purposes of identification of crops and assessment of plant production

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ABSTRACT

The first part of the speech will present the results of cooperation between the Department of Agriculture in the Central Statistical Office and the Space Research Centre of the Polish Academy of Sciences in Warsaw. It will be concerned with the possibility of distinguishing particular groups of crops and classes of land cover, including identification of selected crops on the basis of satellite images (taken by Sentinel 1 type satellite) to the lowest possible level of aggregation, i.e. voivodship (NTS2) or district (NTS3). Such research was conducted on a selected Polish voivodeship in 2015. The speech will present the applied method of sample selection (ca. 550 measurement plots) based on administrative sources of the IACS, the field survey of crops in that area, the adopted methodology of identification of crop groups, as well as the possibilities to use data from Sentinel 2 type satellite for such kind of work.

The second part of the speech will present a study of the data acquired from a drone approach for the purposes of assessment of production from grasslands. The work was developed in cooperation with the Department of Agriculture in the Central Statistical Office and the Institute of Geodesy and Cartography in Warsaw in 2015. The analysis was conducted on 21 plots with total area of approximately 460 ha of permanent grasslands in the selected voivodships. It is planned to describe the methodology of the research consisting in using non-piloted measuring platform (a drone) equipped with a hyperspectral camera capable of imaging within the scope of 480-890 nanometres. Imaging with the use of a drone took place in the course of two field campaigns conducted at the turn of May and June of 2015, and was supplemented with data from LANDSAT 8 satellite in the case of fragments of plots, for which obtaining data with a drone was impossible due to adverse weather conditions. Additionally, simultaneously with the conducted drone approaches, ground measurements were conducted (74 points within the area of the analysed plots), using specialist apparatus owned by the Institute of Geodesy and Cartography, providing information about LAI (Leaf Area Index), soil humidity and temperature of plant surface. The collected data described above enabled analysing and assessing production on grasslands by assigning to each indicated plot the estimated value of fresh biomass and biomass per hectare. A starting point for such an analysis was a comprehensive set of data, collected within a few decades by the Institute of Geodesy and Cartography, enabling the use of already created, and used by the Institute for many years, models describing the correlation between biomass and the LAI. The collected information about the crop yield from grasslands were compared with the local estimates of experts. During the

speech, it is planned to present chapters describing one by one the specification of data and sensors used to obtain them, the applied methodology of assessment of production size from the designated grasslands, the results of the conducted analysis with breakdown into particular plot groups. A SWAT analysis will be also presented, summing-up the conducted research and assessing the potential of the used method.

Keywords: Drone, IACS, Sentinel, Grasslands

1. Introduction

1.1 Preface

The Agriculture Department at the Central Statistical Office OF Poland (CSO) is responsible for maintaining official national statistics connected with agriculture in Poland. Its standard work based on annual periodic surveys, information obtained from field experts, voivodship experts, and administrative data, includes the processing of information on issues such as area assessment, yields, and crops at the voivodship level (NTS2). There is a demand for data pertaining to aggregation at the district (NTS4) or commune (NTS5) levels. Unfortunately, the information that has been collected to date during questionnaire surveys is based on farmers' declarations as regards the land used, but without details on the locations of such land. This makes it impossible to aggregate results at a level which in terms of area is classified lower than voivodship. Therefore, new methods, possibilities and solutions are sought for in order to increase the accuracy of estimates. The Agriculture Department is closely following the latest technological developments and possibilities of applying them for its own needs, in particular the Copernicus programme and missions by the Sentinel satellites. The satellites of this type are developed under the Copernicus programme, funded by the European Commission and the European Space Agency (ESA). It should be noted that while being free of charge, the efficient use of data transmitted by these satellites requires substantial experience and knowledge on remote sensing. For this reason, close cooperation with a number of institutions is being conducted, allowing these data to be used directly.
The report consists of two thematic blocks presenting the results of cooperation between the CSO and scientific institutions in order to improve the quality of published data and enhance their usefulness by increasing the resolution of presented data.

1.2 Part I

The first part of the report presents the results of cooperation between the CSO, the Regional Statistical Office in Olsztyn (RSO), and the Space Research Centre of the Polish Academy of Sciences (SRC) within a pilot study in one of the voivodships, aimed at assessing whether it would be possible to single out and identify individual crop groups on the basis of radar data from the Sentinel 1 satellite and field calibration based on data from the Agency for Restructuring and Modernisation of Agriculture (ARMA) – the database of the Land Parcel Identification System (LPIS).

1.3 Part II

The second part of the report discusses the results and experience gained in the implementation of a contract between the CSO and the Institute of Geodesy and Cartography in Warsaw (IGiK). The contract regarded the preparation of a study on the possibility of assessing grassland production on the basis of image information transmitted with the use of an unmanned measurement platform (a drone) and a hyperspectral camera.

2. Part I

2.1 The objective of the study

As part of the study, crops in the Warmia and Mazury voivodship were identified with the use of Sentinel-1 satellite radar images. The images served the creation of a data time series presenting how the crops evolved throughout 2015, and then were processed and classified. As reference data, the administrative databases on crops, including data from the LPIS database were utilised. The results were aggregated at the district and voivodship levels.

2.2 The methodology for selecting samples and conducting in situ survey.

The Warmia and Mazury voivodship is located in the north-eastern corner of Poland. To select a random sample, the coordinates of points from the European LUCAS 2012 survey were used. First, an analysis was carried out to designate points potentially located on agricultural areas. With the use of ArcGIS software (the Intersect function), the LUCAS 2012 points were analysed in relation to the vector layer of managed land (ML) from ARMA. As a result of the analysis, 885 points were selected on record parcels with the area of nearly 213 km^2.

Figure 1: *A sample point selected for the analysis*

In order to increase the likelihood of selecting points that were located within large-area crops, 885 points were additionally analysed in relation to the record parcel layer. As a result of this analysis, the designated points were grouped in line with the adopted field size buffers. Each interviewer had to visit all points assigned to him/her and collect the necessary data, as specified in the form for the in situ survey. The interviewers were provided with GPS receivers with navigation capabilities in order to arrive in a given point and record its actual location, as well as GPS-capable tablets to take geotagged photographs. For each analysed point, a description had to be prepared in accordance with a questionnaire drawn up earlier. The collected data regarded issues such as the type of crop – a dropdown list of plants, with the possibility of providing more details on a given species, the homogeneity of a crop, the plant development stage, land topography, the type and humidity of soil, the amount of weeds, and the angle in which a photograph was taken in relation to the cardinal directions. In total, the interviewers provided descriptions for 596 points and took 1847 photographs. The field studies were held between 15 June 2015 and 22 July 2015.

2.3 Reference data

Satellite data were classified on the basis of information from the database on crops in the Warmia and Mazury voivodship in 2015. The database contained geospatial information on control areas, crops cultivated on them, the interviewer's location, a survey on the state of a crop and a field, and photo documentation. The report was made on the basis of type-2 data registered in the VH and VV polarisations. Since the beginning of 2015, more than 300 Sentinel-1 capturing the area of this voivodship. The data were collected automatically and for further analyses, 13 scenes were selected.

2.4 Data processing

The multitemporal coherence matrices for satellite radar images were calculated with the MT_SAR software developed specifically for this purpose by the SRC. With the software, multitemporal polarimetric processing can be performed, including correlation and coherence matrices serving as a basis for applying polarimetric decompositions that model the mechanisms of reflection of radar beams from structures on the surface of the Earth. The software can also automatically process large image sets. In order to speed up the calculations and for safety reasons (minimising the risk of interruption of prolonged calculations), the images were divided into smaller pieces.

Figure 2: *Contour of the voivodship (in green) with a mosaic of cut-up pieces*

For each of pieces, calculations were carried out with regard to the coherence matrix, entropy, and the polametric Alpha parameter. Upon completion of the calculations, the pieces were merged together. By means of the functions offered by the Sentinel-1 Toolbox, each of the 13 images selected with the Wishard's classifier was subjected to polametric unsupervised classification. The methods of supervised classification were deployed on the basis of training fields defined by means of the information on crops obtained by CSO interviewers for statistically selected plots within the analysed voivodship. Segments were created with the use of optical data from the Landsat 8 satellite and LPIS vector data provided by the ordering party. With LIPS taken as reference, the first level of segmentation was developed, overlapping borders of the LPIS plots. The segments thus obtained were used in the next step of the segmentation process, where the plot-designation plots were divided depending on the value of Landsat spectral images, in such a manner as to ensure that the newly created segments reflected the structure of sown areas.

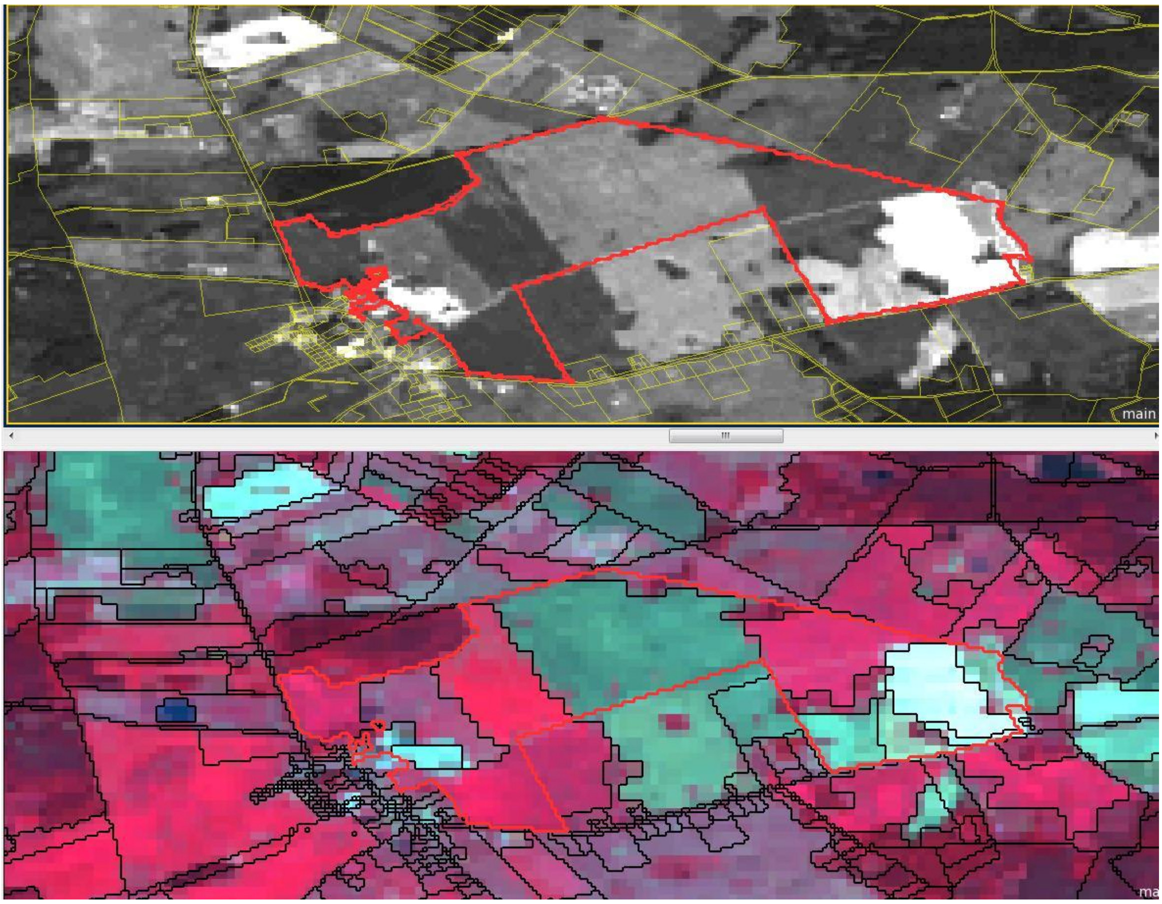

Figure 3: *Updating the borders of arable fields. Top – plot borders determined on the basis of the LPIS database; bottom – new crop borders obtained on the basis of segmentation of a multispectral Landsat image.*

2.5 Results of the classification

Three different classification algorithms were followed: Decision Trees, K-Nearest Neighbours and Support Vector Machine. The accuracy of the obtained results of classification was assessed on the basis of training fields and also with the use of an independent set of data from farmers' questionnaires collected in the ARMA system. The most reliable results were obtained for the classification carried out on the basis of Wishard's distance parameters, with the K-Nearest Neighbours method (KNN) and with the use of the temporal series of the σ0 back-reflection coefficient with the Support Vector Machine (SVM) method. To continue the assessment of the classification results, the areas of crops obtained through the classification of Sentinel-1 radar images and the estimated sown areas recorded in the CSO system were compared. Next, the results of crops were aggregated at the district level.

2.6 Summary and conclusions

Each classification of satellite images should conclude with an assessment of the results, to provide a basis for establishing the usability of image processing methods. In this case, the classification was assessed by being compared with the official CSO data on the status of crops in the Warmia and Mazury voivodship in 2015. At the same time it should be noted that, given the limited number of validation points, the results of the validation are indicative only.
The conclusions:

- The random selection of training fields should be replaced with the supervised method which allows selecting the sufficient number of large, adequately shaped fields that are well representative of each crop.
- The training fields should be identified at the level of the LPIS database, not on the basis of GPS indications during field measurements.
- Each point should be verified on the basis of photographs taken during a visit on the field.
- The validation on independent data were subjected suggests that the method has considerable potential, it also indicates the need for seeking other solutions, e.g. supplementing the data with optical photographs.
- The results of object classification depend on the quality of segmentation.
- The analyses of multitemporal radar data are connected with the necessity of processing very large image sets. All stages of classification work must be optimised in terms of the duration of operation and calculation capabilities.

3. Part II

3.1 The objective of the study

As part of the work we attempt to use drone with a hyperspectral camera for the purpose of estimating the production of permanent grassland.

3.2 Characteristics of the study area and used equipment.

The analysis covered the area of 21 plots indicated by the CSO, with total area of 460.2 hectare, located in the area of the Biebrza National Park (the BPN). During implementation of the project, to obtain hyperspectral imaging from low altitude an unmanned measurement platform (drone) was used in the form of multicopter with six rotor. Multicopter VersaX6 with take-off mass of 4 kg is able to carry measurement apparatus with weight up to 1.5 kg. The system of autonomous flight handling integrated in the platform allows conducting ortophotogrammetric flights in semi-automatic mode, when the platform follows the route of flight scheduled before along with possibility to set points of hovering optimising acquisition of data from hyperspectral camera. Total of 19 flights was performed along the routes programmed on the basis of cartographic materials prepared before and land survey. The distance of single flight was within the range of 1,000 – 2,000 meters and was performed at the altitude of 150 or 200 meters. To obtain hyperspectral imaging the Rikola full frame camera was used, imaging within the range of 480-890 nanometers. During flight imaging was performed in 16 spectral channels.

3.3 The survey methodology

Imaging from drone took place in the course of two field campaigns conducted on May and June 2015. For the needs of the project, fragments of two scenes coming from Landsat 8 satellite were used. In addition, simultaneously with conducted flights the ground measurements were performed (74 points on the area of the analysed plots) using specialist apparatus being in the possession of the Institute of Geodesy and Cartography, offering information about LAI (Leaf Area Index, ratio of projection area of leaves), humidity of soil and temperature of plants' surface. The collected data described above allowed for analysis and calculation of the production from the grasslands by assigning to each indicated plot an estimated value of fresh biomass and biomass with regard to one hectare. The main and the most time-consuming stage of the analysis was to prepare adequately the imagery acquired from the drone. Those images were then calibrated and combined to create a single mosaic for each of flights. The next step was establishment of colour composition (in false colours) and calculation of normalised difference vegetation index - NDVI, used in further parts of analyses.

Together with values from range (-1, 1) we obtained information on the development state and condition of vegetation, and high values of index correspond to the areas overgrown with thick vegetation of good condition. Based on the dedicated models, calculated values of fresh biomass from hectare were assigned to homogenous areas of the analysed fields and after calculation of surface of those areas a total estimated weights were obtained of fresh biomass (in tons) and of biomass from hectare (in tons/hectare), separately for each of the analysed plots.

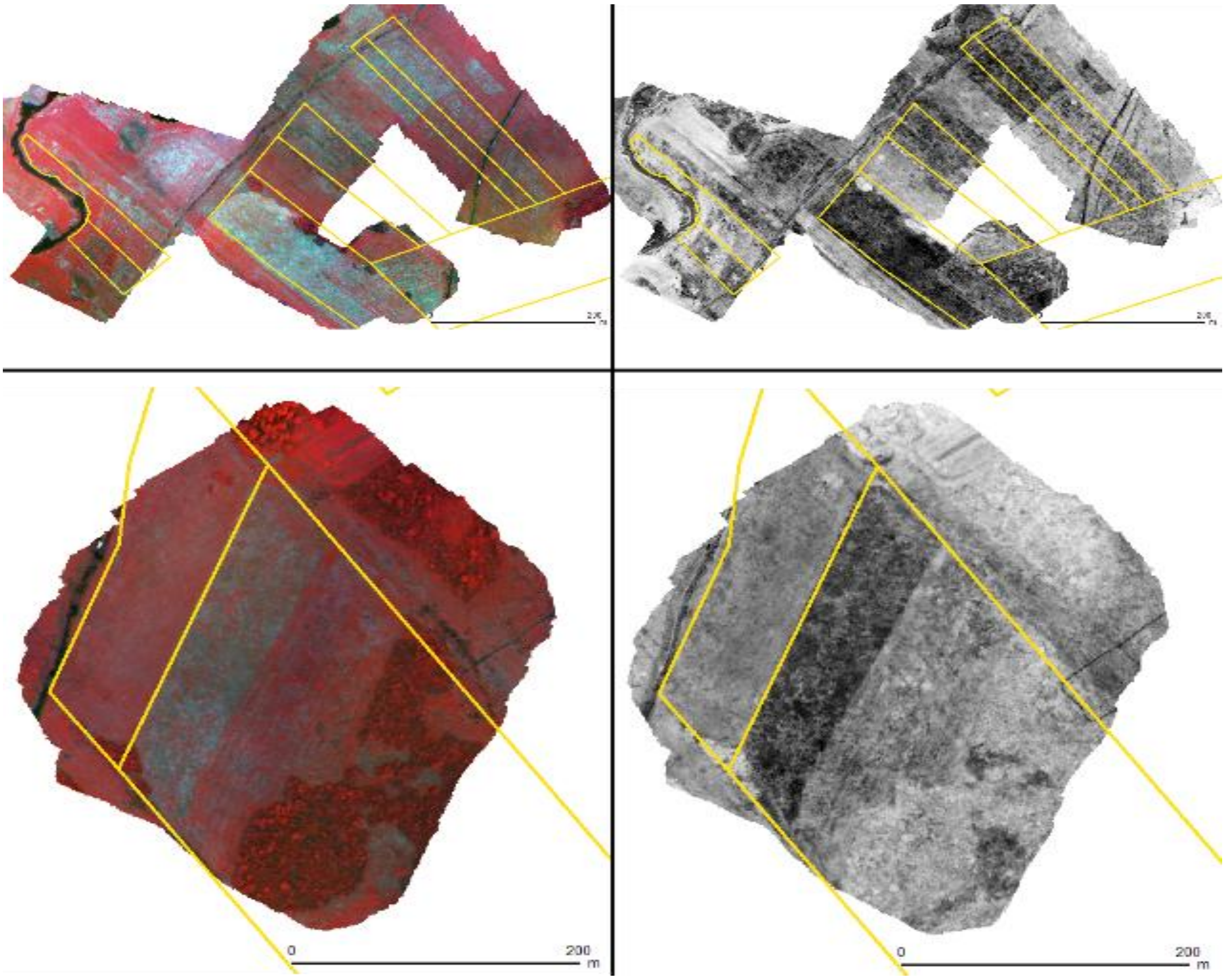

Figure 5: *Two examples of data obtained from drone; on the left, the composition of channels 16-6-4 (bluish areas correspond to sections of meadows with larger share of dry vegetation) on the right established NDVIs.*

3.4 Evaluation of accuracy and summary

To summarise this project, it is worth paying attention to pros and cons of the decision on using this technology to obtain teledetection data, so that it could be used intentionally and reasonably for subsequent analyses. An unquestionable advantage of imaging with the use of a drone is the possibility of taking pictures at low heights, as low as a few dozen meters, as well as smooth selection of height in vertical profile (which is impossible in the case of an aircraft or a satellite). Thus, such pictures are characterised by high spatial resolution, impossible to obtain by satellite images. Spatial resolution at the flight ceiling of 200 m. is approx. 12 cm. Such level of detail is necessary for precise determination of models, as well as for modification (detailing) of mathematical models used for image analyses, e.g. satellite images with greater data generalization, covering significantly larger areas. Obtaining such detailed images for large surfaces, e.g. community area, would be excessive. Therefore, for such areas, imaging is made at higher ceilings (at the same time, the image covers a significantly larger area). Important factors include also mobility, flexibility and relatively small cost of conduct of a single flight that can be carried out with a possibly short preparation time. Additionally, the need to maintain eye contact with the device by the drone operator provides a chance for good recognition of the imaged areas from the ground level and execution of additional measurements, which positively affects the accuracy of analyses.

On the other hand, the use of a drone has clear limitations that were impossible to avoid also in the case of the concerned project. The time of a single flight amounting to ca. fifteen minutes, high dependence on weather conditions, fairly low threshold conditions for wind power, during which flights cannot be performed for safety reasons (but also due to image quality), as well as the need to maintain eye contact with the drone limiting the scope of the survey - those factors result in the fact that the use of a drone in the case of analyses of large surfaces becomes difficult and ineffective.

But stronger winds means that even when using advanced stabilization, the individual channels can be spatially offset in relation to each other, which raises the need to use the compilation of time-consuming algorithms automatically adjust to each channel, or very time-consuming - even manual geometry corrections. This need not occur when we could use the muli-lens camera recording the appropriate channels at the same time (which of course increases the weight of the camera).

Trying to simulate the performance of imagery from drone on a scale of Podlaskie province with an area of 20180 km^2, where being a potential interest to agricultural land is 10741 km^2 (CSO, 2013) and based on framework price list of one of the companies carrying out flights by drones, total, multimillion cost and the huge amount of time needed for the execution of such a large area of the project make use of established technology, it is impossible to predict.

3.4 Recommendations

With the analysis of agricultural production with the use of remote sensing techniques, the first step should be to align the source of the obtained data for the planned scale of the study and the needs related to spatial resolution. While in the case of single plots, imaging from the level of a drone can provide valuable material for the purpose of conducting detailed analysis of production from grasslands, as well as provide possible additional significant data for verification of models used for analysis of image content. In the case of municipality or district levels, it may be more reasonable to use data from small airplane flights, with the use of the same equipment as the one used in drone studies, or even data from satellite (e.g. data from satellites Landsat 8 or Sentinel-2), which may enable analysis in the scale of a voivodeship, districts or the whole country.

Nationwide demonstration cases of Sentinel-2 satellite exploitation towards early crop area indicator

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ABSTRACT

Satellite Earth Observation (EO) is a relevant source of transparent, timely and consistent information to monitor crop growth, to provide early area indicator and to stratify the agricultural regions. Thanks to the Copernicus program of the European Union, the satellite EO has recently entered in an operational mode where the data quality, the free and open access and the long-term continuity are major breakthroughs opening the avenue for more ambitious contribution to crop area and production estimate. This is the reason why developing operational agriculture applications from Landsat-8 and Sentinel missions became a strategic target for the remote sensing community, e.g. GEO-Global Agricultural Monitoring Initiative (GEOGLAM) building on GEO's Agricultural Community of Practice (AG COP) and the Joint Experiment of Crop Assessment and Monitoring (JECAM) supported by the space agencies' committee (CEOS). In particular, the Sentinel-2 mission was designed to optimize the observation capacity for regional to global agriculture monitoring at field scale in terms of spatial and spectral resolution (10 or 20 meters for targeted spectral bands), revisit frequency (5 days when two satellites in orbit), and coverage (systematic global acquisition). The combination of these features makes them most relevant to deal with a large diversity of agricultural landscapes.

In this context, the European Space Agency launched in 2014 the "Sentinel-2 for Agriculture" (Sen2-Agri) project, which aims at preparing the exploitation of Sentinel-2 data for agriculture monitoring through the development of an open source processing system. Based on key end-users requirements, this is designed to generate four relevant products, i.e. (i) cloud-free surface reflectance composite, (ii) dynamic cropland mask, (iii) cultivated crop type map and area indicator for main crop groups and (iv) vegetation indicators describing the vegetative development of crops. Crop type area indicators will be available after the first half of the season and thus, can serve as early estimate while waiting for the official agricultural statistics. Even if the area estimates accuracy is not yet matching the statistical standards, this product could be highly valuable as complementary geospatial information in a more and more georeferenced world

Thanks to fruitful interactions with key end-users and the network of JECAM sites globally distributed, the first phases of the project completed the product specifications, the algorithms selection, the system design, development and implementation. The third phase is currently dedicated to the demonstration of the Sen2-Agri system in operational conditions at full scale using Sentinel-2 and Landsat-8 data. Nationwide applications are on-going in close interactions with national and international partners, with the additional objective to transfer the system to the end-user's entity. A group of more than 15 champion users are closely engaged in the Sen2-Agri project including international organizations such as FAO, WFP, CGIAR or JRC of the European Commission as well as national mandated institutions in e.g. Mali, South Africa and Sudan. While the system already delivered successful SPOT4 Take 5 and SPOT5 Take 5 results for a dozen of JECAM sites, nationwide demonstration started in 2016 in Mali, Ukraine and South Africa. Five additional local sites were selected in Morocco, Sudan, France, China, and Madagascar covering up to 300 x 300 km in order to further increase the global representativeness of the demonstration findings.

Early results of these on-going demonstration cases are presented, as well as the preliminary lessons learned in the real-life context of the engaged user entities. In particular, the field data campaign, the cultivated area mask and the crop type map are discussed for Ukraine while the other demonstration cases are still going on.

Keywords: crop mapping, Sentinel-2 satellite, early estimate of cultivated areas

1. Introduction

Since years, satellite Earth Observation (EO) was proved to be a relevant source of comprehensive, timely and spatially consistent reflectance measurement to derive land cover map or even land use map in order to stratify national or regional territory for agricultural sampling. For crop area estimate, stratification allows either to optimize the sampling rate for area estimate and/or to improve the area estimate quality. Mapping crop to derive area estimate was found very challenging for various reasons: (i) classification accuracy hardly reaches the required level to capture the often marginal inter-annual change of the respective crop type areas, (ii) classification precision and accuracy are very dependent to the number and the dates of cloud free image acquisition, (iii) classification results are sometimes biased towards specific crop according to field patterns and pairwise crop spectral signature separability, (iv) statistical system cannot afford to rely on exploratory satellite mission which cannot ensure long-term continuity of observations.

More recently, satellite remote sensing is also used to empirically estimate the yield wherever the field size is compatible with the spatial resolution of existing satellite time series.

With the Sentinel-1a satellite in orbit since April 2014, the Copernicus program of the European Commission started to launch a fleet of EO satellites, which change completely the game for agriculture remote sensing. Unlike many other EO satellites, the Copernicus space segment is designed as an operational service providing consistent data quality, open and free access and long-term continuity (more than 20 years). For instance, Sentinel-1a and -1b, already both in orbit, carry exactly the same instruments providing complementarity but more importantly redundancy. Recurrent satellites for each of the Sentinels are in preparation and will be ensuring long-term continuity. While Sentinel-1 SAR instruments operate in the microwave domain to observe through the clouds, Sentinel-2 satellites capitalize on the heritage of Landsat and SPOT experiences to provide the first non-commercial EO system really designed for agriculture remote sensing. Combining visible and near-infrared bands with red-edge bands allows capturing most of the key vegetation properties while three other specific spectral bands support a better atmospheric correction (figure 1). The 10-day revisit cycle with a 10 – 20 m resolution and a wide swath of 290 km make it capable to acquire observation time series over large areas while capturing the field level. These features allow addressing a lot of the diversity of the agricultural landscapes. Launched in June 2016, Sentinel-2a will be complemented by Sentinel-2b scheduled for early 2017 to enhance the revisit cycle to 5 days. This is expected to provide dense time series adapted to temporal crop dynamics in most cropland regions. Some areas cloudy during the growing season would require even a more frequent observation capacities or the complementarity of SAR system not affected by cloud coverage like Sentinel-1. The Copernicus fleet also includes several additional satellites such as Sentinel-3 providing 300 m daily observation once both will be operating. Last but not least, the global systematic acquisition of Sentinel-2 and the open and free access license policy clearly open the door for more ambitious contribution of satellite remote sensing to agriculture assessment.

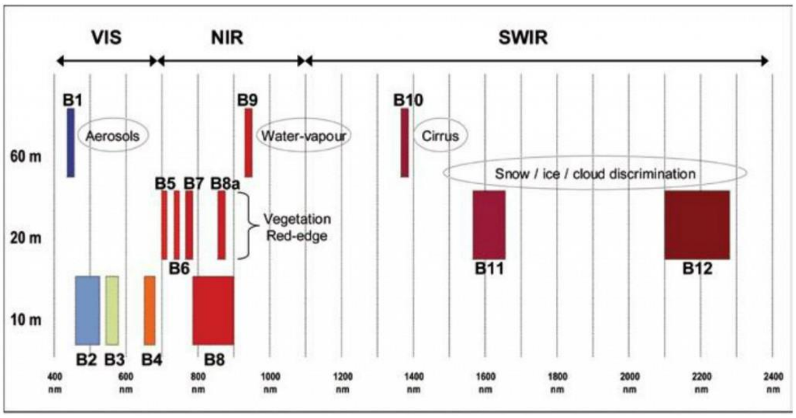

Figure 1: *Sentinel-2 spectral bands distribution (source: ESA).*

In this evolving environment, developing operational agriculture applications from Landsat-8 and Sentinel missions became a strategic target for the remote sensing community. Building on GEO's Agricultural Community of Practice (AG COP), the Joint Experiment of Crop Assessment and Monitoring (JECAM) and the Geo-Global Agricultural Monitoring Initiative (GEOGLAM) both supported by the space agencies' committee (CEOS) are instrumental to develop best practices and speed up the operational adoption of state-of-the-art remote sensing methods.

In this context, the European Space Agency launched in 2014 the "Sentinel-2 for Agriculture" (Sen2-Agri) project, which aims at preparing the exploitation of Sentinel-2 data for agriculture monitoring through the development of an open source processing system. Based on key end-users requirements, this is designed to generate four relevant products, i.e. (i) cloud-free surface reflectance composite, (ii) dynamic cropland mask, (iii) cultivated crop type map and area indicator for main crop groups and (iv) vegetation indicators describing the vegetative development of crops. Crop type area indicators will be available after the first half of the season and thus, can serve as early estimate while waiting for the official agricultural statistics. Even if the area estimates accuracy is not yet matching the statistical standards, this product could be highly valuable as complementary geospatial information in a more and more georeferenced world.

Thanks to fruitful interactions with key end-users and the network of JECAM sites globally distributed, the first phases of the project completed the product specifications, the algorithms selection, the system design, development and implementation. The third phase is currently dedicated to the demonstration of the Sen2-Agri system in operational conditions at full scale using Sentinel-2 and Landsat-8 data. Nationwide applications are on-going in close interactions with national and international partners, with the additional objective to transfer the system to the end-user's entity. A group of more than 15 champion users are closely engaged in the Sen2-Agri project including international organizations such as FAO, WFP, CGIAR or JRC of the European Commission as well as national mandated institutions in e.g. Mali, South Africa and Sudan. The system already delivered successful SPOT4 Take 5 and SPOT5 Take 5 results for a dozen of JECAM sites.

2. Objectives

This demonstration study aims to assess the performances of the Sen2-Agri system to deliver in a timely manner the cropland and area indicator for the main crops at national level. This pre-operational system designed as a generic open source software relies on near real time acquisition of Sentinel-2a and Landsat-8 imagery. The crop type mapping also requires timely in situ data collection while cropland mapping can run either from in situ data or only from existing land cover map. A crop type area indicator corresponds to unqualified crop area estimate and is obtained by pixel counting corrected for possible bias as assessed by a confusion matrix.

These nationwide applications respectively in Ukraine, Mali and South Africa are planned in close collaboration with national partners, with the additional objective to transfer the system to the national entity. This is the reason why the Sen2-Agri system is operated in a centralized way on one hand and in parallel at national level closely engaging and empowering the national stakeholders. National stakeholder's workshops are organized to provide insights from a user's perspective as well as to assess the quality and the relevance of the delivered information. Five additional local sites were selected in Morocco, Sudan, France, China, and Madagascar covering up to 300 x 300 km in order to further increase the global representativeness of the demonstration findings.

The objective of this paper is to report the preliminary outputs of the Sen2-Agri system, mainly illustrated through the Ukraine demonstration case, and to discuss the first lessons learnt.

3. Methods

Being part of the ESA Data User Element programme, the product to deliver by the Sen2-Agri system was entirely driven by a user-oriented approach in order to address concrete user needs and requirements. A suite of four core products was defined as top priority and are delivered automatically along the growing season by the system which was designed to take advantage of the near-real time imagery acquired by Sentinel-2 satellites as well as Landsat-8. Before the launch of the satellites, systematic benchmarking of state-of-art methods led to develop specific processing chain for each product (Bontemps et al., 2016). Only the cropland mask and the crop type mapping are presented in this paper.

The dynamic cropland mask delivered several times during agricultural seasons consists of a binary map at 10-meter spatial resolution separating annual cropland areas from other areas. Cropland is defined according to the JECAM guidelines (JECAM, 2014) as follows: “the annual cropland from a remote sensing perspective is a piece of land of a minimum 0.25 ha (minimum width of 30 m) that is sowed/planted and harvestable at least once within the 12 months after the sowing/planting date. The annual cropland produces an herbaceous cover and is sometimes combined with some tree or woody vegetation”. There are three known exceptions to this definition. The first concerns the sugarcane plantation and cassava crop, which are included in the cropland class, although they have a longer vegetation cycle and are not planted yearly. Second, taken individually, small plots, such as legumes, do not meet the minimum size criteria of the cropland definition. However, when considered as a continuous heterogeneous field, they should be included in the cropland. The third case is the greenhouse crops that cannot be monitored by remote sensing and are thus excluded from the definition. This definition discards perennial crops and fallow, as they are less important to monitor from an annual perspective.

The mask is delivered for the first time after 6 months of data acquisition and is then updated monthly. The season start date is a parameter defined a priori by the user. From one year of data acquisition, the production is based on a 12-month moving window. The regular update is expected to lead to an accuracy progressively increasing along the growing season. The processing chains producing the cropland mask are respectively described by Matton et al. (2015) and Valero et al. (2016) whether in situ data are available or not.

The cultivated crop type map is a map of the main crop types (or crop groups) for the whole country at 10-meter spatial resolution. It builds upon the cropland mask to process the time series only over the cropland areas. The main crop types are defined as (i) those covering a minimum area of 5% of the annual cropland area and (ii) whose cumulated area represent more than 75% of the annual cropland area. A maximum of 5 crop types are considered by country in the demonstration. In an operational context, the user can map the crop types he wants, providing that he collects the corresponding in situ data. The crop type map is delivered twice during the growing season with user-defined season start and end dates. The first map is produced after six months of data acquisition, with a legend that might be slightly different from the final one depending on what can be discriminated during the early stages of the season (e.g., summer vs. winter crops, irrigated vs. rain fed fields, etc.). Its accuracy may be variable but is intended to provide the best current information critically needed for crop monitoring systems. The second map comes at the end of the growing season and is expected to have much higher accuracy. The product allows deriving an early crop area indicator, which consists of the proportion of each crop type reported on the map within a 1 km² pixel. In the case of significant bias, the proportions will be corrected using the information provided by the confusion matrix of the crop type map. The area indicator can also be delivered at the most convenient aggregation level from the user point of view, i.e. administrative or census entity.

Aiming at developing an operational processing system globally relevant and coping with the large diversity of agro systems is not straightforward (Bontemps et al., 2016). It raises several challenges. From the remote sensing point of view, being relevant over the whole range of agricultural systems require to deal adequately with the global diversity of surface reflectance values to extract meaningful land cover information. Furthermore, the local heterogeneity of the agricultural practices (rotations, unusual crops, grassland edges, etc.) and the agro-meteorological variability will prevent the use of expected trajectories for crop discrimination and will require methodologies able to account for specific local conditions.

As described in Bontemps et al. (2016), products relevance does not only depend on their accuracy but also on their timeliness. Indeed, the value of most agricultural information rapidly decreases over time, as the seasonal production cycle leads to a sequence of critical dates for information delivery. The challenge is to provide the capacity to handle rapidly the processing of whole country, with the associated large volumes of data and products. The demonstration study also addresses challenges from the methodological, digital and organizational points of view. Indeed, most operational monitoring systems rely on proxies and qualitative indicators based on medium to coarse spatial resolution sensors. While the potential of high spatial resolution imagery is widely recognized, most of the research activities in this area currently rely on one site, one crop and one sensor. Supporting the development of operational agriculture monitoring methods based on high resolution images will first require collecting both EO and in situ data coming for the same season. Second, enough in situ data are to be acquired over each country to allow both algorithm calibration and independent validation of each product.

Three national demonstration cases (table 1) have been selected according to criteria including the representativeness of the selected countries with regard to a large demonstration ambition. These concerned the type of agricultural systems to monitor (e.g. crop type diversity, spatial heterogeneity, croplands fragmentation and field size distribution) and the agro-climatic conditions defining the actual availability of valid cloud free observation at the critical periods of the growing season.

Table 1: *Summary of national demonstration cases.*

Country (study area)	Main characteristics	Main crops and calendar	National Stakeholders
Mali (447 948 km²)	➢ Northern hemisphere ➢ Sudano-sahelian climate ➢ Field size: 1–5 ha	➢ Millet, Sorghum, Rice, Maize, Cotton ➢ From June to October with field preparation in March/April;	➢ ICRISAT ➢ Ministry of Agriculture : IER and Cellule Planification et Statistiques
Ukraine (576 604 km²)	➢ Northern hemisphere ➢ Humid continental climate, with snow cover in February and March ➢ Field size: 30–250 ha	➢ Wheat, sunflower, maize, barley, soybean ➢ From September to July and from April to October	➢ Space Research Institute of National Academy of Science ➢ National agro-meteorological service (Ministry of Emergency)
South Africa (619 606 km²)	➢ Southern hemisphere ➢ Sub-humid to semi-arid climate ➢ Field size: 40 ha	➢ Maize, wheat, sunflower, soybean ➢ Major season from December to June; from April to November	➢ Agriculture Research Council (ARC)

4. Results

While the Sen2-Agri system is currently running at national scale for Ukraine, Mali and South Africa, the performances are here illustrated from the preliminary results obtained in Ukraine.

4.1 In situ data collection

The purpose of in situ data collection within the season is twofold in the context of Sen2-Agri: for the calibration to support the training of EO data processors (Sentinel-2, Landsat 8) and for the validation to assess the quality of the Sen2-Agri products. The validation sampling is spatially independent of the calibration samples. It will allow assessing the map accuracy by compiling a confusion matrix and deriving various accuracy metrics (Overall Accuracy, Precision, Recall, and F-Score) in order to document the quality of the Sen2-Agri products.

The objective of the calibration or training sampling is to cover the diversity of situations existing at national level in order to represent the range of possible signatures for croplands versus non croplands and for the five main crop types. In addition, discriminating and mapping these crops required also to collect data about the other crops. The samples are really targeted to establish all the links between a given target of interest and the range of its features used for classification (i.e. Sen2-Agri processors). Various types of sampling seem appropriate as long as it is fairly well distributed across the territory and containing enough information for each targeted class. In order to cover the diversity or gradient observed over large areas, it is recommended to stratify the croplands according to the interaction between agrosystem type – crop distribution – cropping calendar – biophysical context.

For each sampled parcel, the crop type must be identified from ground observation during the on-going growing season. As adopted by the JECAM network, a comprehensive 'windshield survey' along the main and secondary roads is found very efficient for in situ data collection for calibration purpose. A particular attention is required to reduce the bias related to the road proximity by getting off road regularly. For the calibration of the cropland mask, two options can be considered to sample non-agricultural land cover. If up-to-date very high resolution imagery is available from Google Earth or Bing geoportal for a large part of the area of interest, a systematic random sampling is proposed to collect by photo-interpretation a sufficient number of non-agricultural land cover types. Alternatively, the non-cropland samples can be selected during the crop type validation sampling by windshield survey along the same roads. The figure 2 reports the sample distribution of the nationwide field campaign completed in July 2016 by the field team of the Space Research Institute (NAS, Ukraine). In Ukraine, an agro-ecological zoning strongly correlated to crop distribution delineates four very distinct strata, which are classically use for agriculture reporting.

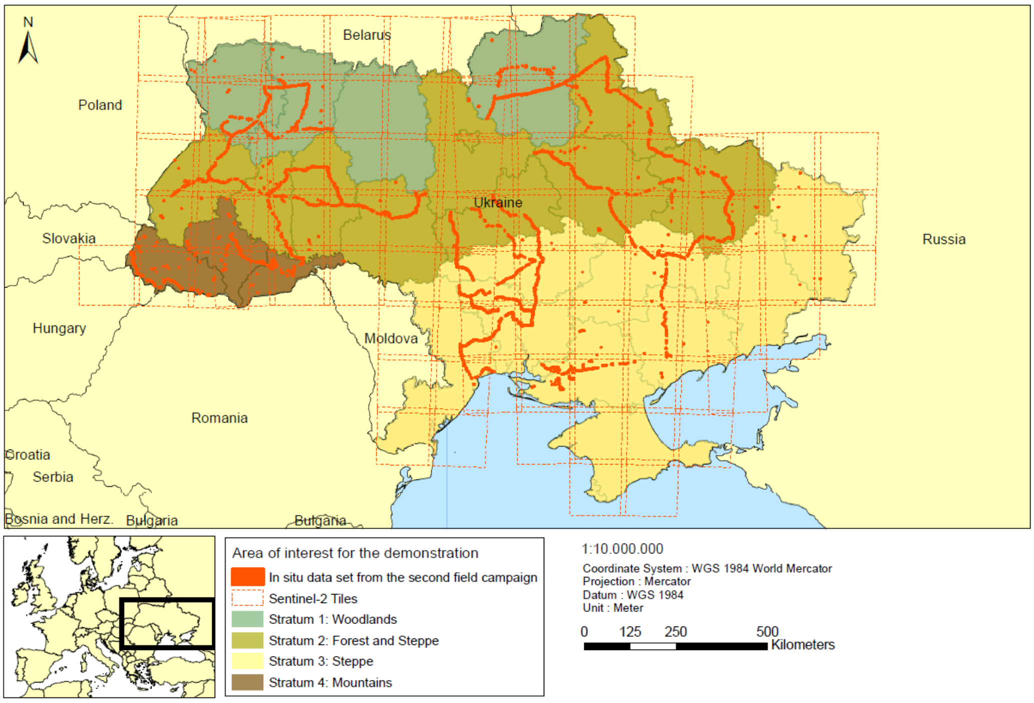

Figure 2: *Agro-ecological zoning of Ukraine used to stratify the Sentinel-2 time series processing and windshield sampling across the country for calibration purpose.*

4.2 Sentinel-2 data observation

Each Sentinel-2a acquisition has been processed from the 1st April to the 9th September 2016 in order to accumulate cloud free surface reflectance along the growing season. Using the MACCS module (Hagolle et al., 2010, Hagolle et al. 2015) included in the Sen2-Agri, a spatio-temporal cloud screening allows to detect the clouds and the associated shadows. The figure 3 shows the number of cloud free observation available over the 2016 growing season for each pixel of 10 m, highlighting the orbit overlap (in green).

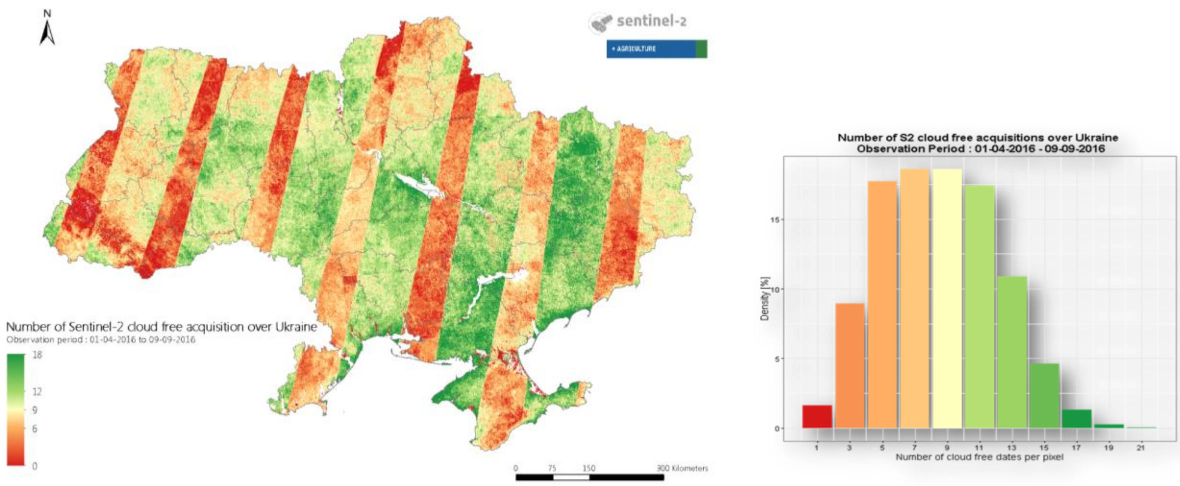

Figure 3: *Number of cloud free observation provided by Sentinel-2a over Ukraine during the 2016 growing season.*

4.3 Production and validation of crop mask

Once the field data quality controlled, they must be uploaded into the Sen2-Agri system to produce the crop mask and the crop type map. The figure 4 corresponds to a single tile (100 x 100 km) of the Ukraine territory to highlight the spatial details of the Sentinel-2 images acquired on 17 July 2016 and the associated in situ data.

The full time series of all Sentinel-2 observation acquired from April to September 2016 over the whole of Ukraine (more than 1,5 Tb of compressed input data) was automatically processed to surface reflectance (6 Tb of processed surface reflectance data). Thanks to the upload of the in situ data, the time series was then classified to derive the crop mask at 10 m resolution by early October for the on-going growing season over a national territory of more than 600,000 sq km. The figure 5 displays samples of this unique result of 10 m crop mask. This early estimate of the 2016 cultivated area can be compared with the available early statistics for 2016 compiled from the sowing area declaration by the farmers aggregated at oblast level.

The quality of the crop mask displayed on figure 4 is assessed by the set of accuracy metrics already mentioned. It is clear that the accuracy varies spatially according the fragmentation of the landscape, the crop diversity, the density of field data and, last but not least, as long there is only one Sentinel-2 in orbit (till 2017), the frequency of cloud free images along the season. Fortunately, these characteristics can be easily documented and therefore the area estimate uncertainty can be predicted.

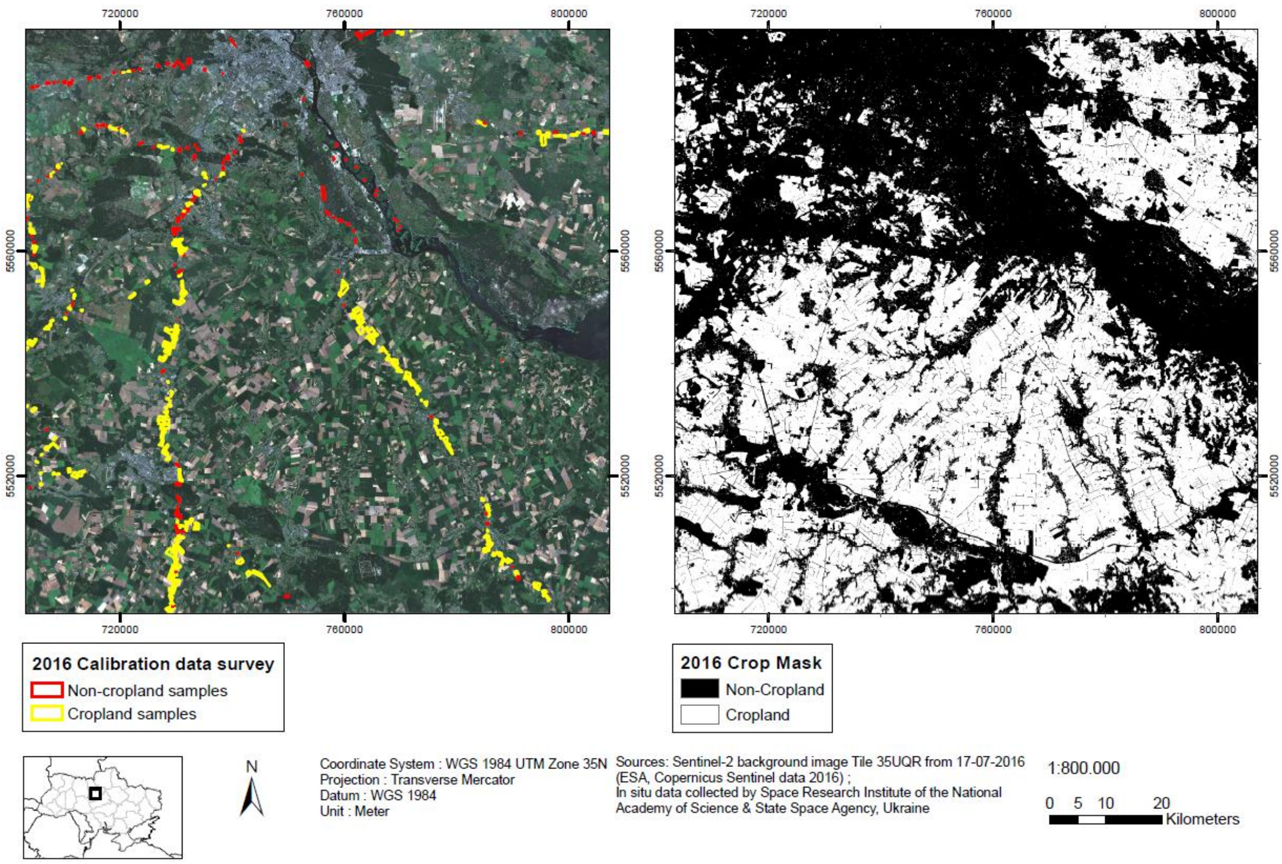

Figure 4: *Sentinel-2 10-m color composite acquired on 17 July 2016 over the South of Kyivs'ka oblast (on the left) overlaid by the field data used to produce the 2016 crop mask for the corresponding area (on the right side).*

4.4 Production of crop type map

Using the same in situ data, the Sen2-Agri system can also deliver a mid-season crop groups map and a more detailed crop type map by the end of the growing season. Zooms on the outputs obtained are displayed at figure 5. First, a map discriminating winter crops versus summer crops was produced while at the end of the season a more precise map of the different main crop types will be produced. Please note that the season was not over at the time of writing and the crop type map illustrated at the figure 4 is only an intermediary product.

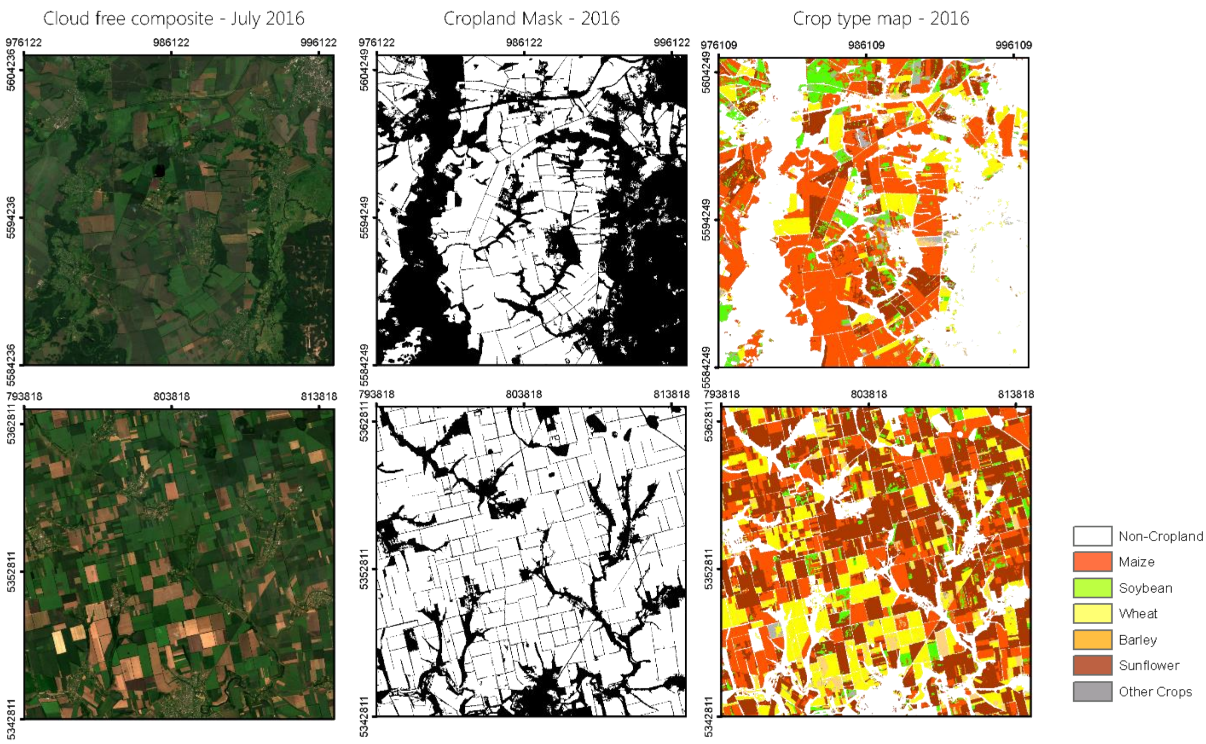

Figure 5: *Details of the 2016 cropland and main crop types map for two zoom in Ukraine.*

5. Perspective

The on-going demonstration of the Sen2-Agri highlights the significant impact of the availability of the Sentinel-2 time series on the capacity to deliver along the season various products including crop mask and crop type maps. The accuracy obtained for some of these products indicates that the early area estimate can be derived and be relevant as a complementary information to the official agricultural statistics. By the end of the growing season in the various demonstration countries, the final nationwide maps and derived area estimate will be available and compared with the existing official statistics. In addition, a user-oriented assessment, involving the national stakeholders such as the Ministry of Agrarian Policy and Food of Ukraine, will be reported in order to assess the Sentinel-2 demonstration products utility and benefit and the possible improvements.

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Grassland biomass assessment with remote sensing tools and open source software

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ABSTRACT

Images collected by optical and radar satellite sensors represent a most viable solution for the extraction of biophysical parameters of the earth surface. The mid-resolution dataset acquired by Landsat and Sentinel satellites have recently become available free of charge for all users. At the same time, some software of image processing and GIS, like *QGIS*, *R*, and *ImageJ*, have reached a high level of maturity and a large community of users, thanks to their open source license. In this project free satellite images and open source software have been used for the assessment of the grassland biomass. The overall goal is the enhancement of the statistics of grassland production and dried fodder for the animal breeding. Currently the National Institute of Statistics collect this kind of dataset at the province level.

The project, still in progress, consists in some "in situ" surveys in a specific site in central Italy and in the building of a regression model between the grassland heights and the corresponding radiometric values of the most relevant image bands.

Keywords: biomass, Sentinel, Landsat, grassland

1. Study areas

During the planning phase, three areas have been identified for the collection of training and test samples, in the North, Central and Southern Italy. A specific mission in the National park of Murge, in Puglia, South of Italy, has shown however the unsuitableness of the local grassland for the model, due to the presence of stones and shrubs over the ground and the low number of pastures in the small, scattered and flatten areas. The collected samples of the grass height have also demonstrated the diversity of vegetation classes and the need to build a complex regression model considering the height of each class, or each group of classes, separately.

The foreseen campaign of measures in Northern Italy has not taken place until now due to limited time and resources. Therefore, the model has only been trained with the two-year campaigns carried out in Central Italy, in a site named Pian Grande.

Pian Grande is an upland karstic plain in the national park of Monti Sibillini, located between Umbria and Marche, in the Appennini mountains, in central Italy. It is a quite suitable site for the grassland production because of the lack of trees and shrubs over the flat plan, located at 1300 mt above sea level. The plain is the bottom of an ancient mountain lake, now dried up, and has a rectangular shape with an area of around 15 Km^2. From the vegetational point of view, it is possible to consider the existence of 4 types of homogeneous areas:

- areas with agricultural crops (grass meadows, barley and lentils) located in the nearby of Castelluccio village and below the slopes of Vettore Mt., corresponding to the class 2.1.1 (Non-irrigated arable land) of CORINE[1] Land Cover 2012 map;
- areas with natural grassland, equivalent to the class 3.2.1;
- areas with pastures, that occupies the central portion of the plain, corresponding to the class 2.3.1 (Pastures);
- bare rocks (3.3.2) or sparsely vegetated areas (3.3.3), located in the nearby of Vettore Mt.

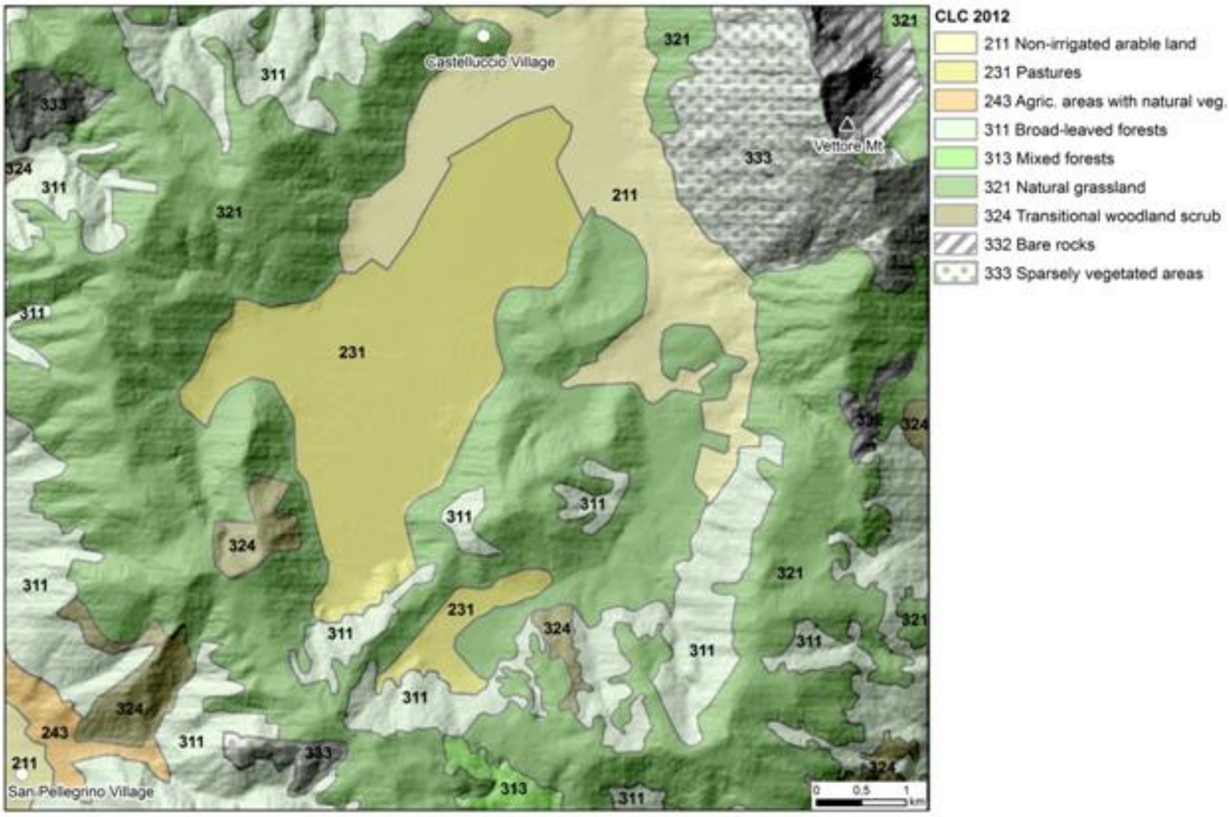

Figure 1: *CORINE Land Cover 2012 map*

The pasture reaches its highest growth at the end of June, depending on the temperatures, after a suggestive blossom, and produces high quality bales of hay. The best period for the field surveys is between the end of June and the beginning of July, just before the cut of the grassland. Two missions have been carried out in the past two years (2015-16) during the same period of the year.

[1] http://www.eea.europa.eu/publications/COR0-landcover

2. Sampling methodology

The need of collecting many samples as possible of the grassland height in a limited time and with the most possible accuracy, taking also into consideration the pixel dimension of the satellite images used for the model, has suggested to the use of the camera and to postprocess the images in order to derive the height with some image processing tools.

The assessment of the height has been executed with a white cardboard of 300 x 70 cm placed on the grass and used as a background for the photograph in order to derive just a linear section of the grass height. Every picture has been linked to the GPS position of the same sample point.

Figure 2: *Survey of a height of a section of grass*

The high contrast of the green vegetation over the white background has helped in the postprocessing of the photographs that has consisted in the extraction, rescaling to a standard width and measure of just the white area (c section in the figure 3) in terms of number of pixels. The division of that area by the fixed width produces its mean height and, by difference with the total height of the cardboard, the mean height of the grass.

The pictures have been analysed with an open source image processing software: *ImageJ*[2]. The software is written in Java and is available for Windows, Linux and Mac OS and OS X. Some of the software tools used in the software for the process are the *Colour Threshold*, for the selection of the white pixels, and the *Colour Pixel Counter*, for the determination of their number. In the 2015 survey a simpler brown cardboard has been used, but sometimes the colour separation and the extraction of grass has been difficult, above all in case of dry hay. Another lesson learnt during the first year of the project is to avoid measures in the second half of July, when the grass is usually cut and compacted in bales.

This method has allowed a very fast survey and a high number of samples collected during each day of measurements. 88 samples have been acquired in a two-day campaign on June 2016, while just 20 were the points surveyed in 2015 because of the partly mown pasture.

[2] https://imagej.nih.gov/ij/index.html , Wayne Rasband, U.S. National Institutes of Health

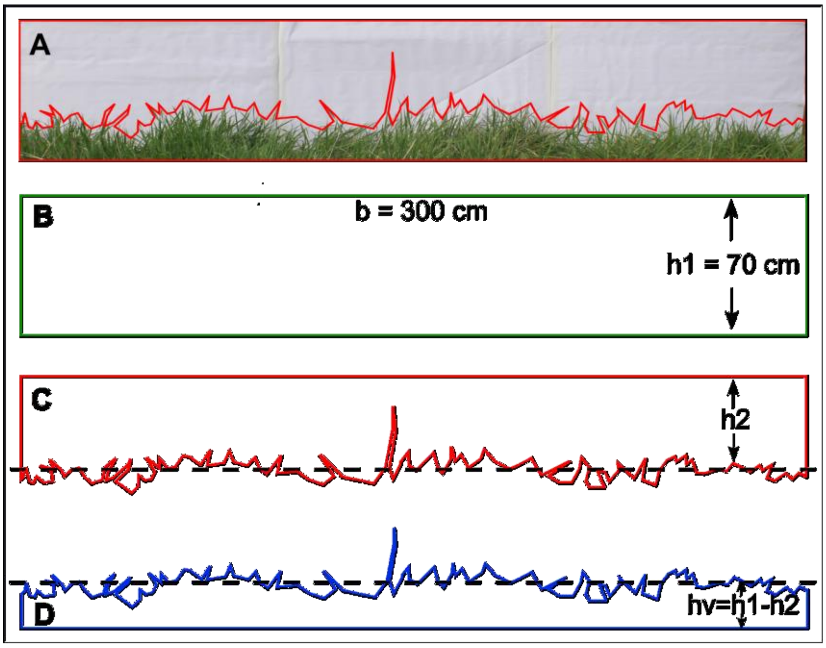

Figure 3: *Postprocessing of the pictures*

3. Satellite images

Currently two mid-resolution satellites acquire images from the earth surface with optical sensors and deliver them free of charge to all users: the Landsat 8 (Nasa) and the Sentinel-2 (Esa).

The OLI sensor of Landsat 8 has replaced the ETM+ one mounted on Landsat 7 but maintains the same bands and the same ground resolution (30 meters) of the previous satellites, allowing in this way the time series analysis. Sentinel-2A is one of the satellites of the Copernicus Esa observation programme and delivers images at a spatial resolution of 10 meters in visible - near infrared spectra. By the end of 2016 the new Sentinel-2B will join the Esa constellation, increasing in this way the revisiting frequency on the same area.

Radar images have also been considered for the correlation model: the Sentinel-1 satellites acquire polarised images in C-band with a spatial resolution of 20 meters. From the first results of the model it seems S-1 images are not so useful for the determination of grass height (see S1_VH and S1_VV in Table 1). Nevertheless, it has been planned to test the model with the high-resolution radar images of the *Cosmo-Skymed* Italian mission.

The values for every image and band have been extracted with the *QGIS*[3] *Zonal Stats* tool with a 20-meters buffer centred on each samples and by extracting basic statistics, like mean and standard deviation, from the overlapping pixel values.

4. Statistical analysis

Descriptive statistics are used to describe the basic features of the data by means of some numeric indexes: mean, standard deviation, standard error of the mean (SEM), coefficient of

[3] http://www.qgis.org/it/site/

variation, skewness and kurtosis. The univariate correlation has been considered too, with the evaluation of the Pearson correlation coefficients and the relative correlation matrix.

Furthermore, a multiple linear regression model has been implemented, based on ordinary least squares method, that is one of the most frequently used statistical approaches to model the correspondence between spectral and field data (Lu, 2006).

The regression model consists of a dependent variable, the vegetation height (Hv) measured in the in-situ survey, and the independent variables, represented by the spectral radiance levels of the bands from Landsat 8 and Sentinel 1-2 satellites. Adjusted R-square are considered as fitting parameters of calculated models.

A backward elimination approaches based on Akaike's Information Criteria (AIC) was used to identify the model that provides the best description of the data using the smallest number of parameters.

4.1. Sentinel

Descriptive statistics and correlation for Sentinel image are shown in Table 1 and Table 2. A positive correlation exists between the S2_NIR and S1_VV while remains negative for all the others bands. Table 3 shows the T-test between the most significant predictors for the model (Red, Green, NIR) and how they differ from each other.

The regression model with the least AIC is:

$$Hv = 71.186 - 0.168 * S2\_G + 0.083 * S2\_R + 0.010 * S2\_NIR$$

The overall significance of the regression model has been estimated with the F-test (F-statistic: 40.62 on 3 and 66 degree of freedom, p-value: 5.42e-15) and the model shows an Adjusted R-square of 0.63.

Table 1: *Descriptive statistics of Sentinel bands and vegetation height variable*

	Mean	Sd	Sem	Cv	Skewness	Kurtosis	n
Hv	12.53726	4.88430	0.58378	0.38958	0.46653	0.06819	70
S2_R	566.23010	72.28901	8.64018	0.12766	0.03663	-0.93344	70
S2_G	834.29860	38.00711	4.54271	0.04555	0.02921	-0.76980	70
S2_B	816.94480	37.14889	4.44014	0.04547	-0.02553	-1.12067	70
S2_NIR	3447.06900	463.68190	55.42058	0.13451	0.28618	-0.80817	70
S2_SWIR1	1994.56300	144.10530	17.22387	0.07224	-0.06513	-0.81735	70
S2_SWIR2	878.25000	106.24390	12.69857	0.12097	-0.10227	-0.95836	70
S1_VH	0.00696	0.00150	0.00018	0.21648	0.04729	-0.30711	70
S1_VV	0.02249	0.00719	0.00085	0.31961	1.54624	3.85916	70

Table 2: *Correlation matrix of Sentinel bands and vegetation height variable.*

	Hv	S2_R	S2_G	S2_B	S2_NIR	S2_SWIR1	S2_SWIR2	S1_VH	S1_VV
Hv	1.00	-0.50	-0.66	-0.50	0.42	-0.58	-0.54	-0.24	0.16
S2_R	-0.50	1.00	0.77	0.95	-0.77	0.86	0.92	0.19	-0.20
S2_G	-0.66	0.77	1.00	0.85	-0.32	0.84	0.74	0.28	-0.06
S2_B	-0.50	0.954	0.85	1.00	-0.60	0.87	0.88	0.24	-0.14
S2_NIR	0.42	-0.77	-0.32	-0.60	1.00	-0.61	-0.78	-0.07	0.32
S2_SWIR1	-0.58	0.86	0.84	0.87	-0.61	1.00	0.95	0.21	-0.20
S2_SWIR2	-0.54	0.92	0.74	0.88	-0.78	0.95	1.00	0.19	-0.24
S1_VH	-0.24	0.19	0.28	0.24	-0.07	0.21	0.19	1.00	0.16
S1_VV	0.16	-0.20	-0.06	-0.14	0.32	-0.20	-0.24	0.16	1.00

Table 3: *Coefficents of the regression model.*

	Estimate	Std. Error	t value	Pr(>|t|)	Signif. codes
(Intercept)	71.186	9.599	7.415	2.94e-10	***
S2_G	-0.168	0.019	-8.576	2.47e-12	***
S2_R	0.083	0.015	5.436	8.51e-07	***
S2_NIR	0.009	0.001	6.168	4.73e-08	***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

4.2. Landsat 8

Descriptive statistics and the correlation matrix for Landsat 8 image have been evaluated as well (see Table 4 and Table 5). The correlation is similar to Sentinel: positive between the grass height and the NIR band while remains negative for all the other bands. Table 6 shows the coefficients obtained with the T-test.

The resulting model is:

$$Hv = 161.094 - 0.042 * S2\_G + 0.024 * S2\_R + 0.002 * S2\_NIR$$

The F-test reports similar results of the previous case (F-statistic: 33.31 on 3 and 66 degree of freedom, p-value: 3.153e-13) and the model shows an Adjusted R-square of 0.58.

Table 4: *Descriptive statistics of Landsat 8 bands and vegetation height variable.*

	Mean	Sd	Sem	Cv	Skewness	Kurtosis	n
Hv	12.53726	4.88430	0.58378	0.38958	0.46653	0.06819	70
S2_R	7930.85964	313.99845	37.52999	0.03959	0.32972	-0.96813	70
S2_G	8984.19961	195.03900	23.31161	0.02170	0.12753	-1.24466	70
S2_B	9094.65477	168.12788	20.09512	0.01848	0.30531	-1.12506	70
S2_NIR	22488.18104	1755.67616	209.84343	0.07807	0.19165	-0.83607	70
S2_SWIR1	13748.75454	719.60525	86.00927	0.05233	-0.18136	-1.05729	70
S2_SWIR2	8844.71064	462.31373	55.25706	0.05227	0.03363	-1.12945	70

Table 5: *Correlation matrix of Landsat8 bands and vegetation height variable.*

	Hv	S2_R	S2_G	S2_B	S2_NIR	S2_SWIR1	S2_SWIR2
Hv	1.00	-0.47	-0.63	-0.43	0.35	-0.53	-0.51
S2_R	-0.47	1.00	0.88	0.96	-0.70	0.85	0.91
S2_G	-0.63	0.88	1.00	0.91	-0.43	0.87	0.86
S2_B	-0.43	0.96	0.91	1.00	-0.56	0.89	0.92
S2_NIR	0.35	-0.70	-0.43	-0.56	1.00	-0.47	-0.65
S2_SWIR1	-0.53	0.85	0.87	0.89	-0.47	1.00	0.97
S2_SWIR2	-0.51	0.91	0.86	0.92	-0.65	0.97	1.00

Table 6: *Coefficents of the regression model.*

	Estimate	Std. Error	t value	Pr(>|t|)	Signif. codes
(Intercept)	161.0937	22.6334	7.118	1.00e-09	***
S2_G	-0.0421	0.0053	-7.937	3.43e-11	***
S2_R	0.0235	0.0042	5.606	4.38e-07	***
S2_NIR	0.0019	0.0003	5.019	4.18e-06	***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

5. Statistics on grassland production collected by Istat

As part of official statistics, Istat disseminates several statistics on grassland in Italy. The Istat classification of grassland includes the following classes: grass meadow; alternated grassland; grasses; grazings. The Italian Agricultural Census allows to have an analysis with a high spatial detail of grassland areas (at municipal level), in hectares. The inter census sample survey “Farm Structure” provides the same information at the regional level.

The annual estimates of the areas and production quantities of grassland are recorded by: “Estimate of crop, flower and pot plant production and area”. This statistics are produced using expert information. Data are provided by local authorities that collect experts evaluations on area and yield of different crops. The auxiliary information could be included in expert's estimate, such as verifying the availability of external sources (e.g. professional bodies or associations of producers, administrative sources, auxiliary sources of data related to the cultivation being estimated). Crops under investigation are different for each month and take into account the phenological stage of cultivation. For this reason more than one estimate can be determined for each crop during the year (provisional, temporary or permanent).

As part of the official agricultural statistics, more general information are produced by sample survey “Early estimates for main fields crops”, carried out annually in order to provide preliminary estimates of the areas affected by the most interesting crops during the current crop year.

6. Results

The project is still ongoing but the first results show a poor correlation ($R2 \geq 0.6$) between the VNIR bands and the grass height. Radar Sentinel-1 images, even polarised, seems not influenced by different vegetation biomasses of upland pastures, perhaps due to the limited grassland height. From the statistical results seems the higher grass has a bigger component of red while green and NIR decrease. The validation of the model is still to be performed.

However, the sampling method permitted fast operational activities and has given good results. The model seems to work better for mid-height grassland (10-20 cm), perhaps because in case of very low grass the images receive signals from other visible elements, like small stones, dry grass, and the terrain itself, while the higher grass doesn’t change the same radiometric values acquired for mid-height samples.

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THEMATIC SET

F31

USE OF OPINION POLLS FOR INFORMING FOOD SECURITY AND WELL-BEING MEASUREMENT

Session Organizer
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ABSTRACT

As the curtain closes on the Millennium Development Goals, a variety of new mechanisms and instruments have been developed which may be appropriate for measuring the progress and health of societies.

Survey data and opinion polls are being put forward by many parties as key data sources for the Sustainable Development Goals (SDG) process in order to help enable the realisation of the HighLevel Panel's post-2015 vision of creating an information revolution by enabling the disaggregation of data "by gender, geography, income, disability, and other categories."

As demonstrated by the work of The Organization for Economic Cooperation and Development (OECD) and a number of national governments—including Bhutan and the United Kingdom—over the past half-decade, there have been a number of significant breakthroughs in the field of subjective well-being measurement via survey research and opinion polls. These developments have coincided with a growing acceptance of well-being's potential impact to influence policy and policymakers. The use of such survey instruments on a global scale allow new insights into the state of the human condition.

In parallel, the United Nations Food and Agricultural Organisation has developed and validated an experience-based measure of food insecurity (FIES) for global monitoring through its Voices of the Hungry (VOH) project. Once again its implementation through a global survey instrument provides an overview of food insecurity at global, national and sub-national levels.

This call requests papers that can help demonstrate the utility and use of opinion polls to inform the post-SDG framework on the topics of food security, well-being or other interrelated themes, whether in isolation or as part of the larger data ecosystem.

LIST OF PAPERS

Exploring the impact of frequent consumption of fruits and vegetables on life satisfaction: study for the United States

F. Morthera | Gallup | London | United Kingdom

DOI: 10.1481/icasVII.2016.f31

Food insecurity and subjective well-being: an exploratory analysis of global heterogeneity

P. Diego-Rosell | Gallup | Castellón de la Plana | Spain

DOI: 10.1481/icasVII.2016.f31b

Perceived well-being by visiting urban green areas: an exploratory analysis using Partial-Least Squares models

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M. Agrimi | University of Tuscia | Viterbo | Italy
G. Carrus | Università degli Studi Roma Tre | Rome | Italy
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THEMATIC SET

F31

Gender disparities in reported life evaluation within food insecure and regionally diverse populations

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Exploring the impact of frequent consumption of fruits and vegetables on of life satisfaction: study for the United States

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ABSTRACT

A large literature exists on the positive link between the consumption of fruits and vegetables and physical health. The World Health Organization and many western nations have adopted postures that suggest a healthy diet being one where individuals are advised to consume five portions of fruits and vegetables per day (2002). Not a lot of research has been done, however, on measuring the impact of a healthy diet on psychological well-being. Despite the increased interest both by scholars and governments in the study of life satisfaction as a proxy for progress in a nation or society as a whole, there has been little research on a very basic element of human life which is the impact of the people's dietary choices in their happiness.

Building upon the exercise made by Blanchflower and Oswald for the UK (2012), this study investigates on the existence of a link between the regular consumption of fruits and vegetables and life satisfaction in the United States. With the aid of Gallup-Healthways Well-Being Index, a unique data source that surveys 500 US citizens daily on well-being and health related aspects, a cross-sectional analysis was done to determine if regular consumption of the five portions of fruits throughout the week has an important role in emotional wellbeing of individuals. Controlling for different economic, demographic and other socioeconomic factors the data demonstrates that an increased number days having the correct amount of portions is accompanied by an increase in life satisfaction evaluations. Reverse causality remains possible. Limitations to the study, policy implications and further research are discussed.

Keywords: Gallup Healthways Wellbeing Index, Healthy Food, Positive Impact

1. Introduction

Through its year-round daily surveys, the Gallup-Healthways Well-Being Index provides the most up-to-date data and insights available on US citizens' purpose, social, financial, community and physical well-being. Gallup published nearly 60 articles in 2015 about US citizens' health, well-being and life-satisfaction. Some of the key findings showed uninsured rates among US adults falling, obesity surging, cigarette consumption among young adults decreasing significantly over the past decade or nearly two in ten people in the United States saying they take drugs to relax almost every day. Factors contributing to these findings include negative workplace environments and difficulty making positive health decisions about modifiable health behaviours like diet, exercise, and stress.

In that same line of trying to determine what impacts well-being and life satisfaction, this study uses the Gallup-Healthways Well-Being dataset to study what the impact of regular consumption of fruits and vegetables is on life satisfaction in the United States. A large literature exists on the positive link between the consumption of fruits and vegetables and physical health. The World Health Organization and many western nations have adopted postures that suggest a healthy diet being one where individuals are advised to consume five portions of fruits and vegetables per day (2002). Not a lot of research has been done, however, on measuring the impact of a healthy diet on psychological well-being. Despite the increased interest both by scholars and governments in the study of life satisfaction as a proxy for progress in a nation or society as a whole, there has been little research on a very basic element of human life which is the impact of the people's dietary choices in their happiness.

There are particular dietary constituents like vitamins and minerals that have proven to be beneficial to physiological health. Such a great benefit to the body creates the need to answer the question of whether these benefits also happen in the psychological realm. Rooney, McKinley and Woodward (2013) show in the most thorough literature review on the matter how more and more papers are suggesting that choice of food intake may have the potential to influence psychological well-being. Foods with complex carbohydrate content (like beans, peas and bananas), high on vitamin B (in particular folate (spinach, Brussels sprouts) and vitamin B6 (peas and bananas), antioxidants or minerals (iron, calcium and magnesium) contained in fruits and vegetables have been linked to improvements in brain functions including neural development and synoptic plasticity in neurons.

Although there are exceptions like Graham (2008) and Powdthavee (2009), there has not been a lot of work on how happiness interacts with health and dietary choices. Building upon the exercise made by Blanchflower and Oswald for the UK (2012), this study investigates on the possible existence of a link between the regular consumption of fruits and vegetables and life satisfaction in the United States. By using 2014 and 2015 yearly data, this study provides evidence of a positive association between the regular consumption of fruits and vegetables with psychological well-being, using life satisfaction as a proxy. The more days a week a person consumes the recommended 5 units of fruits and vegetables the greater their life satisfaction is. The nature of this relationship is evaluated across a series of controls and possible confounders like income, race or educational level and the results are robust. That is important in this setting, because so many 'healthy' attributes, including high levels of education and income, are likely to be correlated with the eating of fruit and vegetables. The study also finds that higher levels of fruit and vegetable consumption appear to be predictive of future life satisfaction of individuals.

A limitation to the study should be made clear from the beginning. The data set is cross-sectional. Even though the margin of sampling error for the study being 0.2 percentage points at the 95% confidence level, we cannot draw direct inferences about causality. Given the policy implications of this topic and the difficulty of obtaining daily individual food consumption datasets, it would perhaps be valuable to create future longitudinal data sets in which fruit-and-vegetable portions are measured.

2. Methodology

The data for this study comes from the Gallup-Healthways Well-Being Index. Quoting from their own methodology, in the U.S., the Gallup-Healthways Well-Being Index provides an ongoing assessment of Americans' health and well-being. By interviewing no fewer than 500 adults each day, the Well-Being Index gives the ability to analyse and monitor U.S. residents' health and well-being on a continuous basis, allowing for unique insights on how to create behavioural change to ultimately improve well-being and lower healthcare costs. The Gallup-Healthways Well-Being Index includes questions that fall into six sub-indexes: Basic Access, Physical Health, Emotional Health, Healthy Behaviours, Life Evaluation, and Work Environment. The Well-Being Index segments the data for respondents in adverse and optimum situations according to household income, location demographics (based on ZIP code), and personal health status.

Gallup daily tracking relies on live (not automated) interviews, dual-frame sampling (which includes random-digit-dial (RDD) list-assisted landline interviewing and RDD wireless phone sampling to reach those in wireless-only and wireless-mostly households), and a random selection method for choosing respondents within the landline household. Gallup stratifies the random-digitdial (RDD) list-assisted landline and the wireless phone samples to ensure that the unweighted samples are proportionate by U.S. Census region and by time zone within region. Gallup weights the data daily to compensate for disproportionalities in selection probabilities and nonresponse. For this study, yearly data for 2014 and 2015 was combined. The total sample available was of 353,983 individuals, aged 18 and up. The two sequentially asked questions in the survey that are used as key dependant variables in our study are the following:

- "Please imagine a ladder with steps numbered from zero at the bottom to ten at the top. The top of the ladder represents the best possible life for you and the bottom of the ladder represents the worst possible life for you. On which step of the ladder would you say you personally feel you stand at this time?"
- On which step do you think you will stand about five years from now?

These questions are self-reported measures of life satisfaction. The response distribution for the first question shows that more than 45% of the people gave a score of 8 or more with the mean score for the sampled individuals is 7.00 with a standard deviation of 2.00. For the second one, life satisfaction in 5 years' time, the mean score is of 7.81 with a standard deviation of 2.21.
The study uses one key question relating to fruit and vegetable consumption.

- In the last seven days, on how many days did you have five or more servings of fruits and vegetables

Possible responses to this question range from 0 (no days with 5 or more servings of fruits and vegetables) to 7 (having 5 or more servings every day). More than two fifths of the people claim to have less than 3 days with the suggested servings and an overwhelming 30% say they have the 5 servings every day of the week.
We are interested in the size and statistical significance of the coefficient accompanying the consumption fruits and vegetables variable. To allow for possible confounding effects and check for robustness, using a similar methodology as Blanchflower, a series of independent variables were incorporated to estimate equations of the general form of:

Life Satisfaction = (number of days with 5 portions of fruit and vegetables consumed; age; gender; education; income)

3. Results

Table 1 reports the simplest regression specification in which the dependent variable is a person's current life satisfaction on scale from zero to ten and the independant variables are dummies for the number of days with five serving of fruits and vegetables each person had. Everything is normalized against the case of no days having the five portions of fruits and vegetables. A strong positive correlation is noticed. The more days having the right amount of servings the greater the impact on life satisfaction. Those that eat 5 servings on a daily basis have a life satisfaction score that is almost 19 times bigger than those with only one day. (0.028 vs 0.568)

Table 1: *Number of days with 5 servings of fruits and vegetables on life satisfaction*

		B	Std. Error	T
1	(Constant)	6.631	.009	753.810
	1 day of fruit	.028	.018	1.546
	2 days of fruit	.168	.014	12.111
	3 days of fruit	.302	.013	23.892
	4 days of fruit	.451	.014	33.275
	5 days of fruit	.518	.013	40.512
	6 days of fruit	.610	.020	31.246
	7 days of fruit	.568	.011	52.976

Table 2 of is an adjusted version of the first specification adding demographic characteristics: this regression equation incorporates gender, race and age. Like in Blanchflower and Oswald (2008), there is also evidence here of a U-shape in age, lower levels of satisfaction among black people and higher ones for Asian and Hispanic populations (compared to White). The fruit-and-vegetable coefficients, despite decreasing slightly, remain large and statistically significant. It is worth mentioning that the coefficient accompanying daily consumption of the optimal servings has the highest coefficient of impact on life satisfaction.

Table 2: *Number of days with 5 servings of fruits and vegetables and demographic variables on life satisfaction*

		B	Std. Error	T
1	(Constant)	6.862	.021	333.971
	1 day of fruit	.034	.019	1.760
	2 days of fruit	.142	.014	9.933
	3 days of fruit	.255	.013	19.923
	4 days of fruit	.395	.014	29.159
	5 days of fruit	.437	.013	34.494
	6 days of fruit	.484	.019	25.627
	7 days of fruit	.490	.011	45.791
	Gender	-.099	.007	-14.569
	Black	-.171	.012	-14.572
	Asian	.087	.023	3.764
	Hispanic	.034	.012	2.893
	Under 20	.135	.021	6.539
	Under 30	-.061	.021	-2.980
	Under 40	-.120	.020	-5.907
	Under 50	-.190	.020	-9.612
	Under 60	.106	.020	5.356
	Under 70	.234	.021	11.402
	Under 80	.215	.023	9.353

Table 3 shows the most encompassing equation. On top of the already added demographic variables, socioeconomic and other lifestyle habits were added. Income (normalized by household size), employment status, marital status, education level, excessive alcohol consumption, smoking, exercising regularly, having insurance and controlling for having experienced happiness in the previous day were added as controls. The majority of these variables have been used in previous papers that try to explain wellbeing and are used to correct for the possible confounding factors. It is important to consider these variables and control for them as the consumption of fruits and vegetables can be highly correlated with many of these socioeconomic variables. If many of these covariates were not included, it could be argued that the relationship could be spuriously driven by omitted factors like eating healthier by becoming richer, or eating poorly due to a difficult personal situation like a divorce or becoming unemployed.

The coefficients accompanying fruit and vegetable consumption fall, but still remain meaningful and statistically significant. To put the impact into context, having daily consumption of the required amount of fruits and vegetables has a similar impact 0.183 (0.017) on life satisfaction as being married 0.221 (0.016) or exercising regularly 0.237 (0.013). Not surprisingly, a big impact on current life satisfaction is the current state of happiness. Those who claim having experienced happiness in the previous day have a life satisfaction of almost 1.1 points more than those who have not. Being unemployed -0.594 (0.034), smoking -0.298 (0.015) or using drugs on a regular basis to relax -0.234 (0.012) have a strong negative impact.

Table 3: *Number of days with 5 servings of fruits and vegetables, demographic variables and other socioeconomic controls on life satisfaction*

		B	Std. Error	t
1	(Constant)	6.489	.048	135.384
	1 day of fruit	-.008	.029	-.271
	2 days of fruit	.020	.022	.882
	3 days of fruit	.071	.020	3.521
	4 days of fruit	.124	.021	5.806
	5 days of fruit	.129	.020	6.350
	6 days of fruit	.154	.030	5.183
	7 days of fruit	.183	.017	10.498
	Gender	-.210	.011	-18.588
	Black	.030	.020	1.483
	Asian	-.029	.038	-.775
	Hispanic	.245	.020	12.164
	Under 20	-.433	.051	-8.444
	Under 30	-.578	.036	-16.043
	Under 40	-.611	.035	-17.434
	Under 50	-.610	.034	-17.787
	Under 60	-.555	.033	-16.796
	Under 70	-.245	.031	-7.766
	Under 80	-.072	.032	-2.235
	Under $500 a month	-.617	.038	-16.129
	Under $2000 a month	-.676	.019	-35.496
	Under $4000 a month	-.446	.014	-31.866
	Unemployed	-.594	.034	-17.629
	In the Labour Force	-.079	.015	-5.425
	Chronic Illness	-.305	.012	-25.337
	Married/Living together	.221	.016	13.552
	Divorced/Separated	-.107	.021	-4.973
	Widowed	-.014	.028	-.503
	High School	-.040	.016	-2.480
	Bachelor	.096	.014	6.713
	Post Graduatate	.266	.016	16.830
	Have Health Insurance	.429	.021	20.493
	Binge Drink	.017	.020	.856
	Exercise Regularly	.237	.013	18.493
	Smoke	-.298	.015	-19.495
	Experienced Happiness	1.095	.019	58.179
	Had drugs to relax	-.234	.012	-20.279

To check for robustness of the results, the same specifications were used to measure the impact of fruit and vegetable consumption on future life satisfaction evaluation. Even though the scale of the impact of fruit and vegetable consumption is smaller, it remains statistically significant and it goes in the same direction as the evaluation of current life satisfaction. Even when current life satisfaction was entered as an independent variable, the results maintained. Controlling for current satisfaction (which not surprisingly comes into the equation with a large, positive and statistically significant coefficient) a greater number of days consuming the optimal amount of servings has a greater impact on the future life evaluation score.

4. Conclusions, limitations and further discussions and policy implications

With many issue like the rise of diabetes or obesity, many laboratory and other studies have shown the two way relationship between experiences of negative affect and food consumption. People eat more and less healthy food when going through negative experiences and it is through poor eating that other diseases like obesity occur - having a negative impact on life satisfaction. This paper tried to look to the other side of the balance. Other cross-sectional research has shown that healthy eating is associated with lower lifetime prevalence of depression and anxiety (White 2013) but there is not a lot of research showing if healthy eating also has an effect on the day to day evaluation of life satisfaction. This study was meant as a start to bride this gap. This study is meant to be an assessment of whether regular healthy eating, using fruits and vegetables as a proxy, has a positive connection with individual self-measured life satisfaction. Even though no direct causality can be established, the relationship between these two variables is strong and positive, even after controlling for many possible confounding factors. This study corroborates the findings of Blanchflower and Oswald's 2012 study for the UK, and even though this pattern cannot be considered as universal, it shows that in Western developed nations fruit and vegetable consumption can be seen as a determinant of life satisfaction.

Despite the significance of the findings – healthy eating is a good investment for current and future evaluations of life satisfaction – they should be interpreted with caution due to the cross sectional nature of the dataset. Correlation does not imply causation and the lack of panel data or a long term randomized controlled trials where different levels of fruits and vegetables are the sole treatment cannot allow us to suggest that eating more fruits and vegetables will make you happier. Even though the Gallup's dataset is one of the most robust ones for the purpose, given the large amount of confounding factors that can be controlled for, any sort of suggestive causal relationship must be taken with care. A bigger, longitudinal randomized controlled trial could be a way forward, but again, this would present limitations in the implementation of its own (external situations affecting emotions and satisfaction for example could not be controlled for). Asking for more detailed food consumption habits – not just fruits and vegetables – like red meat, fish, or other foods could also help the robustness of the results.

There is relevance for policy and further research that is derived from this study. The positive relationship between healthy eating and happiness found in this study can support the current widespread view of the importance of eating fruits and vegetables on a regular basis. Governments should try to find ways of fostering this type of behaviour. However, as claimed by Graham (2008), it is not obvious that policies that are beneficial from a public health standpoint would make the majority of the population happy. Another alternative for policy, similar to what Blanchflower and Oswald propose, could be using the findings to push the medical community to continue looking for linkages between subjective wellbeing like human optimism and the presence of certain substances in the blood and brain derived from vitamins/minerals/antioxidants that come from fruits and vegetables. If a medical link can be established, the validity of this study increases substantially As for further research, trying to find the funding to have longitudinal data or an RCT could be the way forward. In the meantime, trying to replicate the findings not just with developed nations, but in a wider context for countries with different socioeconomic factors could support or dismantle the universal validity of the findings of this paper.

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Food insecurity and subjective well-being: an exploratory analysis of global heterogeneity

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ABSTRACT

This study uses Gallup World Poll data to estimate the impact of food insecurity on SWB, and the extent to which it has different impacts across the world. We focus on a simple but potent food access question: “Have there been times in the past 12 months when you did not have enough money for food?” A negative answer to this question is associated with devastatingly low levels of SWB, particularly when SWB is measured asan overall life evaluation (Cantril ladder scale) and, to a lesser extent, when SWB is measured on the basis of negative experiencesin the last 24 hours. In addition we explore heterogeneity among 10 broad regions of the world, 126 countries and individuals within a multilevel framework. We identify significant heterogeneity across regions and countries, with greater impact in regions and countries with low levels of SWB. An analysis of income levels at purchasing power parity for the food insecure in different parts of the world suggests that individuals in richer areas may interpret the item in terms of general economic hardship, whereas individuals in poorer areas respond to the food insecurity question in a more literal sense. Future studies should further explain the multilevel structure identified in our exploratory analysis, particularly geographic variation in impacts of food insecurity and the extent to which this variation is due to measurement inequivalence or cultural differences.

Keywords: Food Insecurity, Subjective Well-Being, Gallup World Poll

1. Introduction

Food insecurity is a many-headed hydra that arises from a network of complex interactions between stable factors such as markets, climate, or infrastructure, and unpredictable factors such as natural disasters or wars. Likewise, the consequences of food insecurity are multi-pronged. Most research has focused on its deleterious effect on health (e.g. Olson, 1999), and the costs that negative health outcomes represents throughout an individual's lifetime, as well as society at large. Food is one of the basic needs that must be met before advancing to higher levels of self-actualization (Maslow, 1943). From the wider perspective of human motivation theory, Tay & Diener (2011) identified basic needs, including food and shelter, as a major determinant of life evaluation, even if the impact on SWB of each need was independent of whether other needs were fulfilled, in contradiction with Maslow's hierarchical model.

Even though there is a wide body of literature on the relationship between human needs and SWB, few studies to date have focused specifically on the impact of food insecurity on subjective well-being (SWB). Akpalu, Christian, & Codjoe (2015) recently conducted one such study using data from three urban poor communities in Accra – Ghana, finding a weak correlation between food security and household income. The study also found that income compensating differentials are greater for food insecure households than food secure households, suggesting that the deleterious effect of food insecurity on subjective well-being goes above and beyond the effect of poverty.

A broader study was conducted more recently by Guardiola & Rojas (2016), this time focusing on the relationship between food deprivation and SWB in Latin America. Their findings corroborate those by Akpalu et al. (2015) regarding the greater impact of food deprivation relative to income. The authors also identify several sources of heterogeneity suggesting that religion and relational goods may enhance SWB in Latin America relative to other regions, even among the food insecure. Tsai & Senah (2014) identify additional individual-level sources of heterogeneity in their sample of Ghanaian households, concluding that male heads of household give greater importance than females to usage of land, owning of livestock and amount of food spending.

The current study aims to build on these prior local and regional-level efforts, and expand them to an international level. More specifically this study aims to estimate the average global impact of food insecurity on SWB, and whether the size of this impact varies by country, age group, educational attainment and urban vs. rural setting.

2. Methods

All data come from the Gallup World Poll (GWP), a global research project conducting nationally representative surveys annually since 2006, in more than 160 countries and more than 140 languages. In most of the developing world, GWP surveys are conducted using in-person interviewing and an area sampling frame design. In the developed world, random-digit-dialling or a nationally representative list of phone numbers is used, generally including landline and mobile phones stratified by region. With some exceptions, all surveys, either telephone or face-to-face, are probability based and nationally representative of the resident non-institutionalize population aged 15 and older[1].

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[1] See http://www.gallup.com/178667/gallup-world-poll-work.aspx for further methodological details

We consider in this study cognitive and affective measures of SWB (Diener, 2000): Life Evaluation and Experienced Well-Being. Life evaluation (LE) are measured with the Cantril Self-Anchoring Striving Scale (Cantril, 1965). The question uses a scale from 0 to 10 and asks respondents:

> *Please imagine a ladder with steps numbered from zero at the bottom to ten at the top. Suppose we say that the top of the ladder represents the best possible life for you, and the bottom of the ladder represents the worst possible life for you. On which step of the ladder would you say you personally feel you stand at this time, assuming that the higher the step the better you feel about your life, and the lower the step the worse you feel about it? Which step comes closest to the way you feel?*

Experienced Well-Being is created using experiential measures of emotions, including two positive experience questions (smile or laugh, enjoyment) and three negative experience questions (worry, sadness, anger). These measures were selected out of a larger list of affect measures in the GWP on the basis of providing the largest possible number of country/year observations while maintaining a balanced list of positive and negative measures. The questions are introduced as follows:

> *Now, please think about yesterday, from the morning until the end of the day. Think about where you were, what you were doing, who you were with, and how you felt:*

The positive affect questions are:

1. *Did you smile or laugh a lot yesterday?*
2. *Did you experience the following feelings during A LOT OF THE DAY yesterday? How about enjoyment?*

The negative affect questions are:

1. *Did you experience the following feelings during A LOT OF THE DAY yesterday? How about worry?*
2. *How about sadness?*
3. *How about anger?*

All five affect questions were dummy coded as 1 for a “Yes” answer and as 0 for “No,” “Don’t know” or “Refused” answer. The dummy-coded items were summed to obtain the overall positive and negative experiences index.

We want to estimate the effect on these two SWB measures of a simple but potent food access question: “Have there been times in the past 12 months when you did not have enough money for food?”with Yes = 1, and No/Don’t Know/No Response = 0. Food insecure households are however likely to exhibit a variety of other features that make them prone to lower SWB. They are likely to be poorer, but also to have a diminished ability to cover other human needs or have access to relational goods. An increasingly exhaustive set of covariates is used in order to control for these confounding influences. The first basic control is annual per capita household income, transformed for international comparability into international dollars adjusted for purchasing power parity. The resulting income variable was then log transformed to account for the marginal diminishing returns of income on SWB measures (e.g. Sacks, Stevenson & Wolfers, 2010).

Then universal needs are considered, as operationalized by Tay & Diener (2011), whom in turn examined needs derived from Maslow (1954), Deci and Ryan (2000), Ryff and Keyes (1995), De Charms (1968) and Csikszentmihalyi (1988). We exclude the "basic needs", which include the food security item of interest in the current study. The final list of needs include:

1. Safety and security:
   - Felt safe walking alone
   - Did not have money and/or property stolen during the past 12 months
   - Were not assaulted during the past 12 months
2. Social support and love[2]
   - Have others they can count on for help in an emergency
3. Feeling respected[3]
   - Felt they were treated with respect
4. Mastery[4]
   - Had the experience of learning something
5. Self-direction and autonomy[5]
   - Experienced freedom in life

All itemsare answered on a dichotomous yes/no scale. For the purposes of model estimation, needs were dummy coded, with yes = 1, and No/Don't Know/No Response = 0. Items available for the human needs approach represent a relatively low threshold, meaning that any one needwill be covered for most people. For this reason a second theoretical framework based on well-being domain satisfaction is considered to account for confounding variables. We use the five essential elements identified by Gallup (Rath, Harter & Harter, 2010), including the following itemsfrom the Gallup-Healthways Well-Being Index (GHWI)[6]:

1. Purpose WB
   a. Like What You Do Each Day
   b. Learn or Do Something Interesting
2. Social
   a. Someone Encourages Your Health
   b. Friends/Family Give You Positive Energy
3. Financial WB
   a. Have Enough Money
   b. Worried About Money

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[2]Tay & Diener (2011) also include in their "Social support and love" needs the item "Experienced love yesterday", which is not available for this study's reference period.
[3]Tay & Diener (2011) also include in their "Feeling respected and pride in activities" needs the item "Were proud of something yesterday", which is not available for this study's reference period.
[4]Tay & Diener (2011) also include in their "Mastery" needs the item "Did what she or he does best at work". This item is excluded from the current study, as its inclusion would effectively eliminate from the sample those outside the employed population.
[5]Tay & Diener (2011) also include in their "Self-direction and autonomu" needs the item "Choose how their time was spent", which is not available for this study's reference period.
[6]http://www.gallup.com/poll/175694/country-varies-greatly-worldwide.aspx

   c. Feelings About Household Income[7]
4. Physical
   a. Felt Active and Productive
   b. Physical Health Near Perfect
5. Community
   a. City or Area is a Perfect Place
   b. Recognition for Improving City or Area

After eliminating cases with missing data on any of the analysis variables, the final sample includes 126 countries in 10 broad regions of the world, with a total of 120,582 individual respondents. To estimate an unbiased impact coefficient of food insecurity on SWB we follow recommendations from Ferrer-i-Carbonell & Frijters (2004) and Kristoffersen (2010), and estimate LE and AB using an OLS regression approach:

$$SWB = \beta_0 + \alpha D + \beta F + \varepsilon \quad (1)$$

Where β_0 is a constant term, D is a vector of control variables with unknown coefficients α, F is our food insecurity variablewith unknown coefficient β and ε is the unexplained part of the model. To provide a robustness check on the OLS estimates, we also estimate the effects on SWB using Propensity Score Matching (PSM), which does not require strong linearity assumptions (Rosenbaum &Rubin, 1983). We use nearest neighbor matching based on logit distance in propensity scores using R MatchIt package (Ho et al., 2004). Propensity scores are the true probability of unit i being food insecure, given covariates Di, calculated via logistic regression, where Y is a dichotomous variable which is defined as:

$$Y = \begin{cases} 1 & \textit{for those without money for food} \\ 0 & \textit{for those with money for food} \end{cases}$$

And the probability of Y =1 is given by:

$$Pr = \frac{1}{1+exp[-(\beta_0+\beta_i D_i)]} \qquad (2)$$

Where β_0 is a constant term, and D_i is a vector of covariates with unknown coefficients β_i. Using one-to-one nearest neighbor matching without replacement, the individual the food insecure group is chosen as a matching partner for an individual in the food secure group that has the closest propensity score. All impact estimations take into account the multi-stage clustered nature of the sample, including the effect of sampling design in all variance estimations using SPSS Complex Samples 18.0 with linearization via Taylor series.

Finally, this study explores heterogeneity of impacts across a typical set of demographic factors, including, gender, region, urban or rural setting, educational attainment, age, and religion. In order to

[7]Not part of the GHWI ítems, but included for its high explanatory power, see Diego-Rosell, Tortora & Bird (submitted).

account for the nested nature of the data, we turn to a multi-level modelling framework. In the interest of brevity we refer to the matrix notation suggested by Albright & Marinova (2010),

$$SWB = X\beta + Zu + \varepsilon \qquad (3)$$

where X is an nxp matrix containing fixed effects regressors, $\beta$is a vector of fixed-effects parameters, Z is an nxpmatrix of random effects regressors, u is a vector of random effects, and ε is avector of errors (p.10). All multilevel models were estimated using the xtmixed program in Stata 12.0.

3. Results

Table 1 presents the survey-weighted coefficients for "Lack of Money for Food" under a series of increasingly stringent models, starting with a bivariate regression coefficient with no controls, which is equal for all models presented, continuing with a model including log of income as a control variable, and then showing the effect of adding needs and WB domains. The PSM approach was only partially successful in eliminating differences in covariates between the food insecure and the matched food insecure group, as seen in figure 1. Differences in income remain after matching on the full set of 19 covariates (Cohen's d = 0.56), as do smaller differences in other covariates. For this reason we include a third, further stringent estimation approach that uses the propensity score matched sample, and applies the same regression controls as in the OLS model (shown as PSM +OLS on Table 1).

In spite of these highly restrictive conditions, the effect of food insecurity on SWB remains significantly different from zero at the 95% confidence level across all specifications, going in the expected direction for all three SWB outcomes. However the size of the effect varies considerably depending on the SWB outcome and model specification. The simple bivariate model with no control variables shows that being food insecure lowers life evaluation scores in a 0-10 scale by 1.43 points (t = -26.16, p<.00). This effect is reduced to -0.82 points (t = -16.84, p<.00) after controlling for income in an OLS regression, and further down to -0.75 points (t = -14.68, p<.00) in the OLS+PSM model. The most stringent specification, controlling for income, needs and WB domains in an OLS+PSM model leaves the effect at -0.33 points (t = -6.80, p<.00).

We can calculate the income compensating differentials of food insecurity, considering that the coefficient for the log of income in this same OLS+PSM model is .643 (t = -17.31, p<.00). the ratio of coefficients shows that eliminating food insecurity would have an impact equivalent to more than a half-point increase in the log of income (0.33/.643=0.52), which would be equivalent to more than a trebling of income (10**0.52=3.3). Since the average per capita income in international dollars for the food insecure was $2,680 in 2015, the effect on LE of eliminating food insecurity would be equivalent to a cash transfer of $2,680*2.3 = $6,164 to each food insecure individual, a sum that is arguably much larger than the cost of actually eliminating food insecurity in practice.

The impact of food insecurity on experienced well-being is lower than for LE. Excluding the unrealistic model with no statistical controls, effects range from a high of t = -11.25 (p<.00) to t = -2.18 (p<.05) for positive experiences. Food insecurity has a larger effect on negative experiences than on positive experiences, ranging from t = 17.07 (p<.00) to t = 8.36 (p<.05).

Let us turn now to the exploration of heterogeneity of impacts from a multilevel perspective. We are interested in identifying differences in impacts across regions, with a further analysis of urban/ rural, age, education and gender differences in impacts within regions. For this nested modelling approach an empty, intercepts-only respondent-level model is estimated as the starting point,

$$SWB_{ij} = \beta_0 + U_{0j} + e_{ij} \qquad (4)$$

where SWB outcomes for respondent i in region j are equal to thetotal population mean β_0, plus a region-specific effect Uf or each region j, plus an individual-level error e_{ij}. The region effects U_{0j} are assumed to follow a normal distribution and center around 0, with a variance σ_{u0}^2. Individual errors follow the same assumptions and are denoted by σ_e^2.

The overall mean β_0 (across regions) is estimated as 5.52 for life evaluation, 1.40 for Positive affect and 0.80 for negative affect. The between-region variance in LEis estimated as σ_{u0}^2= 0.80, and the within-region between-individual variance is estimated as σ_e^2= 4.85, for a total variance of 0.80 + 4.85 = 5.65. The intraclass correlation coefficient (ICC) is 0.8/5.65 = 0.14, indicating that 14% of the variance in LEcan be attributed to differences between regions.Following the same calculations, ICC for positive affect is 0.05, and 0.02 for negative affect. Given the relatively low ICC for the two experienced affect variables, this study focuses on LE for the rest of the multi-level modelling exercise.

Region-level effects U_{0j} for LE and their standard errors are presented on figure 2, showing that Sub-Saharan Africa and South Asia are significantly below the overall average in Life Evaluation scores, whereas the EU+ region and the US+Canada+ Australia+New Zealand region are significantly above the overall average. In order to explore regional level variation of food security coefficients we add to equation (4)fixed effects for food security and all the individual-level covariates in the prior models, represented by two new terms, $\beta_1 F_{ij}$ and $\beta_i X_{ij}$,

$$SWB_{ij} = \beta_0 + \beta_1 F_{ij} + \beta_i X_{ij} + U_{0j} + e_{ij} \qquad (5)$$

where $\beta_1 F_{ij}$ represents a fixed coefficient for food security, and $\beta_i X_{ij}$ represents a vector of fixed coefficients β_i on covariates X_{ij} (income, needs, WB domains). We want to test the hypothesis of random food security coefficients across regions, so we add the term $U_{1j} F_{ij}$ to equation (5)

$$SWB_{ij} = \beta_0 + \beta_1 F_{ij} + \beta_i X_{ij} + U_{1j} F_{ij} + U_{0j} + e_{ij} \qquad (6)$$

where $U_{1j} F_{ij}$ represents a vector of random coefficients U_{1j} for the food security indicator F_{ij}. We can use a likelihood ratio test to test whether the food security effect varies across regions. The log-likelihood value for model (5) was -250381.64, and for model (6) was -250296.64 so the likelihood ratio test statistic is LR = 2*(-250296.64 --250381.64) = 170 with 1 degree of freedom (because there is only one parameter difference between the models), which is greater than 3.841, the 5% point of a chi-squared distribution with 1 DF[8].

The food security effect $\beta_1 F_{ij}$ for region j is estimated as -.415, and $U_{1j} F_{ij}$, the between-region variance in these slopesis estimated as .028. For the ‘average’ region we estimate that food insecurity has an impact of -.415 points in LE, with a 95% confidence interval of -.415 ± 1.96*0.08 = -0.5718 to -0.2582. The negative covariance estimate of -.010 means that regions with a high

[8]http://sites.stat.psu.edu/~mga/401/tables/Chi-square-table.pdf

intercept (above-average LE for the food secure) tend to have a lower-than-average effect. Similarly, regions with a low intercept (below-average LE for the food secure) tend to have a more marked increase in LE with food security.

Finally we want to explore whether the impact of food security varies depending on individual-level demographic factors. We continue with our model nested within regions, and add another level of nesting for country, location (urban vs. rural), gender (female vs. male), age (15-29 vs. 30+) and educational attainment (primary or less vs. higher). In order to test the need for a three-level model start with the intercept-only model

$$LE_{ijk} = \beta_{00} + U_{0j} + W_{0jk} + e_{ijk} \qquad (7)$$

where LEfor respondent i in region $j$and country $k$is equal to the total population mean β_{00}, plus a region-specific effect U for each region j, plus a country-specific effect W within each region j, plus an individual-level error e_{ijk}. ICC for country as a third-level nesting variable is 0.21, indicating that 21% of the variation in LE can be attributed to the nesting of countries within regions, with a marginal ICC of 0.10 that is exclusively attributable to the country level, above and beyond the regional effect. Marginal ICCs are also sizeable for educational attainment (0.07), but much lower for the remaining nesting variables we tested, including location (0.03), age (0.02), and gender (0.00). We thus focus on the effect of country and education for the rest of the three-level modelling exercise. We add linear fixed effects for food security and all the individual-level covariates in the prior models, so we add two new fixed terms, $\beta_1 F_{ijk}$ and$\beta_i X_{ijk}$ to equation 7, plus the term$U_{1j} F_{ij}$ for random slopes within regions.

$$LE_{ijk} = \beta_{00} + \beta_1 F_{ijk} + \beta_i X_{ijk} + U_{0j} + W_{0jk} + U_{1j} F_{ij} + e_{ijk} \qquad (8)$$

Equation (8) is equivalent to (6), which showed the significance of region-varying food security effects, but this time with the addition of country/educational effect W_{0jk}. We are interested in the hypothesis of random food security coefficients across countries within regions and across educational levels, so we add the term $U_{1jk} F_{ijk}$ to test for random slopes within countries and education levels

$$LE_{ijk} = \beta_{00} + \beta_1 F_{ijk} + \beta_i X_{ijk} + U_{0j} + W_{0jk} + U_{1j} F_{ij} + U_{1jk} F_{ijk} + e_{ijk} \qquad (9)$$

The LR test for the two equations is significant for random slopes by country (LR=167.14, p<.00, 1*df*), and by education level (LR=28.36, p<.00, 1 *df*).

4. Discussion

The impact estimates we find for food insecurity are significant across all model specifications and sizeable, particularly when considering the income compensating differentials. Our findings are consistent with prior literature, showing that the effect of food insecurity is larger than income equivalent(Guardiola & Rojas, 2016). From the perspective of SWB components, we find that food insecurity has a largest effect on life evaluations, followed by negative affect, and a relatively small effect on positive affect. This is consistent with Tay & Diener (2011), who found a similar pattern for a "Basic Needs" component including food and shelter insecurity indicators.

Our multilevel modelling results show that the impact of food security varies significantly by region, with poorer regions having a more marked increase in LE than richer regions when individuals move from being food insecure to food secure. This finding is surprising considering that our models control for income expressed in international dollars.

A potential hypothesis to explain this finding is that respondents interpret “having enough money for food” differently in different regions. As Figure 3 shows, the average income for food insecure households is, at the global level, almost 4 times lower than that of food secure households. This ratio is lower at the regional level because food insecure households are very unevenly distributed, with Sub-Saharan Africa and South Asia accounting for more than half of all food insecure households. The income ratio between food secure and food insecure households at a regional level is between 1.4 and 2.1, with the ratio increasing with the level of development of each region.

Based on a literal interpretation of our food insecurity question, we would expect that the cut-off point in income where households turn from “having enough money for food” to “not having enough money for food” would be the same in all regions, since income is adjusted for purchasing power differences across countries, and so the same level of income should be needed in all countries to achieve basic food requirements, yet individuals in richer regions have a higher income threshold for reporting food insecurity than those in poorer regions.Taking the East Asia region as an example of a rich region, average annual per capita income among those with “enough money for food” is $18,835 at PPP, compared to $9,065 for those with “Not enough money for food”. In Subsaharan Africa, average income among those with “enough money for food” is $1,791 at PPP, compared to $885 for those with “Not enough money for food”.

While the income gap between the food secure and the food insecure is consistent across all regions, it seems that “not having enough money for food” is interpreted more literally in the poorer regions, whereas it may be just an indicator of general economic hardship in richer regions. These potential measurement equivalence issues highlight the importance of valid and reliable scales of food insecurity such as the Food Insecurity Experience Scale (FIES) developed by FAO (Ballard, Kepple, & Caffier, 2013).

Our current study is not without limitations. Data availability constraints mean that some big countries had to be excluded from the sample, most notably China. Other large countries had a small number of cases (e.g. USA, n=104). Finally, while we strived to adjust our standard errors to account for the stratified clustered sample design of the GWP, the xtmixed program in Stata 12.0 does not allow for survey design adjustments, which probably results in an underestimate of standard errors for the multilevel models. Future studies should try to further explain the multilevel structure identified in our exploratory analysis, particularly variance of impacts of food security at the regional and country levels, which show the largest ICC of all the nesting variables explored.

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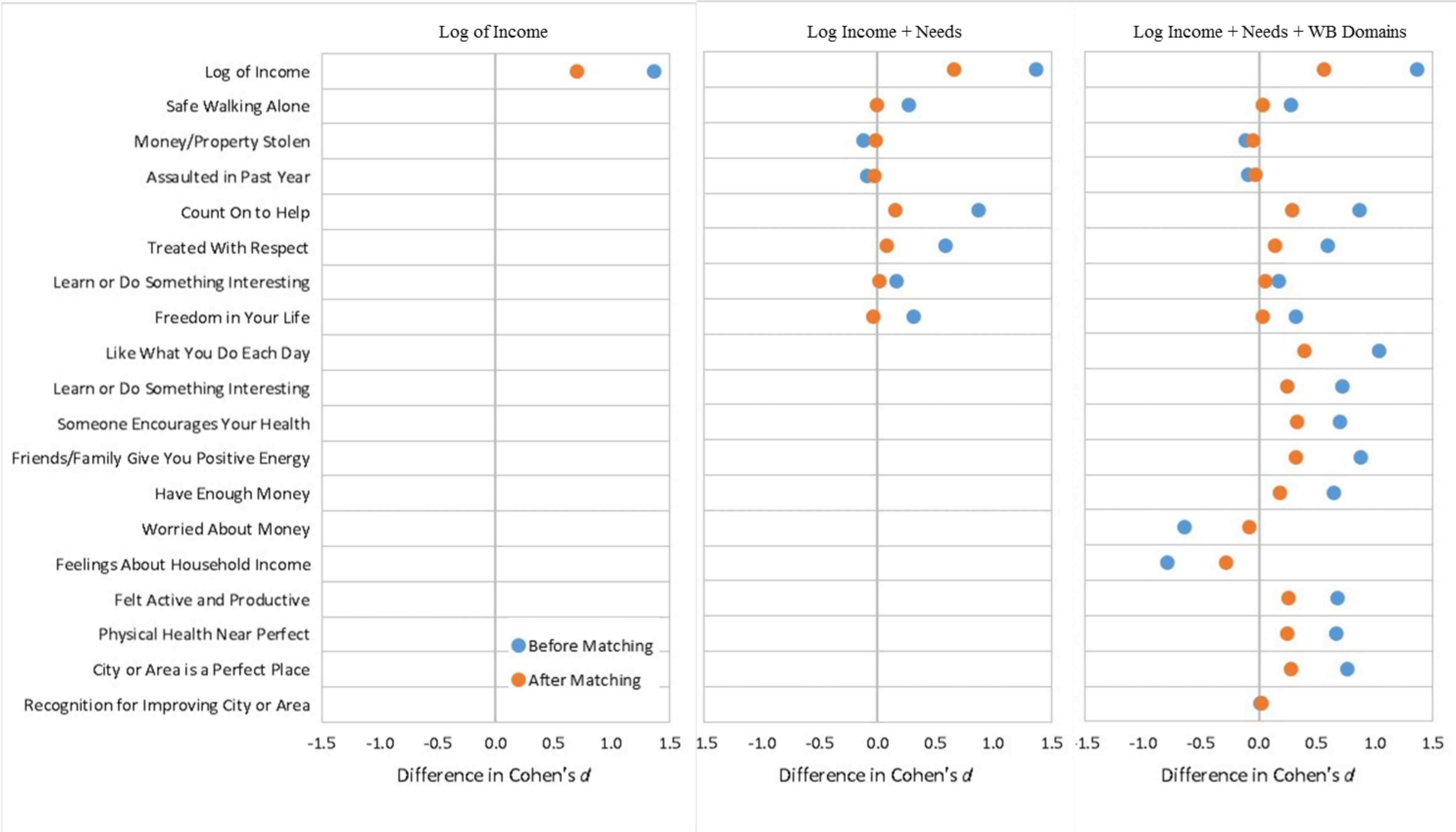

Figure 1: *Dotplot of standardized mean differences for covariates before and after propensity score matching*

Table 1:*OLS, PSM and PSM+OLS coefficients for "Lack of money for food"*

Model	OLS				PSM				PSM+OLS			
	Coef.	St.Err	t	p	Coef.	St.Err	t	p	Coef.		t	p
Life Evaluation												
No controls	-1.43	0.05	-26.16	.00**	-1.43	0.05	-26.16	.00**	-1.43	0.05	-26.16	.00**
Log Income	-0.82	0.05	-16.84	.00**	-0.82	0.05	-14.91	.00**	-0.75	0.05	-14.68	.00**
Log Income+Needs	-0.68	0.05	-14.48	.00**	-0.76	0.05	-14.10	.00**	-0.65	0.05	-13.35	.00**
Log Income+Needs+WB Domains	-0.35	0.05	-7.22	.00**	-0.68	0.06	-11.72	.00**	-0.33	0.05	-6.80	.00**
Positive Experiences												
No controls	-0.26	0.02	-14.51	.00**	-0.26	0.02	-14.51	.00**	-0.26	0.02	-14.51	.00**
Log Income	-0.21	0.02	-11.25	.00**	-0.22	0.02	-11.73	.00**	-0.22	0.02	-11.27	.00**
Log Income+Needs	-0.12	0.02	-7.92	.00**	-0.17	0.02	-8.97	.00**	-0.13	0.02	-8.21	.00**
Log Income+Needs+WB Domains	-0.04	0.02	-2.43	.02*	-0.13	0.02	-5.86	.00**	-0.04	0.02	-2.18	.03*
Negative Experiences												
No controls	0.53	0.03	21.03	.00**	0.53	0.03	21.03	.00**	0.53	0.03	21.03	.00**
Log Income	0.48	0.03	17.07	.00**	0.47	0.03	17.60	.00**	0.46	0.03	16.93	.00**
Log Income+Needs	0.41	0.03	15.73	.00**	0.43	0.03	16.31	.00**	0.40	0.03	15.80	.00**
Log Income+Needs+WB Domains	0.24	0.03	9.16	.00**	0.33	0.03	11.37	.00**	0.23	0.03	8.36	.00**

*p<.05 **p<.01

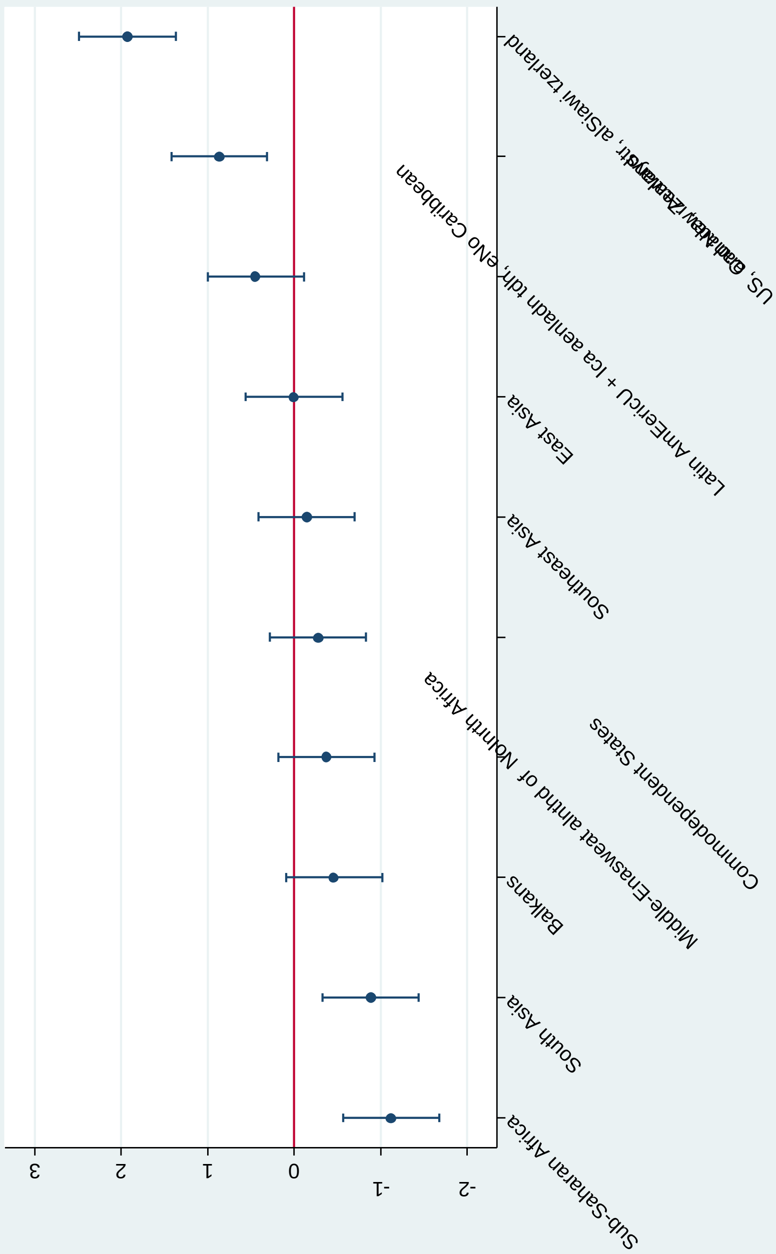

Figure 2: *Region residuals and standard errors for Life Evaluation*

Table 2: *Two-level models of LE with random effects by region and food insecurity*

	Model 1		Model 2†		Model 3†	
	Coef.	**St.Err**	**Coef.**	**St.Err**	**Coef.**	**St.Err**
Fixed Effects						
Intercept β_0	5.52**	0.28	3.20**	0.16	3.24**	0.16
Food Insecurity $\beta_1 F_{ij}$			-0.33**	0.01	-0.41**	0.06
Random Effects						
Intercept U_{0j}	0.80*	0.38	0.23*	0.11	0.24*	0.11
Food Insecurity $U_{1j}F_{ij}$					0.03*	0.01
Model Fit Statistics						
Log Likelihood	-266,349		-250,382		-250,297	
AIC	532,705		500,895		500,729	
BIC	532,734		501,536		501,389	

*p<.05 **p<.01

†Includes controls for needs and WB domains (coefficients omitted)

Table 3: *Intercept-only three-level models of LE by region and country, location, gender, age and education*

	Country		Urban vs. Rural		Gender		Age		Education	
	Coef.	**St.Err**	**Coef.**	**St.Err**	**Coef.**	**St.Err**	**Coef.**	**St.Err**	**Coef.**	**St.Err**
Fixed Effects										
Intercept β_0	5.50**	0.27	5.42**	0.30	5.52**	0.28	5.61**	0.28	5.37**	0.26
Random Effects (Level 1)										
Intercept U_{0j}	0.66	0.35	0.83	0.43	0.79*	0.35	0.75*	0.38	0.49*	0.34
Random Effects (Level 2)										
Intercept W_{0jk}	0.54**	0.07	0.17*	0.08	0.01	0.00	0.12*	0.05	0.40*	0.18
Model Fit Statistics										
Log Likelihood	-260,508		-265,795		-266,333		-265,423		-264,429	
AIC	521,025		531,597		532,673		530,853		528,866	
BIC	521,063		531,636		532,712		530,892		528,905	

*p<.05 **p<.01

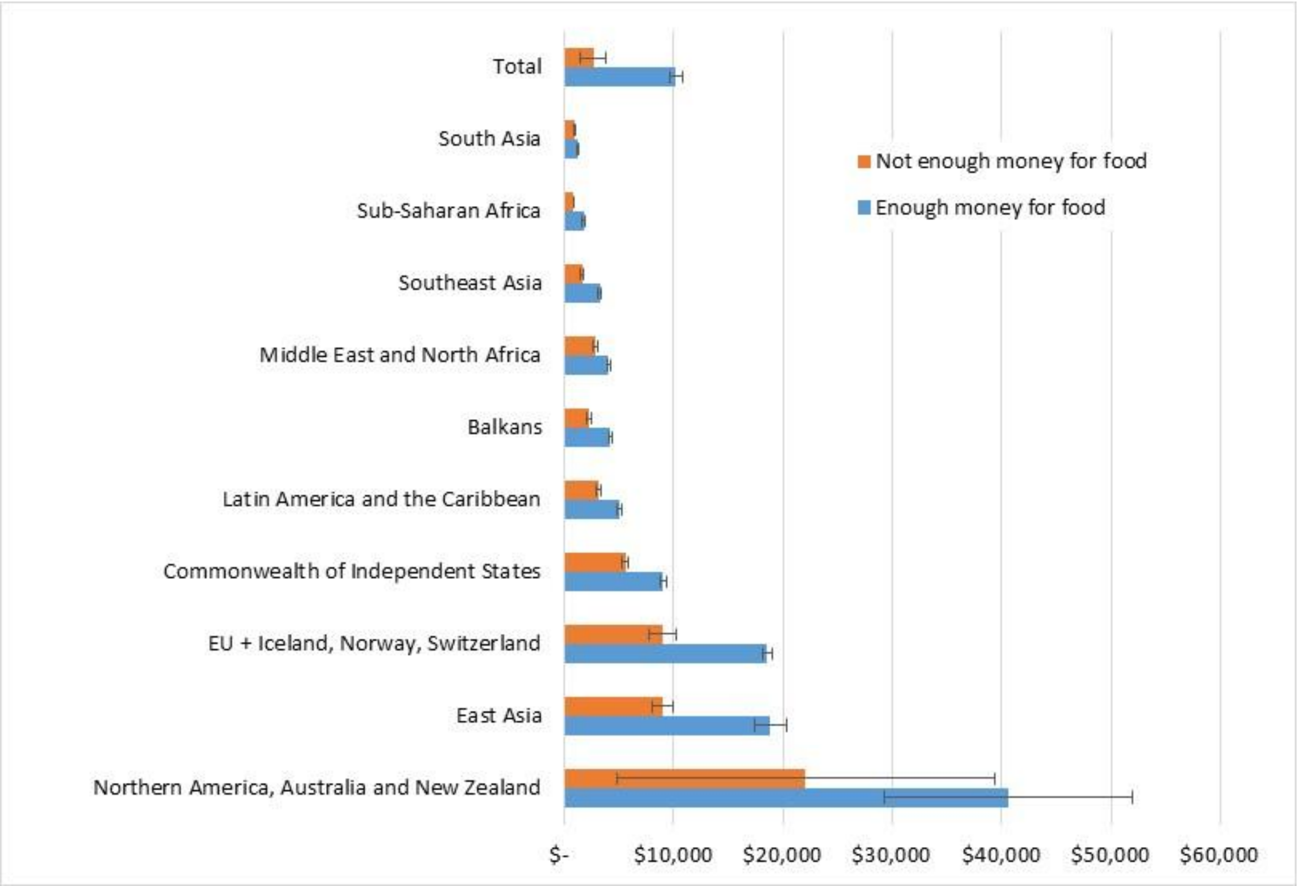

Figure 3:*Average per capita income by food security status and region*

Perceived well-being by visiting urban green areas: an exploratory analysis using Partial-Least Squares models

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ABSTRACT

Literature on human experience in green environments has widely demonstrated how the direct and indirect experience with nature has positive impact on individuals' well-being. Experience with nature reduces psychophysical stress, induces positive emotions and facilitates the renewal of cognitive sources providing both physical and psychological benefits. In addition, many studies on psychological restoration have shown that green spaces have a greater capacity of promoting human health and well-being than built-up areas.

With the increasing interest in the use of urban green space for promoting human health, it is interesting to gain knowledge and development on this important topic, focusing also on the related methodological issues. Indeed, perceived well-being is generally assessed indirectly and a set of proxy variables (i.e. indicators) are used to measure it, thus leading to the definition of well-being as a latent composite construct. As a novelty in the analysis concerning the relationships between perceived well-being and green environment, this study aims at investigating this issue by referring to the Partial-Least Squares Structural Equation Modelling (PLS-SEM) within the framework of Attention Restoration Theory (ART).

We selected three typologies of urban and peri-urban green spaces in Central Italy, characterized by different physical features (e.g. presence of natural and built up elements). A questionnaire including measures of length and frequency of visits, perceived restorativeness - introduced according to the ART - and self-reported benefits of the visit to the green spaces was administered *in situ* within five sites. By adopting the PLS-SEM approach, we explored the relationships between restorative components and psychological and physical self-reported well-being. PLS approach allowed us to verify also the existence of mediator effects in order to better understand these interactions.

Keywords: PLS-SEM, Well-being, Restorativeness, Urban forest

1. Introduction

Environment and environmental conditions have a significant effect on human health and quality of life (EEA 2013). Indeed, direct and indirect experience with nature have positive impacts on individuals' well-being since natural environment helps to recover psychological and physiological resources (Hartig 2004). There is a wide body of literature dealing with the effect of natural elements such as trees, woodland and green spaces on physical, psychological and social well-being (e.g. Ulrich et al. 1991, O'Brien 2005, Carrus et al. 2015; Scopelliti et al. 2016; Tomao et al., 2016). They provide empirical evidence of attention restoration and stress reduction from the experience of nature. Furthermore, some of these studies (e.g. Carrus et al. 2015) report how green spaces promote a higher level of well-being if compared to built-up areas.

The restorative effects of green areas can be assessed based on different theories, including the stress reduction theory (Ulrich et al. 1991) and the Attention Restoration Theory (ART) (Kaplan 1995). In particular, the ART proposes that regenerative environments are characterized by four components: (i) *being-away*, (ii) *extent*, (iii) *fascination*, and (iv) *compatibility* (Kaplan 1995). *Being-away* is linked to the experience of being in an environment physically different from the one of daily routine, where cognitive efforts are requested. The *extent* relates to the physical characteristics of an environment that has to be wide enough to promote exploration without cognitive effort. *Fascination* refers to regenerative aesthetic stimuli of environments. *Compatibility* is the property of places able to support individual expectations.

With the increasing interest in the use of urban green space for promoting human health, our study aims at investigating the relationships between perceived well-being and green environment by proposing a Partial-Least Squares Structural Equation Model (PLS-SEM) and distinguishing between direct and indirect effects related to physical and psychological benefits deriving from urban green space. To the best of our knowledge, this is the first study that combines these two aspects of well-being, the PLS-SEM methodological framework and the ART restorative components.

2. Research hypothesis

Bearing in mind the complexity of ART theory and by considering that the components of restorativeness can be considered as predictors of perceived well-being (Carrus et al. 2015; Tomao et al. 2016), we formulated the following Research Hypotheses (RHs):

RH1: Restorative (ART) components as well as well-being[1] (WB) can be considered as latent variables and can be measured by using manifest variables within the PLS approach.

RH2: Restorative (ART) components have a direct effect on psychological and physical WB.

RH3: Restorative (ART) components have an indirect effect on well-being deriving from visiting green areas and woodlands in urban context.

[1] In this study we refer to well-being as the overall benefits obtained while visiting urban green areas.

3. Method and model specification

3.1 Data

The exploratory study refers to a sample of 200 individuals (50% women; mean age = 41.6 years; Standard Deviation - SD = 15.4). In order to increase the range of knowledge on urban and peri-urban green areas as well as their relationships with human well-being, we selected five sites in accordance with three typologies of green spaces characterized by different physical features: a botanic garden (Rome), two urban parks in Rome (Villa Borghese and Villa Pamphili) and two peri-urban forests (the pinewood of Castelfusano - Ostia, RM - and a high forest beech stand located in Soriano nel Cimino -VT-). A total of 28 visitors in the botanical garden, 66 in the urban parks, 69 in the pinewood of Castelfusano and 37 in the beech forest in Soriano nel Cimino have been involved, requesting them to fill a questionnaire during the visit of the green area. Specific items derived from the Italian version of the Perceived Restorativeness Scale (PRS; Pasini et al. 2009) were included in the questionnaire as manifest variables for measuring restorative components. Specific questions aimed at measuring psychological and physical benefits while visiting study sites were included according to Carrus et al. (2015). All variables were measured through a 5-point scale ranging from 1 to 5.

3.2. Modelling FW within the PLS-SEM approach

According to the ART framework, we modelled perceived subjective well-being and restorative components of green areas by referring to the PLS–SEM approach.

The PLS path modelling is a variance-based technique recommended during the first stages of research in order to test and validate exploratory models, especially when variables cannot be easily determined or measured directly. These types of models well fit human (subjective) well-being whose measurement is generally obtained indirectly by means of data gathered using questionnaires.

A PLS path model consists in two components (Hair et al. 2014). The first is a structural model (the inner model) which illustrates the specified constructs and focuses on the relationships (paths) between them. The second is the measurement models (the outer models), that shows the relationships between the constructs and the indicators also known as manifest variables. Furthermore, while structural and measurement models are present in all types of SEMs with latent constructs, the weighting scheme represents the third specific component of the PLS approach (Monecke and Leisch 2012) and is used for estimating the inner weights linking latent constructs. Table 1 illustrates the Latent Variables (LVs) of the specified structural model (first column) and the related indicators used in the measurement model (second column).

Table 1: *Latent variables and manifest variables*

LATENT VARIABLE	MANIFEST VARIABLES
COMPATIBILITY	Q1. Being in this place is in accordance with my personal interests Q2. In this place it is easy to do what I want
BEING AWAY	Q3. Spending the time here allows me to distance myself from my daily routine Q4. In this place I can run away from the things that usually require my attention
FASCINATION	Q5 This place is fascinating Q6 There is much to explore and discover in this place
EXTENT	Q7 It's like this place had no boundaries Q8 There is a clear order in the physical layout of this place
PSYCHOLOGIAL WELL-BEING	Q9 Do you feel psychological benefits during the visit to this place? Q10 Do you think you will feel psychological benefits during the visit to this place?
PSYSYCAL WELL-BEING	Q11 Do you feel physical benefits during the visit to this place? Q12 Do you think you will feel physical benefits during the visit to this place?
WELL-BEING	Q13 How much do visiting this place make you feel better than before? Q14 After visiting this place, how much do you believe you will feel better if compared to how you usually feel?

In our model *Compatibility*, *Being away*, *Fascination* and *Extent* are exogenous LVs since they do not have any predecessor in the structural models while the other three LVs (psychological, physical WB and well-being) are specified as endogenous LVs. Figure 1 illustrates the structural model specified in our analysis and the relationships between the latent variables.
Figure 2 reports the complete (inner and outer components) specified model, which reflects the RHs. In order to test this model we used SmartPLS 3 software and applied the path-weighting scheme.

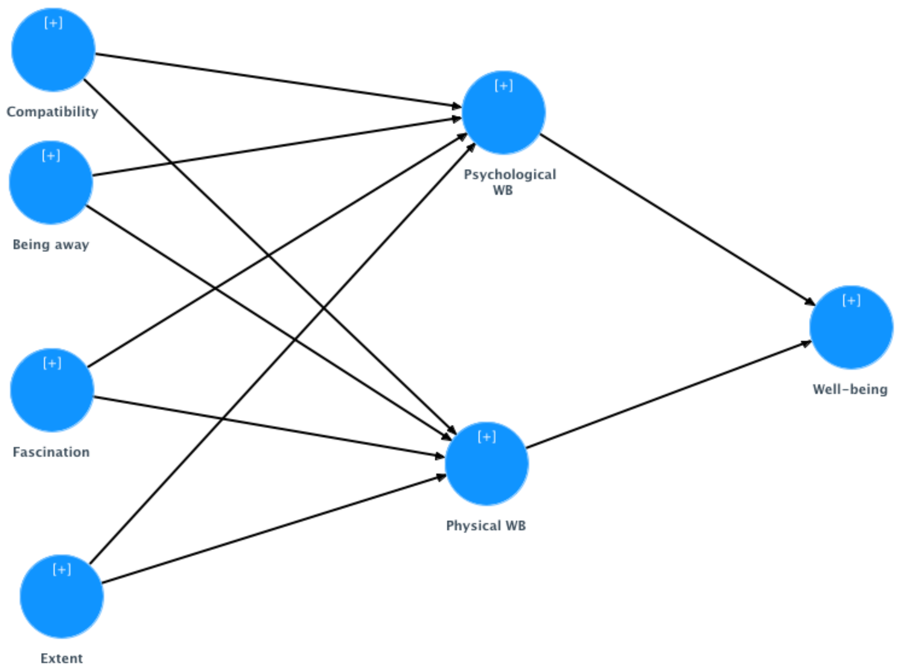

Figure 1: *The specified structural (inner) model*

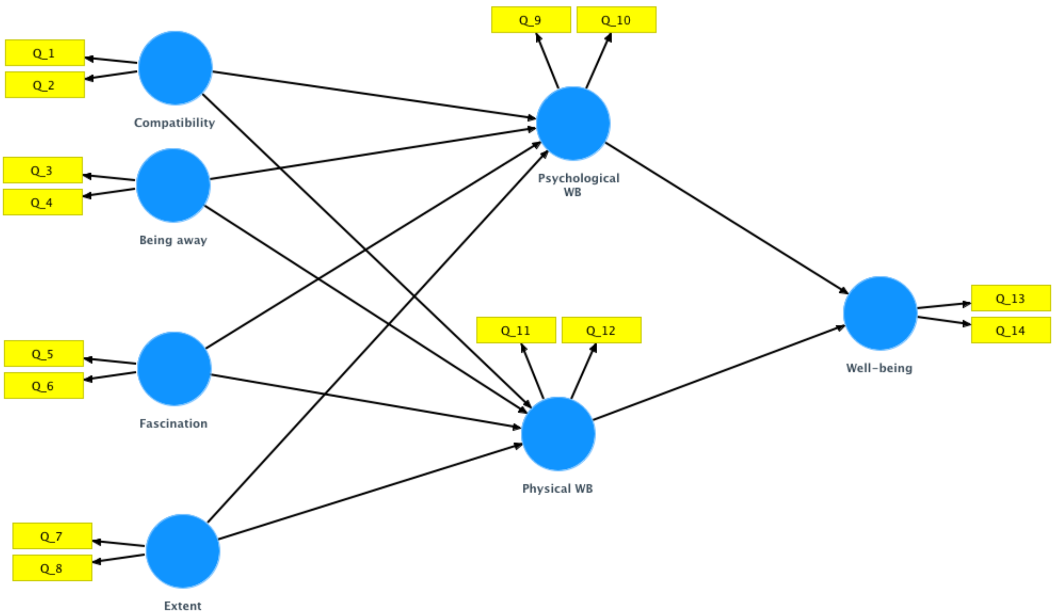

Figure 2: *The specified inner and outer models*

3. Results

The analysis of results was carried out by following recent guidelines for PLS-SEM by Hair et al. (2014). Firstly, we examined the measurement models by evaluating item and construct reliability as well as convergent and discriminant validity of the constructs. Secondly, we evaluated the structural model by verifying its ability to predict the endogenous constructs in terms of goodness of fit, cross-validated redundancy and path coefficients. Once the validity of the models was assessed, we analyzed estimated direct and indirect effects.

The reflective measurement models were evaluated for reliability and validity. Item reliability of our model is higher than 0.7 in almost all of the cases. Only two items (Q2, Q8) have outer loadings between 0.55 and 0.7. However, the Average Variance Extracted (AVE) values, defined as the grand mean of the squared loadings of the indicators associated with the construct, are higher than 0.5 for all the LVs, indicating convergent validity for all the constructs. Composite reliabilities for the 7 constructs range between 0.72 to 0.95, satisfying the requirements suggested by Hair et al. (2014). The values of Variance Inflation Factors (VIFs) are lower than 10 for all the constructs, demonstrating that our structural model results are not affected by collinearity.

Table 2 shows the results concerning the coefficients describing the relationships between latent variables (standard errors were obtained from bootstrap).

The results of direct structural relationships reveal that four out of the ten relationships hypothesized are statistically significant at 1% level (p-value<0.01) and two of them are statistically significant at 5% level (p-value<0.05). In particular, restoration components - except for *extent* - have a direct and positive effect on psychological WB. On the other hand, only *compatibility* has a direct effect on Physical WB. Both psychological and physical WB show a positive and highly significant effect on well-being.

Besides, direct effects on both physical and psychological WB, restorative components – and specifically compatibility, fascination and being away – proved to have indirect significant effects on well-being via both psychological and physical WB.

Table 2: *Estimated direct, indirect and total effects*

	Direct effects		Indirect effects		Total effects	
	Estimate	Sign	Estimate	Sign	Estimate	Sign
Being away -> Psychological WB	0.227	***			0.227	***
Being away -> Physical WB	0.024				0.024	
Being away -> Well-being			0.122	*	0.122	*
Fascination -> Psychological WB	0.191	**			0.191	**
Fascination -> Physical WB	0.085				0.085	
Fascination -> Well-being			0.125	**	0.125	**
Compatibility -> Psychological WB	0.178	**			0.178	**
Compatibility -> Physical WB	0.347	***			0.347	***
Compatibility -> Well-being			0.210	***	0.210	***
Extent -> Psychological WB	0.080				0.080	
Extent -> Physical WB	0.027				0.027	
Extent -> Well-being			0.049		0.049	
Psychological WB -> Well-being	0.500	***			0.500	***
Physical WB -> Well-being	0.348	***			0.348	***

Notes: Significance level: *** p-value<0.01; ** p-value<0.05; * p-value<0.10

4. Discussion and concluding remarks

Findings of this study support the evidence emerged from other studies that mental and physical benefits can be obtained by visiting urban and peri-urban green areas (Hartig 2004; Carrus et al. 2015; Tomao et al. 2016).

We applied PLS-SEM models to self-reported well-being considering it as a latent variable (RH1). Results on item reliability showed how subjective well-being as well as restorative components can be estimated by the selected proxy variables as well path-modelling can be considered as an appropriate framework for linking well-being and ART components. This evidence also confirms that the manifest variables identified by the Italian version of the PRS (Pasini et al. 2009) can be successfully used to evaluate restorativeness, even using PLS procedures.

Our results show that all the intrinsic restoration properties of the green areas have a positive and direct effect on both psychological and physical WB (RH2), even if *extent* is not statistically significant. This evidence highlights how components of restorativeness can be considered as important predictors of well-being, confirming the findings of other previous studies (e.g. Carrus et al., 2015; Marselle et al. 2016; Tomao et al., 2016). On the other hand, the dimensions of green areas, wide enough to capture the individuals' attention, seem to have a more marginal role in well-being perception. This is probably due to the perception, in many cases, of the so called "grey infrastructure" elements (buildings, roads, etc.), that can be seen outside, but also from inside the boundaries of the green areas.

Compatibility has been the only one component having a significant influence on both psychological and physical WB. It also showed a highly significant indirect effect on overall well-being (RH3), suggesting that the characteristics of places able to support individual expectations are very good predictors of well-being and for this reason should be considered in managing and designing public green areas.

Our preliminary and explorative results represent a good starting point for deeper analysis, required to better understand the complex issue of well-being evaluation. In particular, an interesting improvement can be the evaluation of the effect of the "site quality" on well-being perception, for example by comparing scores of latent variables obtained for each green area. Moreover, variables related to the demographic and economic characteristics of the users of green areas could be also introduced in the model in order to verify if and to what extent context variables may affect directly or indirectly perceived well-being.

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Gender disparities in reported life evaluation within food insecure and regionally diverse populations

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ABSTRACT

Reliably measuring food security (FS) is of paramount interest today, as food insecurity plagues individuals even in those countries with a surplus in food supplies. With GDP as an indicator of society's progress proves embattled, well-being indicators such as life evaluation (LE) have edged in to affect (inter)national policy formulation. Numerous studies show females are over-represented among the global food insecure (FI) population, however little research has examined if FS affects men and women's reported LE, and if this effect differs by region and food insecurity severity. The exploratory nature of this paper seeks to analyze whether gender is a global risk factor for experiencing mild, moderate, or severe FI, and to explore how the effect of FI on LE may be more pronounced by severity of FI, and if this association is moderated by gender. Through a collaboration with FAO, this study utilizes data collected through the Gallup World Poll® (GWP), which has included the Food Insecurity Experience Scale (FIES) since 2014. The FIES is an eight-item scale, with the current paper categorizing respondents as FS (zero affirmative responses), mildly FI (1-3), moderately FI (4-6), or severely FI (7-8). A single GWP question (adapted from Cantril's Self-Anchoring Striving Scale) comprises the LE variable, with possible answers ranging 0 to 10, with '0' signifying worst possible life, and '10' signifying best. A multivariate logistic regression model was estimated to examine the likelihood of reporting lower LE based on gender, food insecurity severity and region. Results using 2014 cross-sectional data from 148 countries shows that 45.5% of the population was FI. Of this total, 19.3% were mildly FI, 12.6% moderately FI, and 13.6% severely FI. Significantly more women were found to be mildly, moderately, and severely FI (52.6%, 52.7% and 52.6%, respectfully) than men. Those who were categorized in any FI severity showed significantly lower odds of rating "best possible" LE compared to FS counterparts, with severely FI individuals least likely to rate "best possible" LE (OR: 0.08, 95% CI= 0.07-0.09). Globally, women are less likely than men to rate "worst possible" LE, while simultaneously being significantly more likely than men to experience any level of food insecurity.

Women had consistently higher mean LE responses compared to men at the FS, mild FI, and moderate FI levels, but severe FI level showed nearly equal LE responses between genders. The novel finding that men and women's average LE responses balance only at the severely FI severity points to identifying these factors as crucial for understanding how FI is experienced differently by men and women before FI reaches its most severe level. The need for reliable measurement is evident, and requires a change in methodological approach to ensure both men and women benefit from policy and programmes to address food insecurity.

Keywords: nutrition, well-being

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1. Background

Although it has been widely accepted that there is enough food produced globally to meet the world's population needs (WFP, 2011), no country can claim complete food security (FS) for each of its citizens. The 1996 World Food Summit established the currently most cited definition of FS as, "..when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life," (Food and Agriculture Organization of the United Nations, 1996). The exact number of FI individuals, and the extent to which they suffer, remains unspecified within countries (Cafiero et al., 2014), as currently there is no "gold standard" for measuring FI (Coates et al., 2006) but rather an array of measurement instruments exist and are needed to monitor the multiple dimensions of FI.

The need to measure FS deeper than national level has driven an increased use of population surveys that can better reflect direct evaluations of a household or individual's access to food (Cafiero et al., 2014). Experience-based food insecurity scales, such as the U.S. Household Food Security Survey Module (USDA, 2014), the Household Food Insecurity Access Scale (Coates et al., 2007), and the harmonized Latin American and Caribbean Food Security Scale – ELCSA (Pérez-Escamilla et al., 2007), served as models for the creation of the Food Insecurity Experience Scale (FIES) developed by FAO's Voices of the Hungry1 (VoH) project in 2013.

[1] http://www.fao.org/in-action/voices-of-the-hungry/

The unique contribution of experience-based FI scales is the ability to capture psychosocial aspects, such as anxiety or uncertainty, as well as behaviors relating to the ability to procure enough food at the individual level. The FIES is based on the premise that the evidence of universal dimensions of experienced FI (Swindale, A. & Bilinsky, P., 2006), as well as accumulated research showing the cross-cultural validity and applicability of previous measures, support the use of a standardized measure enabling international comparisons. The FIES is a psychometric scale similar to other widely accepted scales measuring unobservable traits, such as intelligence and depression. Brunelli's 2014 analysis explored if the eight FIES items worked similarly between men and women, as significant discrepancies in item severity could imply the existence of a gender-based difference in the interpretation of that item. Only one item out of the eight item FIES scale was found to have statistically meaningful Wald test p-values that differed between genders, the question being, "...hungry but did not eat because there was not enough money or other resources for food," (Brunelli et al., 2014). Comparability of FIES results across countries was achieved through the Item Response Theory (IRT) models (Nord, 2014; Brunelli et al., 2014). The FIES was constructed using the One Parameter Logistics Model (or Rasch Model) based on IRT. When the model is applied to FI measurement, the probability that a respondent with FI responds positively to a scale item characterized by severity level can be modeled as a logistic function of the distance between these two aspects (Brunelli et al., 2014). This provides a theoretical base and a set of statistical tools that can assess the suitability of a set of questions for constructing a scale, and then compare the performance of the scale in various populations and survey contexts (Nord, 2014).

Globally, women face weaker decision-making within the household, observe differential feeding and caregiving which favor boys and men, and poorer health and nutrition outcomes compared to male counterparts (Asian Development Bank, 2013). Studies show that women in South Asia are served and often eat after other household members, and are less likely than men in the same household to consume preferred foods such as meats and fish, which are often the most nutrient-dense (Brown et al., 2008). Brown et al (2008) also found that during times of crisis in low income countries, women and girls are often expected or forced to reduce their intake of higher quality foods or total food quantity in favor of male household members. NHANES datasets from 2001-2008 show intra-household differences in FS, consistent with concurrent literature: US women were more likely to experience FI than US men of similar age in households with the same FI and income (Nord, 2011). Through psychology, economy, public polling, sociology, and other fields, well-being as a subjective experience has been objectively measured, assessed, correlated with observable brain functions, and shown to reliably reflected the characteristics of individuals and societies (Helliwell et al., 2012). While objective metrics such as life expectancy at birth, diabetes prevalence, and gross domestic product have been used to assess overall wellbeing at the national level for decades (Drewnowski & Popkin, 1997), the 2012 World Happiness Report concluded that measures of subjective well-being provide an alternative yardstick of progress that is grounded in people's experiences, oftentimes differing from other important, conventional metrics that focus on access to resources (Helliwell et al., 2012). This disparity is desirable, as it offers nuanced evidence apart from the economic and social indicators such as income or employment typically used to assess a person's well-being. Hadley Cantril's "Self-Anchoring Striving Scale" is a prominent and widely accepted indicator of LE, which asks respondents their perceptions of where they stand on a hypothetical vertical ladder (Cantril H, 1977). It was concluded that the Cantril Ladder was a pure measure of LE, with Kahneman and Deaton (2010) considering the Cantril Ladder a serious global contender for the best tool for measuring the degree to which individuals view themselves as achieving their overall goals. Currently the Cantril Ladder covers the widest span of countries of any well-being indicator (Helliwell et al., 2012). At the group or national level, reliability is very high for measures such as the Cantril Ladder, due to individual-level random variations and personality fluctuations being averaged away, and underlying circumstances that may change from year to year changing modestly over longer time frames (Blanchflower et al., 2004;

Helliwell et al., 2012). Revised Cantril LE measures carried out using the individual as unit of analysis show that in most high-income countries, women report higher LE than men (Helliwell et al., 2012). When comparing men and women's LE over time, women's well-being ratings do not increase as consistently as those of men (Blanchflower, 2008). Where women report higher life satisfaction than men, all other factors equal, women report more psychological stress and mental illness than men, too (NolenHoeksema et al., 1999).

1.2 Study Rationale and Objectives

Measuring LE in conjunction with FS can offer invaluable information about a society's resiliency and social protection networks, or even signals of underlying crises to come. Assessed at the individual level, measuring LE alongside FS can foster a more complex understanding of the way men and women may have different experiences between and within FI severities.

This exploratory paper seeks to analyze whether gender is a global risk factor for experiencing mild, moderate, or severe FI. The secondary objective is to explore how the effect of FI on LE may be more pronounced by severity of FI, and if this association is moderated by gender.

2. Methods

This quantitative study uses a cross-sectional survey design, conducted through a collaboration with the co-authors as well as the VoH team at FAO, which holds the data license. With few exceptions, all samples used by the GWP are probability-based and nationally representative of the resident population, beginning at age 15. Each country surveyed is covered entirely within sampling, including rural areas. Random respondent selection is achieved by using either the latest birthday or Kish grid method. The GWP uses a standard set of core questions that have been translated into the major languages of the respective country. Data were analyzed using IBM® SPSS® Complex Samples version 21, to improve the validity of statistical inferences by accounting for sample design in survey data analysis. Sampling weights were provided by Gallup. Using only year 2014 dataset, 148 countries with 153,209 respondents comprise the present study.

The FIES comprises the FI indicator, incorporated into the GWP in 2014. The FIES consists of eight questions worded to be as concise and universally relevant as possible. The GWP aims to ensure that the questions, as formulated in the language of administration, faithfully capture the concepts underlying the FI scale. To obtain prevalence rates that are comparable across the large number of countries, the FIES global standard scale is defined as a set of item parameters based on the results from application of the FIES in all countries covered by the 2014 GWP survey. By calibrating each country's scale against the FIES global standard, the respondent severity parameters obtained in each country are effectively adjusted to a common metric, thus allowing the production of comparable measures of severity for respondents in all countries (FAO, 2016).

Respondents were categorized based on the individual's sum of affirmatively answered FIES questions (raw score), a characterization developed in collaboration with the VoH team. Those responding "no" to all eight FIES questions (raw score of zero), are classified as "FS". Those with 1-3 raw score were classified as "mildly FI", 4-6 as "moderately FI", 7-8 as "severely FI".

The LE indicator is adapted from the Cantril Ladder measure, administered in the GWP Core Questionnaire: "Please imagine a ladder with steps numbered from 0 at the bottom to 10 at the top. The top of the ladder represents the best possible life for you and the bottom of the ladder represents the worst possible life for you. On which step of the ladder would you say you personally feel you stand at this time, assuming that the higher the step the better you feel about your life?"

3. Results

50.9% of the total sample (81,528 unweighted count) was female. Of the total sample, 54.5% were found to be FS, 19.3% mildly FI, 12.6% moderately FI, and 13.6% severely FI. Over half of all severely FI respondents reside in Sub-Saharan Africa (58.4%), with this region holding the highest proportion of moderately (33.8%) and severely (22.9%) FI individuals of any region. Europe and Asia had the highest proportions of FS individuals at 75.5% and 65.8% respectively, although Asia's severely FI proportion (6.7%) was nearly double Europe's (3.6%). LE responses follow a Gaussian distribution centering at "5", typically found when using Cantril Ladder item variations. More women reported a LE rating of 8, 9 and 10 than men (11.5 vs 11.2%, 4.3 vs 4.2%, and 5.3 vs. 4.6%). Significantly more women were found to be mildly, moderately, and severely FI (52.6%, 52.7% and 52.6%, respectfully) than men (Table 2), hence proportionally more women (47.1%) than men (43.9%) categorized with any level of FI. 14.1% of all women were categorized severely FI, a statistically significant find, versus 13.1% of all men. Without using Complex Sample calculation (Table 3), women consistently had a higher mean LE response than men did at the FS, mild FI, and moderate FI levels. Only at the severe FI level do LE responses even off between genders. Of the total population who rated their LE "worst possible", 46.1% were severely FI (Table 4). This is compared to those who rated LE "best possible", where 10.4% were severely FI.

Table 1: *Region Frequencies*

Region	Frequency	%	Food insecurity			
			FS	Mild FI	Mod FI	Severe FI
Europe	34,051	22.2	75.5	14.6	6.3	3.6
Former Soviet Union	15,038	9.8	58.9	30.8	7.4	2.8
Asia	28,867	18.8	65.8	18.3	9.2	6.7
Americas	22,116	14.4	51.7	20.1	12.8	15.4
Middle East and North Africa	17,093	11.2	57.0	19.4	13.7	9.9
Sub-Saharan Africa	36,044	23.5	23.9	19.4	22.9	33.8
Total	153,209	100.0	54.5	19.3	12.6	13.6

Table 2: *Gender differences across levels of food insecurity status*

Food insecurity	Men	95% CI	Women	95% CI
FS	50.5	50.1-50.9	49.5	49.1-49.9
Mild FI	47.4	46.7-48.1	52.6	51.9-53.3
Mod FI	47.3	46.4-48.2	52.7	51.8-53.6
Severe FI	47.4	46.6-48.2	52.6	51.8-53.4

p value <0.001

Table 3: *Average life evaluation by food insecurity (unweighted)*

	Average life evaluation		
	Men	Women	Difference
FS	6.11	6.26	+0.15
Mild FI	4.90	5.06	+0.16
Mod FI	4.29	4.38	+0.09
Severe FI	3.73	3.73	0.00

Table 4: *Prevalence of life evaluation by food insecurity (row %)*

Life evaluation	Food insecurity			
	FS/ Mild/ Mod	95% CI	Sev FI	95% CI
"Worst possible"	53.9	52.2-55.6	46.1	44.4-47.8
1	59.9	58.2-61.6	40.1	38.4-41.8
2	67.8	66.5-69.0	32.2	31.0-33.5
3	77.4	76.6-78.3	22.6	21.7-23.4
4	82.8	82.1-83.5	17.2	16.5-17.9
5	89.6	89.2-90.0	10.4	10.0-10.8
6	93.2	92.8-93.7	6.8	6.3-7.2
7	95.5	95.2-95.9	4.5	4.1-4.8
8	96.1	95.7-96.4	3.9	3.6-4.3
9	94.3	93.5-94.9	5.7	5.1-6.5
"Best possible"	89.6	88.8-90.4	10.4	9.6-11.2

p value <0.001

Table 5: *Prevalence of "worst possible" life evaluation for each food insecurity by gender*

"Worst possible" life evaluation	Food insecurity							
	FS	95% CI	Mild FI	95% CI	Mod FI	95% CI	Severe FI	95% CI
Men	18.0	16.1-19.9	18.2	16.3-20.2	19.9	18.0-21.9	43.9	41.5-46.4
Women	15.0	13.4-16.8	14.8	13.1-16.5	22.1	20.2-24.2	48.1	45.8-50.5

p value <0.001

Of the total number of women who rated LE as "worst possible" (Table 5), 15% were FS (versus 18% of men). 48.1% of women who rated "worst possible" LE were severely FI, higher than their severely FI male counterparts (43.9%) though CI ranges slightly overlap. Women were significantly more likely than men to rate LE > 5, notably "best possible" (OR: 1.36, 95% CI= 1.24-1.50). The likelihood of rating LE as "best possible" significantly declines as FI severity increases (compared to FS), controlling for gender, income, region, marital status and education (Table 7).

Table 6: *Association between women and LE*

Life evaluation	OR	95% CI
1	.983	.890-1.086
2	.988	.903-1.080
3	.990	.911-1.075
4	.994	.917-1.078
5	1.143	1.058-1.234
6	1.141	1.051-1.238
7	1.178	1.085-1.279
8	1.259	1.158-1.368
9	1.264	1.148-1.391
"best possible"	1.364	1.243-1.496

p value <0.001

Table 7: *Association between level of food insecurity and having rated "best possible" LE*

	OR	95% CI
Mild FI vs. FS	.247	.212-.287
Mod FI vs. FS	.144	.122-.169
Severe FI vs. FS	.079	.068-.091

p value <0.001

4. Discussion

These findings are consistent with recent literature on gender disparities in FI, while enriching this body of knowledge with the current findings of women more likely to be FI at each severity level. Men and women who rated their LE as “worst possible” experienced different FI severities, with proportionally more FS and mildly FI men, and proportionally more moderately and severely FI women. Globally, women are less likely than men to rate “worst possible” LE, while simultaneously being significantly more likely than men to experience any level of food insecurity. This study cannot infer what factors, and to what extent, influence women’s higher mean LE. However, the novel finding that men and women’s mean LE responses balance only at the severely FI severity points to the need for identifying these influences before FI reaches its most severe level. Women’s higher likelihood of any FI is interlinked with their globally limited access to education and employment opportunities (Asian Development Bank, 2013). These barriers affect not only individual FS, but household members who depended on that woman for income or food.

This analysis supports Brunelli et al. (2014) and others in the appeal for studying FS at the individual level to better explore differences in how FI may affect other aspects of a person’s life, and how these differences can be seen between the genders. This paper views surveys as a useful method for studying LE, as they allow a direct and easily administered measure where people can report on their own perceived LE (Helliwell et al., 2012), as well as implement well-being and FS assessments in unison to understand how FI affects LE in specific economic and social contexts. The need for reliable measurement is evident, and requires a re-structuring of food security monitoring at individual level, to ensure both men and women are adequately benefiting from FS policy and programmes. Further research is necessary to explore why LE is viewed differently by men and women and what nutritional and well-being consequences result.

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THEMATIC SET

F32

USE OF ADMINISTRATIVE DATA FOR AGRICULTURAL STATISTICS

Session Organizer
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ABSTRACT

A large proportion of the data being currently produced in developing countries comes from administrative sources, mainly as a by-product of activities of extension workers and other administrative processes and this situation is likely to stay for a long time because of resource and capacity limitations in many of these countries to conduct proper sample surveys. Also because of the growing need for very low geographical level data and for early warning and pre-harvest crop forecasting data to inform governments on the prospective food situation which is mainly derived from crop monitoring and other auxiliary information produced by field staff. Furthermore, data on livestock, fishery, forestry, land and water is usually derived from administrative reports prepared by subject matter specialists. In developed countries, budget restrictions, respondent burden and availability of new tools and methods are prompting many countries and institutions to undertake research in new ways of producing agricultural statistics with a more important role of administrativesources. However, several studies have underlined the limitations of data from administrative sources in terms of their low quality for a number of technical reasons. This session will present and discuss findings from research undertaken on the improvement and use improvement and of administrative data for a cost effective agricultural statistics system both in developing country and developed country context. Papers can focus on successful research or implementation of methods and tools for use of administrative data in agricultural statistics in a country.

LIST OF PAPERS

Strategies for improving administrative data for use in an integrated agricultural statistics system
A. M. N. Ssekiboobo | School of Statistics and Planning | Makerere University | Kampala | Uganda
B. E. Muwanga-Zake | School of Statistics and Planning | Makerere University | Kampala | Uganda
DOI: 10.1481/icasVII.2016.f32

Use of administrative registers for strengthening the geo-statistical framework of the census of agriculture in Mexico
S. Pérez | INEGI | Aguascalientes | Mexico
DOI: 10.1481/icasVII.2016.f32b

The use of administrative data for the Agriculture Statistics Program
J. Seay | Statistics Canada | Ottawa | Canada
M. S. Beaulieu | Statistics Canada | Ottawa | Canada
S. Prasil | Statistics Canada | Ottawa | Canada
K. Nagelschmitz | Agriculture and Agri-Food Canada | Ottawa | Canada
DOI: 10.1481/icasVII.2016.f32c

THEMATIC SET

F32

The role of quality-frameworks to improve the quality of statistics based on administrative registers - the case of organic meat production

D. Persson | Swedish Board of Agriculture | Jönköping | Sweden
U. Svensson | Swedish Board of Agriculture | Jönköping | Sweden
DOI: 10.1481/icasVII.2016.f32d

Coverage issues in agriculture statistics when using administrative data

T. Tuoto | Istat | Rome | Italy
DOI: 10.1481/icasVII.2016.f32e

Strategies for Improving Administrative Data for Use in an Integrated Agricultural Statistics System

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ABSTRACT

One of the key priorities of the Research Plan of the Global Strategy to Improve Agriculture and Rural Statistics is "Improving the methodology for using administrative data in agricultural statistics" (World Bank, 2010).The School of Statistics and Planning of Makerere University, Uganda (SSP) and the Center for Survey Statistics and Methodology of Iowa State University, USA (ISU), were engaged by FAO in a collaborative research effort with the aim of developing strategies and methodologies for improving the collection and management of data from administrative sources and of their use in an integrated agricultural statistics system in developing countries.

Literature shows that statistics agencies in developed countries have done a lot of research in this area especially with regards to uses of administrative records. On the other hand, the review on developing countries shows that despite questionable agricultural administrative data quality, many countries are collecting and using administrative data. Administrative data requires fewer resources and therefore a more sustainable source. These sources also provide high frequency data and can better generate small area statistics and data on rare commodities based on technical and cost considerations. However, while administrative data may be of acceptable quality for executing administrative functions, concerns have been raised regarding performance and infrastructural issues identified in the gap analysis need to be resolved before data its quality for official purposes especially in developing countries. A comprehensive analytical framework using a structure, conduct and performance paradigm was used to review the administrative sources in terms of production, quality and use of this data; to identify strengths, weaknesses and suitability of the existing agricultural data systems and review and analyze gaps. The structural, conduct, performance and infrastructural issues identified in the gap analysis need to be resolved before data from this source can be integrated in the agricultural statistics system. The field tests have made an attempt to address these issues. Findings from the pilot are given.

Keywords: Sources, Quality, Methodology, Experiences

1. Introduction

The Global Strategy to Improve Agriculture and Rural Statistics adopted by the United Nations Statistical Commission in 2010 aims to improve statistics in agriculture, livestock, aquaculture and agro-forestry production in developing countries and ensure sustainability of their maintenance. One of the key components of the Global Action Plan is its Research Plan whose priorities include "Improving the methodology for using administrative data in agricultural statistics" (World Bank, *2010*).

The major objective of the research is to improve the quality and use of administrative data. It aims at developing strategies and methodologies for improving the collection and management of agricultural data from administrative sources and of their use in an integrated agricultural statistics system in developing countries. The expected primary products of this research include (i) a technical report that includes a country-tested and validated methodology to improve and make available administrative data for producing agricultural statistics and (ii) a proposed strategy on how to use administrative data in cost effective agricultural statistics systems.

A number of definitions of administrative data have been made, including Brackstone (1987), Pronab (undated), UN (2011). However, the working definition of administrative data for this research is *"information collected primarily for administrative (not statistical) purposes by government departments and other organisations usually during the delivery of a service or for the purposes of registration, record keeping or documentation of a transaction (Administrative Data Liaison Service UK, 2015).* This involves routine data collected by agricultural extension workers/chiefs and includes data from farm assistance programs, cattle tracing, veterinary visits and farm inspections; farmers' associations; farm transactions; agricultural inputs dealers, parastatals, etc.

A four-step approach was proposed for this research, namely,

(i) a thorough review on the quality and use of administrative data to improve agricultural statistics in developed countries;
(ii) an analysis of the country assessment surveys and other documentation to identify methodological issues in using administrative data in developing countries;
(iii) based on the findings in (i) and (ii) and experiences in developed countries, develop a general methodology for integrating administrative data and other sources of auxiliary information with survey data as part of an integrated national statistical system;
(iv) three developing countries selected for in-country testing to validate and improve the methodology developed in (iii), after which final guidelines for developing countries to integrate administrative data into agricultural statistics would be produced.

2. Methodology of analysis

The work so far has involved the analysis of (i) **Country assessments reports** with information on the main sources of core agricultural data (Africa and Asia-Pacific regions); (ii) **Literature review** of research activities, empirical studies and country experiences on the sources, production, quality and use of administrative sources for statistical purposes in developing countries; (iii) **Key informant interviews;** (iv) Responses from a **questionnaire** administered to the National Statistical Offices (NSOs) in Africa during the Africa Symposium for Statistical Development held in January 2015, in Uganda; (v) **further analysis** of the data for Africa and the Asia Pacific region assessments (FAO, 2015c); **gaps**; and **in-country testing** in three selected developing countries.

A review of the analytical framework for assessment of Agricultural Market Information Systems developed by Kizito (2011) showed that it is comprehensive and can be used for review of other systems' structure, conduct and performance. The framework was modified for the purpose of assessing the Administrative Data Systems for Agricultural Statistics (ADSAS) in countries.

3. Findings from the Literature Review and the Gap Analysis

3.1 Benefits of Administrative Data

Administrative data is cheaper to use, reduces response burden and improves public image of the NSOs. They can be collected more frequently, are more timely and up to date, can cover the whole target population. Indeed, in many developing countries; it is the only data available-especially for lower level administrative units and rare commodities. Finally, administrative data can also help the NSOs cope with their mandate despite budget limitations.

3.2 Sources of Agricultural Administrative Data

Sources of administrative data identified which have application to agricultural statistics, include: Regular returns/reports by agricultural field/extension staff, agricultural production and inputs manufacturers and distributors, farmers' associations, private businesses data, meteorological data, parastatals handling the major commercial/cash crops and traceability data (e.g. traceability livestock data). Tax data, land ownership records, farm registers and other registration or licensing systems are potential sources of this data but are rarely used in developing countries because of quality and coverage issues. Most of the institutions producing agricultural administrative data are public/government but there is also a lot of potential for the private sector, farmers' and traders' organizations as well as agricultural research organizations.

3.3 Uses of Administrative Data

Common uses to which administrative data is put in developed and developing countries included: sampling frame construction and sample design; covering data gaps from surveys and censuses; forecasting, planning, provision of small area estimates and administrative uses including policy and decision making. While developed countries tended to use scientific approaches for adjusting or improving administrative data before use, developing countries tended to use simpler subjective methods like expert opinion, screen surveys, eye estimation etc. The experiences of developed countries in the use of administrative data therefore give important lessons for developing countries (FAO, 2015a, b).

3.4 Data Processing and Accessibility to Administrative Data

A lot of data from this source remain in raw form and are not turned into usable information in developing countries. Apart from exports and imports as well as agricultural price information which are often published widely, like data from other sources, a lot of other agricultural administrative data are not widely disseminated for use as it is not fully analysed. Data dissemination is often limited to office reports and workshops.

3.5 Data Quality:

Assessment of the quality of administrative data is subjective in most developing countries and the assessments are not detailed enough to cover the different quality dimensions; yet the appropriate form of quality analysis depends on the intended use of the administrative data. Much of the agricultural administrative data is usually collected and compiled without using standard statistical procedures or personnel with training in statistical methods. Documentation of administrative data collection and processing methodologies as well as agricultural data quality parameters is also poorly done.

3.6 Institutional and Organisational Capacity

As a result of decentralization in most developing countries, there are more lower reporting levels, most of which have limited capacity, leading to delayed information flow. Data is often only collected intermittently. There are also frequent institutional changes in the administrative units. Operational constraints make it difficult for extension staff or chiefs in some cases, to cover their areas of jurisdiction to collect data. They have several other responsibilities and are not, normally, and legally under the statistics authorities. Agricultural returns by agricultural extension staff are based on non-standard data collection forms which can lead to reporting errors and inconsistencies. Sadly, in some cases there are even no standard reporting formats.

3.7 Summary of Potential Limitations in the Use of Administrative Data

Limitations of administrative data in developing countries include: Changes in administrative processes leading to inconsistencies in estimates across time, or reduced data availability; non-standard definitions of variables, units and identifiers making synthesis of multiple sources a challenge; under-coverage; reporting errors; and the challenge of maintaining confidentiality. Other challenges include: The NSOs using administrative data source for a purpose different from the one for which the data was originally collected; limited involvement of the NSOs in data collection and analysis; access problems including legal restrictions, policy considerations, organizational arrangements and technical standards; and diverse sources for the same data with undocumented methods leading to conflicting estimates. Reduced contact of the public with the NSOs, timeliness, missing data, and resistance to change are the other limitations.

3.8 Gap Analysis

A gap analysis was carried out (See Table 1) in order to identify areas of possible methodological improvement and solutions for using administrative data in an integrated agricultural statistics system (FAO, 2015d).

Table 1: Gaps Identified and Proposed Solutions to Fill the Gaps

<table>
<tr><th></th><th>COMPONENT</th><th>GAPS</th><th>PROPOSED SOLUTIONS</th></tr>
<tr><td>1.</td><td>Administrative Data Collection and Management</td><td>• Divergence in figures from different sources on the same data item – lack of consistency, coherence and comparability.
• Missing data.
• Poor application of statistical standards and methods.
• Limited use of ICT for data collection and management.
• Use of non-uniform formats across different administrative units.
• Poor data collection tools – questionnaires and manuals.
• Subjective reporting of crop area, production, forecasts of production and yield.</td><td rowspan="2">• Set up a robust Routine Agricultural Administrative data system linked to other agricultural statistics sub systems.
• Produce a comprehensive administrative data systems manual with proper guidelines covering all aspects of the data collection and management system.
• Improve specificity of definitions.
• Standardize data collection instruments.
• Support field supervision on a regular basis. Best practice from India: The Improvement of Crop Statistics (ICS) to supervise data collection and verify the accuracy of the data collected. The Timely Reporting Scheme (ITS) to improve the timeliness of the data (Ministry of Statistics and programme Implementation, India, Undated).
• Introduce and enhance use of modern technologies e.g. GPS tools, mobile phones, PDAs, scanners, etc.
• Train and equip staff to use modern technologies for data collection and management.
• Learning from best practice of other countries.
• Developing protocols for metadata documentation and for correcting data inconsistencies.
• All Agricultural Administrative units should have at least one statistician as part of their staff team.
• Establishment of a Technical Working Group to monitor the process of administrative data production.</td></tr>
<tr><td>2.</td><td>Structure of Organisations Collecting Administrative Agricultural Data</td><td>• Failure to sustain good data collection systems.
• Many & frequent changes in the administrative structure that affect data collection and management.</td></tr>
</table>

	COMPONENT	GAPS	PROPOSED SOLUTIONS
3.	Coordination and Supervision	• Poor coordination or lack of co-ordination between the NSO and the various administrative agricultural data collection and management institutions. • Inadequate statistical infrastructure • Field staff often not well supervised. .	• Establish legal frameworks that support good coordination between the NSO and other players managing administrative agricultural data. • Put in place or improve MoUs to facilitate data sharing. • Best Practice – India: Well established countrywide infrastructure; a permanent village reporting agency (Ministry of Statistics and programme Implementation, India, Undated). .
4.	Human Resource / Incentives to ADSAS staff	• Lack of qualified staff & low staff retention mainly due to poor working conditions. • Poor incentive structures among employees. • High Rate of staff attrition of trained and experienced staff from the government service. • Regular training is not common in most countries. • Extension staff who often collect the administrative agricultural data have many other functions.	• Assess human resource and training needs to identify basic skills requirements. • Improve terms of service. • Incorporate finances required to recruit and train staff into the national budget and those of MDAs, including local governments. • Reduce overlap; streamline activities to clearly make data collection part of the job description. • Training Best Practice: Tanzania Agricultural Routine Data System (ARDS) on: ➢ the common reporting formats, ➢ the Village/Ward data collection format, ➢ data management, ➢ data handling and analysis at district level.
5.	Quality Control Procedures	• Quality assessments for agricultural administrative data systems in developing countries are rarely done. • Most ADSAS in developing countries do not put emphasis on documenting agricultural data quality parameters, and where they exist, they are subjective.	• Set up a Technical Working Group to ensure quality control measures and data validation mechanism/processes are put in place and adhered to. • Determine the data quality dimensions that are more relevant for assessing quality of administrative data. • Develop quantitative indicators of the relevant quality dimensions.
6.	Institutional Capacity	• No interface for dialogue between data producers and users. • Where they exist, channels of communications are not well set up and/or not regularly used as required leading to weak data relevance. • One third (30%) of the African countries for example operate below average of the expected level of the primary institutional infrastructure to produce agricultural statistics (AfDB, 2014).	• The interface for dialogue between data producers and users should be set up where they do not exist and strengthened where they are weak. • Monitoring mechanism should be established to ensure the interface is used on a regular basis. • Institutional infrastructure (physical, statistical, GIS capability, statistical methodologies and classifications) should be strengthened where they are weak. This may require providing technical support to the countries. • Best practices should be drawn from the Asia-Pacific countries of Australia, Japan, Mongolia, and New Zealand (APCAS 2012) that performed well in this dimension.
7.	Adequacy of Resources	• African Countries have inadequate resources to run the agricultural statistics systems effectively and efficiently. This is	The Countries need: • Financial support in terms of greater budgetary allocations for Agricultural Statistics in their national budgets as well as

	COMPONENT	GAPS	PROPOSED SOLUTIONS
		in terms of ➢ Finances ➢ Human resource and ➢ Physical infrastructure including technology. • These result into late or irregular collection of information, inability to hire and retain well trained staff, failure to ensure sustainability and production of poor quality data. • Lack of information on cost effectiveness of agricultural routine data collection systems.	external funding where possible. • Capacity building in human resources for their agricultural activities. • Technical assistance or share technical expertise through staff exchange programmes and study tours. • To use more cost-effective methods. • Lobby governments to provide more financial support for the system (worked well in Asia Pacific to gain access to the national budget for the routine data collection systems (Maligalig, 2015).
8.	Data Use	• Limited use of the agricultural administrative data (especially due to quality concerns). • Limited use for: ➢ Improving frame construction and sampling designs. ➢ Improving efficiency of survey based estimators. ➢ As covariates in constructing model based small area estimates and forecasts. ➢ Crop forecasting	• Use of cross checks and corrections made through survey data. • Combining multiple data sources with complementary strengths and weaknesses. • Use calibration and construct area frames. • Develop methodology for record linkage and evaluation of measurement errors. • Develop good identifying variables. • Make the agricultural statistics production process more objective and transparent through digitisation and automation. • Review and revise the legal framework to cover administrative sources.

3.9 Approach to In-Country Testing

Two types of pilot testing were done – one field-based and another, desk-top. The School of Statistics and Planning (SSP), Makerere University, Uganda led the field piloting in Tanzania and Côte d'Ivoire, while the Center for Survey Statistics and Methodology (CSSM), Iowa State University (ISU), USA led the desk-top data analysis in Namibia. This paper refers to the field-testing. (FAO, 2016e).

3.9.1 Strategy Adopted in the Pilot

The Agricultural Routine Data System (ARDS) in Tanzania identified as one of the best agricultural administrative data collection systems in Africa, due to consistency and coverage, was used as basis for the pilot. The strategy adopted was to identify what improvements were required and then pilot these. For example, there was no primary source of data from the agricultural households. Therefore a household level questionnaire was designed and piloted. In Côte d'Ivoire, there was no routine reporting system. Therefore, a similar system was set up in four villages in Cote d'Ivoire on a pilot basis.

The routine reporting system of Tanzania and the data collected by administrative agencies in Côte d'Ivoire were evaluated, reviewed, and strengthened with respect to a number of dimensions corresponding to different issues as identified in the gap analysis. These included: coordination and supervision; skills and knowledge in agricultural data management and analysis; usage of comprehensive methodologies and technologies in data collection and management; conversion factors for agriculture (crops and livestock); presence of an agricultural statistics dissemination strategy; quality control; linkages between data from administrative sources with surveys and censuses; and cost of the administrative data.

A mini-survey to come up with conversion factors in the pilot areas was also carried out in Cote d'Ivoire as there were no conversion factors. The pilot also included introduction of new technologies like data collection using Tablets, area measurement using the GPS tools and collection of crop production using crop cards.

3.9.2 Visits to the Pilot Countries

There were a total of four visits to each of the pilot countries by the SSP Team. Each visit had a checklist of issues. A pre-pilot (first) visit was made to Tanzania and Côte d'Ivoire by an SSP team of two; to better understand the agricultural administrative data systems of these two countries.

A second visit by the SSP team was at the beginning of the pilot where a number activities were conducted including: Confirming the current coordination structure of the agricultural statistics system and the mandates of partners (NSO and Ministries) in collecting agricultural-related information; finding out current supervision arrangements; launching the pilot including briefings to all concerned; designation and training of respective staff to participate in the pilot; and agreeing on the dates for the third and fourth visits by the SSP team with stakeholders.

During the third (pilot mid-term) supervision visit, it was established whether the study countries had conversion factors; discussions were also held on the adequacy of funding, a review of data returns and flow at various levels was also done and other potential sources of administrative data identified. The fourth and final visit to wind up the field tests was also used to ensure that the issues identified in the gap analysis were all responded to. Measurements were compared: farmers' estimates of area against measurements obtained using GPS equipment; farmers' estimates of production versus actual record keeping through the crop card. The uses of modern technologies in data collection, in this case the tablets, was explored to speed up data collection and transmission at the local level and contribute to generation of real time data.

3.9.3 Findings

The introduction of a questionnaire, the crop card and the respective instructions' manuals as well as the tablet were considered to be very good innovations in both countries. The farmers themselves noted that the benefits were two-way in that the enumerators got the information they wanted while the farmers got extension advice and also got to know the exact size of their fields.

The main challenges included the fact that most of the plots were far away from the villages and scattered and not easily accessible; continuous harvesting especially where the crop card was not administered; farmers who did not want to be identified because they are squatters; synchronization of the data and sometimes lack of internet and; provision of area and production estimates by illiterate farmers. There were clear over-estimates of areas by the farmers when compared to the GPS estimates. Farmers production estimates were also over-estimates compared to the crop card. The facilitation given to field staff and supervisors was also greatly appreciated. The challenge is whether it is sustainable.

It was proposed to have intensive sensitization of the farmers before the pilot, to give more time for the training of field staff, to program the Crop Card on the mobile phone so that farmers can report regularly and electronically and, to geo-reference the plots as well since they are quite far from the homesteads. The collaboration between the NSO and MoA in Tanzania, in administering, coordinating and supervising the ARDS is a best practice that can be replicated in other countries including Cote d'Ivoire.

The existence and adherence to quality control measures and data validation mechanism/processes were examined; which data quality dimensions are more relevant for assessing quality of administrative data and their quantitative indicators (measurement of dimensions); and find out whether performance assessments of the system are done, review them and make recommendations.

As far as cost of administrative data is concerned, it is well known that establishing costs is a difficult but important task. With costs diffused throughout the data collection process, the goal was to estimate respective costs at each level of the process and make the process more cost-effective.

4. Conclusions

The Literature Review clearly shows that statistics agencies in the developed counties have done a lot of research in this area especially with regards to the several uses of administrative records. On the other hand, the Literature Review on Developing Countries shows that despite questionable administrative data quality, many countries are already collecting and using administrative data in a number of situations. In fact, administrative data are the major source of data in many developing countries, especially for agricultural statistics. There are also new potential sources of data, especially from the private sector. This is partly due to the privatization of formerly official functions and the growth of the private sector. The major problems are mostly data quality and infrastructural issues. Increased use of administrative data will therefore require these issues to be addressed. The field tests, whose analysis has started, have attempted to address these issues and tested strategies and methodologies that would improve the generation and use of administrative data.

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Use of administrative registers for strengthening the geostatistical framework of the Census of Agriculture in Mexico

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ABSTRACT

For a few years now the statistical use of administrative registers has been fostered, as they have been an important tool to reduce costs in producing information and the burden on respondents, for this reason the institutions responsible of producing statistics have boosted capacity building, in order to increase knowledge on the use of administrative sources and ensure the quality of the data produced.

In Mexico, INEGI has established agreements with various institutions to take advantage of the information produced by the administrative registers they produce, with the aim of producing demographic, economic and social statistics.

Regarding the agriculture and forestry sector, in Mexico some of the main sources of administrative registers have been identified, among which the following are worth mentioning: the Ministry of Agriculture, responsible of regulating the actions related to the agricultural and fishery activity; the National Forestry Commission, in charge of fostering the conservation and restoration of forests; and the National Agrarian Register, responsible of controlling and updating part of the rural property in the country.

In this context, there have been collaboration agreements with the Ministry of Agriculture and the National Agrarian Register, who provided inputs such as vector files of land plots and tables of producers from their respective programs, with the objective of analyzing them to determine their utility for strengthening the list and area frames of the Census of Agriculture.

In the beginning, incorporating the tabular and cartographic information into the geo-statistical framework of the Census of Agriculture, was thought to be simple, since it was easy to use digital files; however, the process has not turned out this way, given that there are many considerations to take into account for using the information obtained.

Thus, before incorporating the vector and tabular information to update the list and area frames of the Census of Agriculture, it is necessary to consider important aspects like: the projection in which the land files were produced, the geodetic reference system, as well as the standardization of the vector files obtained from different sources. Whereas for the tabular data, it is very important to obtain the minimum information necessary for the identification of both the producer and his address, independently from the structure that defines every agency.

Key words: administrative registers, census of agriculture, geostatistical frame, list frame, area frame.

1. Introduction

One of the viable alternatives for obtaining data with statistical purposes is the exploitation of administrative registers generated by federal agencies and private entities. In this regard, INEGI has reached agreements with public sector institutions that collect information from individuals and legal entities for using it as a data source to produce statistics with a geographic breakdown.

INEGI currently produces and publishes statistics from exploiting administrative registers in the following matters: economic (mining, foreign trade, and public administration), social (culture, labor relations, suicides, security and public order and health) and demographic (births, deaths and marriages).

Concerning the exploitation of administrative registers from the agricultural sector, INEGI has established alliances with some institutions in order to use their tabular and cartographic information, with the purpose of strengthen the permanent updating of the geostatistical framework of the Census of Agriculture.

2. Analysis of administrative registers from RAN and PROCAMPO to strengthen the geostatistical frame of the Agricultural Census

As a result of the 2007 Agricultural Census conducted in Mexico, the digitalization of approximately 70% of the land plots, where agricultural activities are held, was obtained. The remaining 30% of the land plots is not accurately demarcated since their specific boundaries are unknown, however, they are identified by INEGI in a “control area” (one section of the 187,326 parts that INEGI used to divide the national territory). Additionally, as a result of the Census of Agriculture, it was determined that 49% of the producers are linked with their land plots as production units, while the other 51% production units are not linked.

With the purpose of increasing this 49% of production units, several attempts have been made for incorporating information from administrative registers into the Agricultural Census’ information; nevertheless, most of the registers of producers' associations were discarded, since they contained heterogeneous and incomplete information, and they could not be used for this aim.

During the review of different sources, it was identified that RAN and PROCAMPO registers’ have three basic characteristics that allow a better and detailed analysis:

1. - They contain the producer’s table (a list of several variables that includes the name and address of the producer and other information)
2. - The land plot of the producer is a located territory and has defined boundaries.
3. - Both elements are in digital format; the first one is in database file (.DBF) format and the second one is in shapefile (.SHP) format.

Considering the necessity of being provided with the largest number of rural land plots, properly identified and linked with its producer, INEGI glimpsed the possibility of strengthening the sampling frame of the Census of Agriculture, by exploiting RAN and PROCAMPO information.

In view of the above, it was necessary to train INEGI staff in the use of GIS. With these systems, spatial comparison of the vector files of the land plots from the Census of Agriculture and those from the mentioned sources could be made by using different tools. Besides, high resolution satellite images (with a spatial resolution of 2.5 and 1.5 meters) were used and added into the GIS, in order to use them as a background. Satellite images were used to support the correct location of the boundaries of land plots that normally coincide with roads, rivers, and some other physical boundaries. Additionally, batch processing of geographic information is allowed by the GIS, which reduces the required time to compare land plot files and its databases.

Although digital files are easy to use and integrate into other sources of data, it is important to consider the following aspects before the analysis, and exploitation of administrative data:

1. - Geographic information must be in the same geographic and reference systems and in the same cartographic projection; for all cartographic elements, it is important for the register to be generated with the reference geodetic system's parameters and with the projections that are officially managed in the country, as well as using the parameters that are normally published in official journals for public knowledge, in order for the matching to be as accurate as possible.

Figure 1: *Shift effect observed by the different geodetic reference systems in shape files.*

2. - Database information must have the same structure (size and content of fields must be normalized). Concerning tabular files, it is required that they have basic information needed for the identification of both the producer and his address, regardless of the structure defined by each agency. It is therefore recommended for the name of the producer to be split by the last name of the father, the last name of the mother, and the name itself, in separate fields as it is common for the full name to be included in a single field, which makes information difficult to handle. It is also recommended for the information on the address to be organized according to the technical rules generated for its standardization; these rules usually specify the minimum information on streets and surrounding streets that allow locating addresses; furthermore, localities must be properly identified with the name and geostatistical code that have been assigned to them. Normalization of the database structure will prevent any problem in the process of the information and it will also allow the interchange of data between databases.

3. Analysis of information from the RAN

The measurement and certification of land plots and plans from each "ejido" in México, (shared lands of social property), was done between 1993 and 2003 and backed up on magnetic media by the RAN. The technical works of measurement were carried out by INEGI until 2003; after that, RAN has kept on updating its information. Now INEGI considers important to use these administrative registers to update its information as well.

INEGI obtained the vector files of land plots and producer's tables from RAN, with the purpose of analyzing them and determine if they were able to be used for complementing the information produced by the 2007 Agricultural Census. The criteria set to analyze the information were the following:

1.- The land plots that spatially coincided with information that INEGI already had, were not used to add information to the area frame of the Census of Agriculture; they were only used to verify that INEGI's data is updated.

2.- RAN's land plots, located inside one of INEGI's land plots, were considered as a subdivision, as long as they coincided with its boundaries. In this case, RAN's land plots were considered as part of the updating of the area frame of the Census of Agriculture.

3.- RAN land plots that are subdivisions of a land plot from INEGI, but whose boundaries overlap INEGI's boundaries, will be visually analyzed in detail to determine if they will be used for the updating process.

From a total of 5 685 450 land plots received in shapefiles format, approximately 94% were part of the land plot shapefiles of the Agricultural Census. The high coincidence of land plots from this source is explained because INEGI initiated the social property land plot certification task in Mexico in 1993 and then, in 2003, the activity completely became RAN's responsibility. The remaining 6% corresponds to the land plots incorporated and surveyed by RAN from 2003 up to date and they are divided as follows:

3.31% of the remaining land plots correspond to lands that can be directly incorporated in the shapefile format of the Agriculture Census' land plots, or with minimal editing; these land plots corresponded to subdivisions of larger areas that were already defined in the Agricultural Census, or to common use spaces of the "ejidos" that were divided and distributed among the landowners.

Figures 2 and 3 show different examples of RAN's land plots that were incorporated within the boundaries of a large land plot of the Census of Agriculture, with the respective information of producers.

Figures 2 and 3: *Examples of information of RAN incorporated into Census frame*.

The remaining 2.71% corresponds to land plots whose configuration does not match exactly with the spaces bounded by the Agricultural Census, making it necessary to perform a detailed visual reviewing using the satellite image to determine whether the land plot is incorporated or omitted. In some cases even when land plots do not match, RAN's land plots have a better definition of boundaries (see Figure 4), so they are used to update INEGI's frame. INEGI is currently in the process of determining the land plots of this segment that could be incorporated in the land plot shape.

Figure 4: *Review of RAN's Land plots using satellite image*

Furthermore, the review of the tabular file associated to the shape, allowed identifying the name of the producer along with the information about the “ejido” he or she belongs to, as well as the number of the land plot; however, the tabular file lacks producer’s address (street, number, name of locality, etc.), which is a fundamental data to locate the producers during a census or survey. In this regard, INEGI is in the process of comparing the names with the names included in the Agricultural Census in order to associate the corresponding addresses in case of matches. At the same time, INEGI is requesting RAN to complete producer’s information.

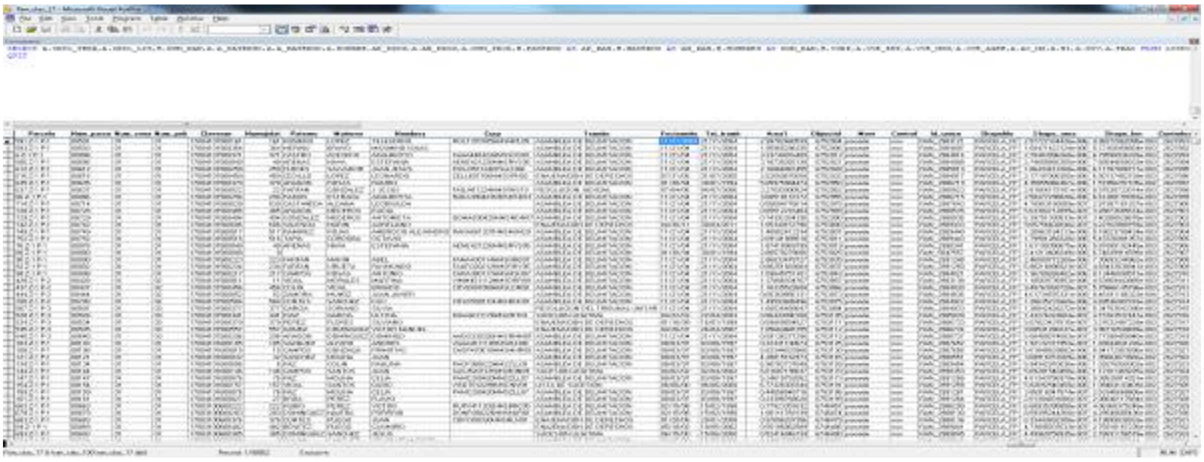

Table 1: *RAN´s information structure, without address data*

4. Analysis of information from PROCAMPO

Information generated by SAGARPA was also considered to be used, specifically data coming from the support programs for farmers that cultivate specific products in their lands. This is the case of PROCAMPO; to keep this register, SAGARPA identifies the land plot being supported; then determines its area and obtains the producer’s information to whom the economic resources are being allocated to; the tabulate and cartographic information collected were also backed up in magnetic media, and it is also considered potential information for updating.

The review of the cartographic information revealed some differences in the configuration of the land plots; the most important was that data from PROCAMPO included land plots with boundaries classified in the Agricultural Census as “big land plots”, without an inner subdivision. PROCAMPO’s boundaries, in most cases, can be considered divisions of the Agricultural Census’ original land plots, however there are some cases where PROCAMPOs’ land plots corresponded only to the cultivated area supported economically by the program. In those cases, where minimal edition is required, will be reviewed before making the decision of integrating them or not.

Besides, there are land plots whose shape differs from the shape in the Agricultural Census, so a one to one detailed review is needed in order to decide which land plots can be incorporated and which are eliminated. This could be done by using the satellite image as background. Figure 5 shows a group of land plots from PROCAMPO that fill a “big land plot” of the census frame with detailed information.

Using the same criteria applied to RAN’s information, from a total of 3 308 038 land plots received from PROCAMPO, 83.9% were already in the land plot layer of the Census of Agriculture; 8.3% corresponded to land plots that could be included with a few modifications; and finally, 7.8% were land plots that must be reviewed, one by one, and then decide upon their incorporation.

Figures 5: *Land plots from PROCAMPO (pink) to be incorporated into Census frame.*

In the case of the tabular information of PROCAMPO, the review reflected lack of data, although the directory contains the names of the producers that are supported by the program, and, in most cases, the street name and number. It also lacks the locality and the address, so INEGI is working with SAGARPA in order to obtain the complete information.

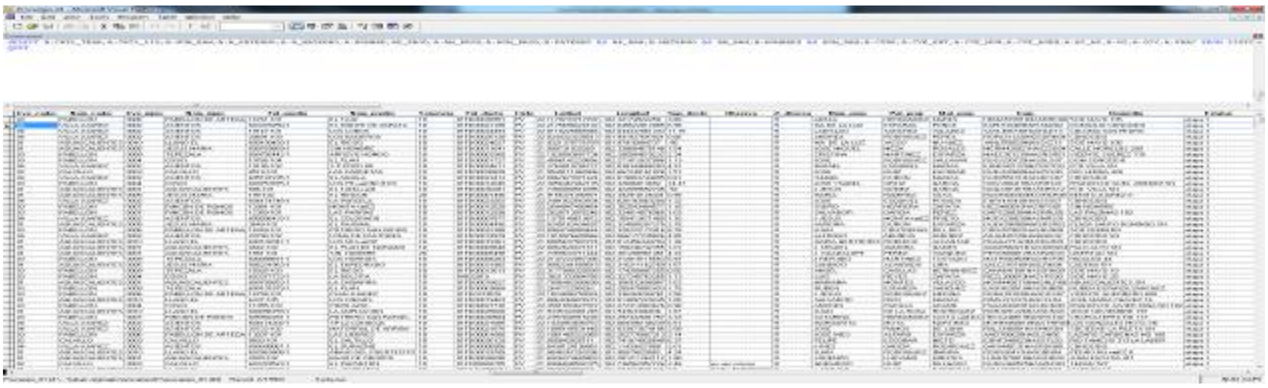

Table 2: *PROCAMPO´s information structure, without accurate address data*

Even though producers' names from PROCAMPO are not included in INEGI's information, they were used to update the information of the Census of Agriculture, since the information of the census corresponds to 2007 and PROCAMPO information is updated to 2012-2013.

5. Conclusions

The use of specialized software of GIS and high resolution satellite images, represents a huge advantage for analyzing, exploiting and managing cartographic and database information produced by institutions in the public and private sectors. Those advantages have been exploited by INEGI to compare vector data from different sources and to use them for strengthen the geostatistical framework of the Census of Agriculture.

Exploiting information from public institutions, as RAN and SAGARPA, represents a great opportunity for INEGI to update the list frame and the area frame of the Census of Agriculture; however, it is very important that information increasingly meets established standards in order to ease this task. The differences of the structure of the databases and the different reference systems of geographic and cartographic information are the main things to keep in mind while working with this kind of data.

With this work, it was possible to increase the percentage of production units (producers linked with their land plots) from 49% to 59%. Concerning the amount of land plots with delimited boundaries, the 295, 155 land plots that RAN added to the shape of the Census of Agriculture, compared with the 2 719 500 land plots that have not been delimited, corresponds to 11%.

Concerning PROCAMPO' data, the 189 853 land plots that were identified for possible addition in the area frame, are still in the process of detailed reviewing to decide whether they will be used to complement the shape of land plots of the Census of Agriculture or not. This amount represents 7% of possible land plots to be added.

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The Use of Administrative data for the Agriculture Statistics Program

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ABSTRACT

The Agriculture Statistics Program at Statistics Canada (Statistics Canada) has undertaken a project to increase the use of administrative data: to replace current survey and census data, to fill data gaps, and for census and survey data validation. Overall the Administrative Data project aims to reduce response burden and increase program efficiencies.

This project involves first identifying specific sources of administrative data that have attributes that make them well suited for further use. Secondly, an assessment is conducted of their usefulness to replace survey or census data, to enhance data validation, or to assist into frame maintenance alongside an assessment of the requirements for their integration into the program.

This paper will present some of the findings resulting from this project, some of the long-term considerations required, as well as the methodology used to evaluate the quality of the sources that have been identified.

Keywords: Administrative data, validation, quality, respondent burden, efficiency

1. Introduction

Following the last major review of Statistics Canada's Agriculture Statistics Program[1] (ASP) in 2010-12, the agency has explored new processes with the objective to reduce respondent burden and continue to provide high quality information on agriculture (Smith J. 2011, Smith et al. 2013)).

One of these initiatives was to integrate more administrative data[2] in order to reduce respondent burden further, to improve quality of survey estimates and to reduce data collection costs. The ASP uses more than 200 sources of administrative data. The primary objectives are to validate collected information and to avoid collecting data already gathered by other agencies and programs. The APS's vision is to continue the acquisition of administrative data for replacing traditional survey data collection methods.

Section 2 is presents new administrative datasets that were assessed and used. Section 3 describes the evaluation guidelines for using administrative data with a specific dataset, AgriInsurance. The last section concludes by looking forward on initiatives to expand the use of new administrative data into the Canadian ASP.

2. Administrative data sources (including Earth observation)

2.1 Taxation data

The ASP uses a census of farm tax filer records annually to estimate detailed farm revenues and expenses. In 2011, the Census of Agriculture (CEAG) program undertook the Agriculture Taxation Data Replacement Initiative. The purpose of this feasibility study was to evaluate the robustness of taxation data as a replacement to detailed operating expenses provided by respondents. The project, completed in 2012, concluded that from most operations in Canada, detailed expenses could be obtained from taxation data. As a result, the 2016 CEAG removed detailed farm expenses from its questionnaire as this information is available from the taxation data.

2.2 AgriStability

In Canada, the AgriStability program was established in 2008 as part of the Growing Forward policy framework implemented by Agriculture and Agri-Food Canada (AAFC). The purpose of the AgriStability is to provide income stability to farmers by managing risk inherent to the agricultural sector (AAFC, 2013).

As the evaluation of AgriStability datasets are still in early stages, the potential of using this program data for replacement in surveys is still unclear. An initial assessment indicated that the AgriStability datasets contain highly detailed income, expenses, and commodities data. However, the data availability is not timely enough to replace survey data. The lag time between the end of a program year and reception of a full dataset is approximately 2 years.

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[1] ASP includes mainly a suite of primary agricultural programs on commodities, farm financial and practices based on surveys, Census of Agriculture and administrative data.

[2] Information that is collected by other organizations and departments for their own purposes, and is sought, at the micro or aggregate level, by Statistics Canada in respect to the objects of the *Statistics Act*. It excludes data that do not pertain to the Canadian society or economy. By definition, Statistics Canada's use of this information for statistical purposes is secondary to the objective of the original collector of the information.

2.3 Remote sensing[3] to derive crop area and yield

For a number of years, the ASP has used remote sensing data for data confrontation against data collected from the field crop surveys and the CEAG. For survey data replacement, the Remote Sensing and Geospatial Analysis (RSGA) team produces two major outputs. The first output is the generalized crop area estimates based on AAFC Annual Crop Inventory data. The AAFC spaced-based annual crop inventory data map the expected extent of annual and perennial crops as well as land use and cover classes covering the agricultural regions of Canada with a spatial resolution of 30x30 m pixels (AAFC, 2015). The second output incorporates CEAG coarse resolution satellite data, survey yield[4] estimates and agroclimatic data to produce Model-based Principal Field Crop Estimates as at August 31.

The first yield model estimates were published on September 17, 2015, three weeks in advance of the traditional September crop survey publication. After an extensive evaluation of the modelled and survey results for 1987 to 2015 period, the decision was made to terminate the September crop survey and replace it with Model-based Principal Field Crop Estimates. This successful implementation was a concrete example where crop survey data could be replaced with modelled data derived from administrative data and historical survey data.

2.4 Animal traceability

Animal Traceability in Canada has been developed as a cooperative effort between agricultural industry organizations and the federal, provincial and territorial governments. The goals of traceability are the identification of animals, recording and reporting animal movements, and premises identification. Traceability facilitates accurate tracking of animal locations during disease outbreaks, and provides information to contain negative impacts associated with such emergencies.

While hog traceability has been fully implemented, other livestock sectors in Canada are at various stages of implementation. The *Health of Animals Regulations* (revised in 2015) are currently being amended to include full identification and movement requirements for cattle, bison, sheep, goats and cervids. Traceability data will be required under Part XV of the regulations. These data are held by the Canadian Food Inspection Agency (CFIA), and is intended for regulated traceability use only (unless consent is given by regulated parties for other uses).[5] Statistics Canada could use traceability data to validate or replace part of the Livestock survey data.

2.4 AgriInsurance

The AgriInsurance program in Canada has been in place since 1959, to provide crop insurance to producers. The program helps to reduce producers' losses by supplying funding where natural hazards have negatively affected production. The program data are acquired by the ASP by agreement with provincial program administrators.

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[3] Earth Observation and remote sensing are used interchangeably in this paper.

[4] For more information on the crop yield model: Chipanshi, A., Zhang, Y., Kouadioc, L., Newlands, N. ,Davidson, A., Hill, H., Warren, R., Qian, B., Daneshfar, B., Bedard, F., Reichert, G., (2015), Evaluation of the Integrated Canadian Crop Yield Forecaster (ICCYF) model for in-season prediction of crop yield across the Canadian agricultural landscape, Agricultural and Forest Meteorology, Vol. 206, 15 June 2015, Pages 137–150.

[5] For information on uses of this information, as well as privacy restrictions, please contact Eric Aubin - National Manager for the Livestock Traceability Program (CFIA) at 1.613.773.6173.

AgriInsurance covers a wide variety of crops including field crops (corn, wheat, oats, barley, soybeans, etc.), horticultural products, and other non-traditional products such as bees and maple syrup. Currently the ASP acquires operator information for each insured operation, individual crop type acreage, yield, and associated field management practices. The level of detail varies by province, but data provided for the Prairie Provinces (Alberta, Manitoba, and Saskatchewan) are generally more detailed. These three provinces account for 48.5% of all farms reporting land in crops based on the 2011 CEAG, and accounted for 81.6% of all total crop area of the Canadian Prairies. AgriInsurance programs do include livestock plans, although the current scope of the ongoing project focuses solely on the crop portion of AgriInsurance. Table 1 illustrates the current and potential use of AgriInsurance data.

Table 1: *Current and potential uses of AgriInsurance data within the ASP at Statistics Canada*

	Validation or ground truthing	Replacement	Frame maintenance	Combined with other data
Census	Current	Potential – 2021	Current	Potential – 2021
Crop surveys	Current	Potential – 2018	To some extent	Potential – 2018
Remote sensing	Current	Potential – 2017	n/a	Potential – 2017
Livestock	Potential	unknown	To some extent	unknown

3. Evaluation guidelines for using administrative data

At Statistics Canada, the Directive on Obtaining Administrative Data for Statistical Purposes, governs the quality evaluation of administrative data. This directive establishes an agency-wide approach to administrative data quality, mandates support for its quality evaluation and ensures that the quality information is documented centrally. Quality is measured using Statistics Canada six dimensions of data quality: relevance, accuracy, timeliness, accessibility, interpretability and coherence.

An evaluation framework, along with evaluation tools and procedures have been developed and tested at Statistics Canada. Unsuitable administrative data sources are quickly rejected early in the evaluation process.

The framework is composed of two phases. The Exploration Phase collects background information (for example, variables available and data format) from the administrative data holder without requiring the acquisition of the complete dataset. Following this phase, a recommendation is issued to continue with more in-depth evaluation.

This second phase, the Initial Acquisition Phase, is where the data itself is accessed and evaluated. This evaluation results in a recommendation whether to proceed or not with a full acquisition of the administrative data source.

The tools developed at Statistics Canada to collect information for the evaluation framework are a standard questionnaire, a toolbox of suggested methods and indicators, and compilation tables where the evaluation results are summarized. The sections below outline the information that is gathered through the use of these tools. In order to highlight the application of the Directive, AgriInsurance data is used as a case study given its level of detail and breadth of information.

3.1 Exploratory phase

The replacement strategy begins with an overall review of potential sources of administrative data available to respond to a statistical need. Once a potential source has been identified, learning about the data from the supplier without accessing the data is the first step.

3.1.1 Target population and coverage

This step includes an evaluation of whether the target population is stable over time and documents the sources of under-coverage and over-coverage. The reference period(s) of the administrative data is recorded, noting when there are differences between that of the population covered and those for the existing Statistics Canada products.

3.1.2 Timeliness of acquisition

In addition, information on the tentative date of acquisition is collected, including dates when various versions (preliminary and final) of the data could be received. Timeliness varies widely across datasets, but is always a concern given the trade-off that often occurs between timeliness and accuracy.

For example, although highly accurate, AgriInsurance data is not available until more than halfway through the calendar year for planted area, while harvested area is not available until well after publication of official yield statistics. This limits the datasets use for direct replacement in crop surveys while having little effect on both the Remote Sensing and Census programs. However, the ASP continues to work towards developing methods that would mitigate the trade-off between timeliness and accuracy. Working towards the utilization of smaller subsets of data which are available in a timely manner have the potential to be useful towards building a quality product. The different data subsets obtained at different time of the growing season are assessed against benchmark estimates to determine which one will produce more accurate estimates.

3.1.3 Content assessment

Further, an initial assessment of the coherence is done for each variable between the administrative data and the statistical concept. For example, any farm operator registered under the AgriInsurance program would provide information similar as the one collected by the survey (type of crop, cultivated area, etc.).

3.1.4 Collection, processing and non-statistical considerations

Next the collection procedure is evaluated, taking into account any processes which may have an impact on the intended use such as the legal authority under which the data are collected and the frequency of collection. Similarly, the data processing (e.g. coding, imputation) by the provider is assessed, paying particular attention to whether the data may have been modified in the course of these various operations.

The subsequent section of the Exploration Phase takes into account other non-statistical considerations associated with using the administrative data. An estimate of the costs from acquisition or from increased processing is balanced against savings in collection costs. Likewise, a review of the human resource requirements associated with using the data is undertaken. In addition, the impact that using the administrative data will have on response burden is assessed.

3.2 Initial acquisition phase

3.2.1 Initial contact for access

Once an identified potential administrative dataset meets the criteria described above, initial contact and discussion on access start with dataset holders. Engaging potential data providers is key at this early stage to develop trust and to illustrate the added value of a data sharing agreement to all parties, and in particular to the farm operators. These contacts are occasions to share information about the goal and the intended uses of the data, the legal requirements and existing safeguards in place to guarantee the confidentiality and protection of the administrative dataset. For example, Statistics Canada has the legal authority to collect and obtain information and its obligation to protect the confidentiality of information is outlined in the *Statistics Act*. Under Section 13 of the Act, Statistics Canada has the authority to obtain any documents or records maintained by a government department, a business or an organization.

The Exploratory phase continues with a formal request for the data (or a subset used as a pilot project) and metadata such as record layout of variables in the administrative dataset in order to identify potential linking keys.

If the evaluation in the Exploration Phase has led to a decision to proceed further with the quality review, acquisition of the administrative data file is required. In this phase, a number of calculations and indicators are produced, mainly with regard to data accuracy.

3.2.2 Unique linking keys

The initial assessment starts with finding unique linking keys between administrative files and the current information existing in the statistical agency census and business register. On any administrative dataset, there are multiple variables used as identifiers (e.g. program, participant name, address…). The development and use of a unique key will expedite the linking of datasets over time.

The need for linking datasets varies depending on the program. Commodity surveys and CEAG data all require precise linkages for potential replacement of variables with administrative data. By comparison, area and yield model estimates produced using remote sensing do not require linkages at the individual operator or farm. The linkage could be done at an aggregated geographical area (representing several fields or plots). AgriInsurance data contains such linking keys, and therefore meets the basic minimum requirement for replacement moving forward.

3.2.3 Coherence

Although a full assessment requires a completion of the linking process, preliminary assessments of the AgriInsurance file indicates a high level of coherence of concepts between the administrative file and the statistical concept of the data to be replaced. All field crop types currently collected on the crop surveys, the CEAG, and in the area and yield model are present in the AgriInsurance dataset. They require little to no aggregation or disaggregation of variables. Data is reported at both the field level and operator level, meeting the specific needs of the Remote Sensing program, and the survey and CEAG programs.

3.2.4 Fitness for use

In terms of fitness for use, Statistics Canada requested the AgriInsurance data to be delivered in a raw format (as capture initially without imputation). This provides the opportunity to identify where potential issues may exist with regard to data quality, and usability. For example, an initial assessment of AgriInsurance datasets resulted in the identification of double counting. This double counting was largely unavoidable due to the manner in which AgriInsurance programs collect data. Awareness of these potential errors allows the RSGA to easily remove cases of duplication.

3.2.5 Accuracy

Accuracy is defined as the degree to which information correctly describes the phenomenon it was designed to measure. The evaluation of accuracy is achieved by looking at potential sources of error, which include coverage error, non-response error and error due to reporting, measurement or processing. Coverage error is assessed through the identification of under-coverage or over-coverage of the target population. Non-response error is evaluated through the amount of missing data for one or more variables relevant to the intended use.

Accuracy could be assessed at the aggregate level (e.g. the total crop area under crop insurance compared with official area estimates).

A comparative analysis between satellite imagery and AgriInsurance data has been done for two provinces for seeded area by type of crop. Where there was a field identified on AgriInsurance, the satellite successfully identified the same type of crop.

The analysis could also be done at the farm level data where reliable linking keys were identified to compare the divergence of information reported to the program data with the survey data. Reporting, measurement and processing errors are identified when the value of a variable in the administrative dataset is different from the survey value; understanding the reasons behind the differences would support adequate decisions during the evaluation. These types of errors are evaluated by identifying items such as invalid, inconsistent or imputed data for relevant variables.

4. Discussion – looking forward

Administrative data is recognized as a key component of the integrated survey framework promoted in the FAO Strategy to Improve Agricultural and Rural Statistics. *Governmental interventions such as subsidies, regulation, and legislation often require agricultural holders to report production information. Land ownership and cadastral surveys provide useful information for constructing registers. Food inspections, animal health inspections, and trade data provide input to the utilization accounts.*

The ASP already uses over 200 administrative datasets in collecting, processing, analyzing and publishing its statistics. These datasets are mostly supplied to Statistics Canada at the aggregated data level. They are extremely valuable as a supplement to data collected from more costly surveys and censuses. While administrative data will not eliminate the need for a CEAG, the investigation found that some administrative sources have the potential to replace part of a future census or to be used in ongoing agricultural surveys.

Recently, Statistics Canada successfully negotiated long-term data sharing agreements with provincial program administrators and national bodies of supply managed industries for. To promote increased use of administrative data and to meet its statistical requirements, Statistics Canada has also continued to support national initiatives, such as that led by the CFIA, which has oversight of the certified organic industry through the Organic Products Regulation of the *Canada Agricultural Products Act*, as well as the national traceability program.

Statistics Canada will continue its efforts to obtain and assess administrative data for the purposes of data confrontation, imputation, and enhancing or replacing some content of the agriculture surveys or for future censuses. Most of the successes in the use of new administrative data were related to the acquisition and integration of crop insurance data with remote sensing data for modelling field crop yield and production estimates. These estimates were used as official statistics in the 2016 field crop survey report.

Looking forward these different initiatives raise questions as to what else could be done to reduce respondent burden and data collection costs. One area that requires more investigation is non-public sources of data. For the first time, the 2016 Canadian CEAG is going to measure how many farm operators use new technologies such auto-steering, precision agriculture, GIS and smart-phone devices. This is an opportunity to assess the potential use of big data often created with these new technologies and to innovate with new data collection tools.

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The role of quality frameworks to improve the quality of statistics based on administrative registers – The case of organic meat production

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ABSTRACT

It is an important and difficult task to make sure that the quality of statistics obtained from administrative sources is sufficient for statistical needs. In recent years several studies have been made investigating quality frameworks for administrative registers. These includes the quality of the register itself, the possibilities of integrating administrative registers into statistical registers and how to document the quality of the statistics produced.

The aim of this paper is to discuss how quality frameworks can be used to improve and declare the quality in the statistics obtained from administrative sources. The frameworks will be discussed in relation to where in the statistical production process it can be included. The usefulness of two frameworks will be compared, i.e. the framework published by Statistics Netherlands (Daas et al. 2009) and the framework published by Laitila et al. 2011.

The paper will end in a discussion on the usefulness of the quality frameworks for administrative registers to improve the quality of the statistics and make suggestions for additional aspects that will have to be taken under consideration.

The case of using administrative registers from the control bodies to produce statistics on the structure of organic farms and on the amount of organic production will be used. The case will show how the quality frameworks can be used to discuss the statistical quality when using administrative slaughtering registers to producing animal production statistics. The case will also show how several registers; the registers from the control bodies, the farm register, the cattle database and the slaughter register, can be merged in order to get the statistics required.

Keywords: Administrative registers, Quality frameworks, Organic

1. Background and aim of the paper

It is a difficult decision whether to conduct a survey or derive statistics from administrative registers. This is especially true for official statistics, which must be a source everybody can trust.

A few years ago the demand for statistics about organic farming grew high. The Swedish Board of Agriculture (SBA) faced different alternatives. One alternative was to continue to publish figures from the three different audit bodies that make sure a farmer meets all of the requirements for organic farming. That alternative, however, would mean many drawbacks would persist. The figures were not comparable with the other agricultural statistics that we publish. The figures were shaky when broken down beyond national level. The advantage was that we already had a system to handle the data.

The second alternative was to conduct a sample survey of organic farms. There were, however, some disadvantages to this choice as well. To send out a questionnaire and to register all of the responses would incur an annual cost. We were also considering the burden for the respondents to fill out the questionnaire. The advantage was that the statistics would be comparable with all of the other agricultural statistics.

The third alternative was to derive the statistics from registers. The disadvantage was that it would take us some time to figure out how to do it. Also, we had to make sure that the administrative registers were of good quality. The advantage was that, once done it could be used year after year with minimal costs. The farmers with organic production would not have to fill out an extra questionnaire, hence the response burden would be zero.

After considering the pros and cons, we started to investigate how to proceed with alternative 3, to derive the statistics from administrative registers. We figured that the best way of producing comparable statistics was to link the statistics with the Farm Register (FR). If we could link the Organic Register (OR) with the FR, we could not only derive statistics for the whole country but also for any other geographical subdivision which might be requested. But we needed a framework to put our registers in.

In recent years several studies have discussed quality frameworks for using administrative registers for statistical purposes. The aim of this paper is to discuss the concepts developed by Daas et al. 2009 and Laitila et al. 2011 for the decision whether to use administrative registers to produce statistics about organic production.

2. The case of the statistics on organic animals

In all we found that we had three different registers to use. The first register is the FR, which contains information about all of the holdings in Sweden. Most notably for this exercise the number of animals of different kinds on the first Thursday in June every year. There is also information about social security numbers (SSN) of the holders and of other persons sending information to different registers at the Swedish Board of Agriculture (SBA). There is also information about the Production Location Number (PLN), i.e. the place where animals are held, the address and the phone numbers to the holding. Every third year we conduct a census updating all of the holdings in the register. Among the things that we update are the unique client id for all clients connected to one of the three control bodies certifying organic farming in Sweden. The FR is regulated by Swedish legislation.

The second register is the slaughter register (SR) that contains information about the number of slaughtered animals and their weight. The register contains information about the SSN of the persons reporting the slaughtering to the slaughterhouses and also from which PLN the slaughtered animals were coming from. The SR is regulated by Swedish legislation.

The third register contains information about holdings with organic production, the Organic Register (OR). This register is a combination of the registers of the three control bodies. The SBA receives these registers and merge them. This register contains information about what kind of organic animals that are raised on the holding. However, the way the animals are counted differs. For some animals it is the average number of animals during the year and for some it is the maximum number of animals during the year. There is information about the SSN, address and phone number of the holder. The holding's client id with their respective control body is also included in the register.

The aim is to combine all of the three abovementioned registers in order to extract the number of organic animals and the amount of organic slaughtering.

2.1 Setting up the frame

The idea for the number of organic animals is that we would match the OR with the FR. If a holding had organic cows in the OR, then all of the cows in the FR would become organic. And if a holding had organic pigs in the OR, then all of the pigs in the FR would become organic. We had to make one exception for poultry, because the different kinds of poultry are so different. If a holding had organic broilers in the OR then the broilers in the FR would become organic, but all of the other types of chickens would not become organic.

One of the big advantages with using the number of animals in the FR is that the data is fully comparable with the other figures from the FR. With the FR we can also determine an exact geographical point where the animals are located.

Some of the difficulties were that one holding in the FR could be two holdings in the OR, so there was not a one-to-one ratio. Some manual work was required to establish a link between the holdings in the OR and the corresponding holding in the FR, as this could not be done automatically. Overall the matching was not much of a problem though.

The idea for the organic slaughtering was the same as the idea for the organic animals, but we also had to include the SR. If a holding had cows that were present in the OR and also had slaughtering of cows, then all of the cows slaughtered would become organic.

Both Laitila et al. and Daas et al. contains suggestions of a system of indicators for quality assessment of administrative data, so that one can get an overview of the registers. On indicator level the concepts of Laitila et al. and Daas et al. are to a large extent overlapping. However, there are some differences in the way indicators are systemized and how quality is assessed. Daas et al. sees three dimensions: the administrative register in itself, metadata about the source and the data in the source. Indicators are developed within each dimension. Laitila et al. discusses indicators in three dimensions: output data quality, input data quality and production process quality. However, they group the indicators related to the work process, i.e. indicators related to information from the administrative authority, indicators related to data editing of the source, indicators related to integrating the source with the statistical register and integrating the survey with similar variables.

The indicators in the hyper-dimensional described in the text are summarized in table 1. The SBA is the supplier of the data sources of the FR and the SR. The supplier of the OR are the three control bodies that supplies one separate register each to the SBA.

Table 1: *Evaluation of registers according to the hyper-dimensions of Daas et al. 2009 and Laitila et al. 2011*

	Farm Register	Slaughter register	Organic register
Evaluation of registers according to Daas et al. 2009			
Source dimensions			
S1. Supplier	+ + + + +	+ + + + +	+ + + +
S2. Relevance	+ + + + +	+ + + +	+ + +
S3. Privacy & security	+ + + + +	+ + + + +	+ + +
S4. Delivery	+ + + + +	+ + + + +	+
S5. Procedures	+ + + + +	+ + + +	+ + + +
Metadata dimensions			
M1. Clarity	+ + + + +	+ + + + +	+ +
M2. Comparability	+ + + + +	+ + + + +	+
M3. Unique keys	+ + +	+ + + +	+ + +
M4. Data treatment	+ + + + +	+ + + + +	+
Information from the administrative authority according to Laitila et al. 2011			
Relevance			
A1. Relevance of the population	+ + + + +	+ + + +	+ + +
A2. Relevance of units	+ + + + +	+ + +	+
A3. Relevant matching keys	+ + + + +	+ + + +	+ + +
A4. Relevance of variables	+ + + + +	+ + +	+ +
A5. Relevance of matching time	+ + + + +	+ + + +	+ +
A6. Study domains	+ + + + +	+ + +	+ +
A7. Comprehensiveness	+ + + + +	+ + + +	+ + + +
A8. Updates, delivery, punctuality	+ + + + +	+ + + + +	+ +
A9. Comparability over time	+ + + +	+ + + +	+ + +
Accuracy			
B1. Primary keys	+ + + +	+ + +	+ +
B2. Quality of reference variables	+ + + +	+ + + +	+ +
B3. Doublets	+ + + +	+ + + +	+ +
B4. Missing values	+ + + + +	+ + + + +	+ +
B5. Wrong values	+ + + +	+ + + + +	+ +
B6. Output of preliminary data	+ + +	+ + + +	+

What we found is that the FR and the SR are of very high quality. The OR, however, does not have the same quality standards. The FR is the base in Swedish agricultural statistics and contains all of the base variables. It is updated yearly.

Regarding the dimension of supplier (S1) the FR and the SR are situated at the SBA. The OR is sent to the SBA from the three control bodies. The knowledge of the OR is OK. Regarding the dimension of relevance (S2), the relevance of the units (A2) and the relevance of the variables (A4), the slaughter statistics is a register where the slaughterhouses report the number of animals that have been slaughtered and their corresponding weight each day. However, the register does not have any information of the animals slaughtered on the farms. The OR stems from the audit bodies that control that a farm meets the requirements of certified organic production. However, the OR contain a few variables of interest to us, namely what kind of animals are certified as organic and information to conduct our matches with other registers.

The privacy and security (S3) for the FR is very good. Nobody outside the statistical department at the SBA has access to the data. It is also protected by Swedish law. As for the SR nobody outside the SBA has access to the data. The situation is somewhat similar for the OR. Addresses might be disclosed but the number of animals will not be disclosed.

Regarding the delivery (S4), procedures (S5) and updates & punctuality (A8), then for the FR and the SR there is not much of a problem, because these registers are situated at the SBA and historically they have always been delivering data in time. There are usually no major errors in the material and if found, they are corrected swiftly. We are of course very familiar with how the data is collected and if we should have any questions they will be answered in a short period of time. The OR, however, usually requires more work. When the registers arrive they must be checked for errors and requests must be sent to the control bodies for them to correct the errors.

For the clarity and comparability (M1, M2) and the relevance of the variables and time (A4, A5), the base variable is holdings in the FR. Linked to these holdings are the number or animals from the FR and the number of slaughtered animals from the SR. The auxiliary variables come from the OR, i.e. what kind of organic animals are on the farm. In the FR the number of animals are counted on the first Thursday in June, but in the OR the number of animals could be either the maximum or the average during the year. Regarding the relevance of time, there should not be any problem, because all of the registers have strict codes regarding when a year begins and ends.

As for the unique keys (M3), primary keys (A1) and doublets (B3), there is some concern for all of the registers, because we know there are doublets in the material for the FR and the OR. For the FR, this is less of a problem in the census years and more so in the years between censuses. Holdings with organic production can choose between one of the three accredited control bodies and sometimes they change control body between the years. Since the registers of the control bodies are not fully up to date, one holding can be present in more than one register. As mentioned before, the holding is the primary unit in the FR, but in the other two registers, holding is not a primary key but instead a person. In some cases, two or more units from the SR or the OR must be put into one holding in the FR.

Data treatments (M4) are conducted on the FR every year before it is being published. There are checks whether the holding is part of the population, checks for extreme values, do all holdings have a holder, and is the data consistent and so on. For the SR, the holdings should report the animals that are being slaughtered. The same information should also be reported by the slaughterhouses. This form of double reporting should indicate that there are very few posts that are faulty. The OR is kind of different, because the audit bodies do not seem to put that much effort into data treatment. There are not many missing values (B4) but there could be substantial amounts of wrong values (B5). This of course, is a burden put on the SBA.

The third hyper-dimension introduced by Daas et al. 2009 is the data dimension that focuses on the quality aspect of the data in the source. Laitila et al. 2011 focus on the indicators of input data and production process quality. Hence Laitila et al. 2011 focus on register level, but Daas et al. 2009 assume that we base our analysis on the overall performance combining all of our registers and in the end receive the statistics. The quality is therefore assessed on the whole approach and not only on the registers themselves (Table 2).

Table 2: *Quality of the data for statistical purposes according to Daas et al. 2009 and Laitila et al. 2011*

Daas et al.	Model of the number of organic animals and organic meat production	Laitila et al.	Model of the number of organic animals and organic meat production
Q1. Technical checks	+ + +	D1. Relevance of variables as such	+ + + +
Q2. Over coverage	+ + + +	D2. Relevance of variables as auxiliary information	+ + + +
Q3. Under coverage	+ + + +	D3. Relevance of variables to improve statistics	+ + + +
Q4. Link ability	+ + + +	D4. Under coverage in administrative registers and in FR	+ + + +
Q5. Unit non-response	+ + + +	D5. Over coverage in administrative registers and in FR	+ + + +
Q6. Item non-response	+ + +	D6. Duplicates in administrative registers	+ + + +
Q7. Measurement	+ + + +	D7. Wrong units in administrative registers and in FR	+ + +
Q8. Processing	+ + + +	D8. Missing values	+ + + +
Q9. Precision	+ + + +	D9. Wrong values or wrong units, cross section data	+ + + +
Q10. Sensitivity	+ + + +	D10. Wrong values or wrong units, longitudinal data	+ + + +

Regarding the technical checks, there are no problems reading the data of the FR and the SR. The OR comes from the three audit bodies and is of worse quality. However, the data is fully readable after some extensive manual labor (Q1).

The variables in the OR are used as auxiliary variables and variables to improve the statistics (D2, D3). From the register we know which holdings are conducting organic farming. Since a holding can be both organic and conventional, we also use the information of what animals are organic. So if a holding is raising organic cattle, then all the cattle on the holding and all of the slaughtered cattle are assumed to be organic. In our model, it has worked out very well and the information has been very useful.

Over coverage in the SR is estimated to be negligible because of the double reporting conducted by the farmer and the slaughter houses. In the OR there could be over coverage if a holder is not removed from the register even though they have ceased producing organically. However, the over coverage is assumed to be very small. Over coverage in the FR is negligible for the years when we conduct a census (Q2, D5). For the years between there can be some over coverage since we do not send out questionnaires to every holding. It must, however, be emphasized that the over coverage is small and will not lead to any big overestimation. For all three registers combined, the over coverage is assumed to be very small.

The under coverage is assumed to be small for all of the registers and the linkability is assumed to be high (Q3, Q4, D4). The newly started holdings almost certainly will apply for subsidies and will therefore be incorporated in the FR. Less than 0.1 % of the animals in the SR are not linked to the FR now. For sheep there has been a few years where we could not link as much as 1 % of the slaughtered animals. In the OR there are usually 1-3 holdings that we cannot link, but those holdings could very well be closed down. There must be some mismatches between the registers, but we do not believe that the number is very high. It is of course hard to give a specific number, but from what we have seen, it is most certainly quite low.

Regarding the unit non-response and the item non-response (Q5, Q6, D8) we have a response rate of about 97 % in the FSS and in the livestock surveys. In the SR the response rate should be very close to 100 % because of the double reporting and in the OR the response rate should also be very close to 100 % because otherwise the farmers will not receive any subsidies or be able to sell the meat as organic. The item non-response, however, is harder to measure since we do not know if a holding has forgotten to fill in the number of sows under the pig section in the FSS or the livestock survey. For the bigger holdings we might find out that information is missing, but for the smaller ones it is very difficult.

The number of organic animals in our model is compared with the number of organic animals reported by the Swedish organization KRAV. The number of organic animals are about the same in both our model and KRAV:s figures (Q7). We also compare the amount of organic meat with other organizations to see if our figures are in line with them. There can of course be some small random errors. The systematic errors are assumed to be small, but we are underestimating the number of slaughtered animals due to the slaughtering on the farms. However, the slaughtering at the farms are close to insignificant.

In the processing (Q8) there are almost no adjustments and imputations made, because we see the FR and the SR as already finalized. Hence, there are no checks for outliers. In the OR there may be occasional adjustments and imputations made. Since we have figures for all of the holdings, there is no standard error in our estimates (Q9). However, when we made a time series from 2009-2013 for the variables involved, we noticed smooth trend lines (D10).

In the process we have made comparisons between the OR and the FR (D1, D9). The data in the two different registers are not totally comparable since the FR measures the number of animals the first Thursday in June every year and the OR measures animals differently. For example, the OR measures the total number of broilers produced during the year. However, in this case we divided the number of broilers with the production time and received a number that we could compare with the FR. Our comparisons turned out well and even though there could be differences, we concluded that the material from the OR was of good quality.

In our model there could be missing values or duplicates in the OR, but we believe that the numbers are small (Q10, D6). The total bias of the totals is assumed to be low.

2.2 What is the result?

After some testing and evaluation, we came to the conclusion that we had a very good model. The figures are in line with other sources and we can easily update the model each year with new figures. The response burden on the farmers is zero, because we use administrative registers and the cost for us is very low since we do not need to make another survey.

3. Discussion

The two frameworks have proven to be an excellent help in deciding the direction of the work with organic meat production. We wanted to use registers to obtain the organic meat production, but we weren't sure of if the registers were good enough. Both of the frameworks are thorough and takes every detail into account. They are also an objective and a standardized way of determining the quality of the registers that you are about to use. They have helped us to really consider what options there are, as well as declaring the quality of statistics obtained from administrative sources.

We found that the FR and the SR were registers of good quality and with the two models by Daas et al. 2009 and Laitila et al. 2011 we could quantify just how good they really are. However, these registers are maintained by the SBA and are thus in our own control. The OR was less good, but sufficient enough to be used in our model. Since the OR is not in our own control, we depend on the three organizations that maintain the register, and as we could see, there were some problems with the register. When we combined all of the registers however, the framework proved to us that our model was of very good quality. We were also able to see where the model could be improved.

The two frameworks are similar. One advantage of the framework of Daas et al. 2009 is the focus on the procedures for accessing data and the legal prerequisites. One advantage of Laitila et al. 2011 is the focus on the production process indicators as a separate step.

It is obvious that the quality frameworks can be used to determine whether to use administrative registers or not. For us the frameworks have proven to be very helpful in our decision-making.

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Coverage issues in agriculture statistics when using administrative data

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ABSTRACT

Resumé: Administrative sources provide huge amount data that could be directly or indirectly introduced in several phases of the statistical process. The use of administrative data for statistical purpose often requires matching records, due to the fact that an administrative source alone is unlikely to be enough to produce high quality results with negligible or admissible errors. One of the first purposes of combining administrative data is to collect a statistical register of the target population or at least a master frame for sampling: in some developed countries, census has been totally substituted by a set of high quality administrative registers. In general, the use of administrative data in official statistics seems a crucial step for modernizing the existing processes. This paper focalises the coverage aspect connected to the use of administrative data in census context, in particular because in this case the perspective is moving from the traditional census under-count issues to the strong relevance of over-count related to the use of administrative sources.

Keywords: Coverage errors, Register and sampling frame, Linkage errors

1. Introduction

Nowadays administrative data represent a great opportunity for agricultural statistics: their use allows to meet the increasing needs of knowledge and information even at local level, by means of already available data, without further collection cost and response burden. Administrative sources provide huge amount data that could be directly or indirectly introduced in several phases of the statistical process in order to improve the overall quality of information. However, the complete and conscious utilization of administrative data for statistical purpose requires to positively answer to questions related to their quality according to the statistical perspective and the effect of their usage on the overall quality of the statistical results.

The use of administrative data for statistical purpose often requires matching records, due to the fact that an administrative source alone is unlikely to be enough to produce high quality results with negligible or admissible errors. One of the first purposes of combining administrative data is to collect a statistical register of the target population or at least a master frame for sampling: in some developed countries, census has been totally substituted by a set of high quality administrative registers. In general, the use of administrative data in official statistics seems a crucial step for modernizing the existing processes. In evaluating the impact of the use of administrative data when building a statistical register (both for substituting traditional census or for preparing a master frame for sampling), with respect to the coverage issues, the perspective is moving towards the strong relevance of over-count of administrative sources. In fact, administrative data essentially ensure a broad coverage of the interest population thanks to several separate sources, even if a little degree of under-coverage for particular population subgroups could still remain. Conversely, over-coverage is expected to be the more substantial problem. Further coverage problems could be generated by the record linkage procedure utilized in order to match all the information related to the same units reported in the different data sources. This could dramatically happen when administrative sources refer to units that are associated only indirectly to the statistical units of interest.

This paper focuses on the effect of administrative source use, with particular attention devoted to over-coverage errors and matching errors. The work reports examples from the 2010 Italian Agricultural Census. In this context the target is to estimate the unknown total amount of farm

2. The coverage issues

Data collection is inevitably subject to error, whatever is the method used to collect it. Therefore, it is necessary to devise a mechanism to assess the quality and reliability of data sources, in order to make robust adjustments and to improve the quality of the resulting estimates. Coverage error in data collection can be classified in two main groups: under-coverage (units which are completely missed by the data collection process but should be included in the population definition) and over-coverage (additional erroneous units which appear in the collected data source but which should not be included in the population). For agricultural census, example of over-coverage might include, together with duplicate records, big kitchen garden erroneously classified as little farm; farm not more operating (death farm) but not cancelled on the list.

In the traditional census, coverage issue is primarily concerned with estimating and adjusting for under-coverage. This is generally achieved through an independent coverage survey (the PES, Post-Enumeration Survey) and a capture-recapture or Dual System model (Wolter, 1986) aiming at estimating those units which have not been enumerated both by the census and the survey. The capture-recapture (CRC in the following) model is subject to some strong assumptions:

1. the interest population is closed;
1. records from both data sources can be matched without errors;

3. units have the same capture probabilities within each sources (homogeneity probability assumption);
4. over-count in both sources is negligible;
5. the two sources of data are independent.

In formula, say N_{11} the units enumerated in both the census and the PES, N_{1+} the units recorded in the census and N_{+1} those captured in the PES, the Dual System estimator (DSE in the following) of the unknown total amount of the population N is:

$$\hat{N}_{DSE} = \frac{N_{1+} \times N_{+1}}{N_{11}} \quad (1)$$

Several extensions and adjustments of the DSE have been proposed over the time in order to avoid biases due to any failure of these assumptions – resulting in the DSE under-estimates or over-estimates of the true total amount of the population. For instances, without being exhaustive, the main methods used to include dependencies between sources and heterogeneity of captures are extensions of log-linear model (Fienberg 1972; Cormack 1989; Chao 2001, Agresti 1994), conditional multinomial logit model (Chen and Kuo 2001; Zwane and van der Heijden 2005), latent class model (Bartolucci and Forcina 2005) and Bayesian capture-recapture model (Ghosh and Norris 2005).

As far as the matching errors is concerned, Ding and Fienberg (1994) propose simple method to achieve “linkage error unbiased” estimates of population total by explicitly modeling the two types of matching errors. Generally, linkage errors are commonly subdivided in two groups: false matches when records referred to different entities are linked, and missing matches when records that really represent the same unit are erroneously left unmatched. False matches directly deflate the population totals, causing under-coverage of the census list, while missing matches directly inflate the population totals, causing over-coverage of the census list.

Recent works take into consideration bias due to the over-coverage of sources, particularly relevant when dealing with administrative data, affected by significant level of list inflation due to different reasons. Meeting the assumption of close population should help to reduce the over-coverage. It is clear that matching errors will determine bias in over-coverage adjustments, with inflation of over-coverage in case of missing matches and deflation of over-coverage in case of false matches. More and more complicated is the case in the farm field, because of farm demography, changing in organization and operational status, difficulties in verifying farm definition for small farms, etc. All these factors directly and dramatically affect the linkage results, with consequence impact on over-coverage assessment.

Large et al. (2011) propose an adjustment to the DSE in order to correct the census totals by the over-coverage components. For household and population census, they consider four types of over-count:

- duplicate returns at the same location (for example, a paper and internet return for the same household)
- duplicate returns from different locations (for example, students at their term-time and parents’ address)
- a return counted in the wrong place (local over-count),
- erroneous returns (units which should not be in the census population such as a baby born just after census day and included on the return).

Therefore, they estimate the correct number of census returns by both local and duplicate over-count and include it in the DSE.

The US Census Bureau carries out a further sample survey (the E sample) in the same areas of the PES in order to estimate erroneous records, that should not have been collected in the census. Due to US level of erroneous enumeration, a dedicated survey is considered in order to determine the correct enumeration, via field work in E sample survey. Therefore, the erroneous records are removed before DSE is calculated. In 2010, the estimation procedure uses logistic regression. These models allow the use of more variables, and therefore produce better estimates of percentage undercount by single demographic characteristics. Three logistic regression models were developed, according to the following dependent variables:

- the probability of being a 'data-defined' enumeration (the data source for estimating the model parameters is all census people in housing units)
- the probability of being a correct enumeration (the data source for estimating the model parameters is the people in the E sample)
- the probability of being matched (the data source for estimating the model parameters is the people in the P sample)

Predictions are then made by inputting the values of the independent variables for each census case into the estimated models. This enables the prediction of correct enumeration rate (with E sample) for census and match rate (with P sample) for census at person level and use these predicted values in the DSE estimation. The approach adopted for the E sample seems the most feasible to view out-of-date or incorrect administrative source records, that could be considered being equivalent to erroneous enumerations in the US census. This means to carry out two separate independent under-coverage and over-coverage surveys, and their records should be matched each other's prior to DSE being calculated.

3. Lesson learned by the 2010 Census of Agriculture in Italy

Coverage issues related to the usage of administrative archives for census purpose have been dramatically experienced in carrying out the PES for the 2010 Italian Agricultural Census. The last Italian agricultural census was register-assisted, that is a preliminary list was provided before the census field operations in order to assist to census mail out. This preliminary list was obtained by matching at unit level several (more then 10) agriculture-related lists: the main ones were agricultural benefit registers, fiscal registers, chambers of commerce registers, cadastral archive, the previous agricultural census list. The goal was to build a list of farms as complete as possible; each record on the list includes name, address, and telephone number of the farm operator plus additional information on the agricultural place, as the address of the farm headquarter and the size in acres of the farm. Most names on a newly acquired list were already on the building frame so those found were set aside and a score of activity status were assigned to each unit. A huge matching work has been done in order to recognize the same farm across the several administrative registers, each of them may report only partial information on the farm size, the farm operator, the land owner or someone involved in the farm operation (for instance a member of the family, a partner, an administrator…); however, with respect to the most ambiguous case, the pre-census list were built admitting some over-coverage. Then, the Census proceeded with field operations on the basis of this preliminary list.

Independently from the census and its preliminary list, to measure the census coverage errors, a PES was designed keeping in mind mainly the under-coverage issue, as usual in the previous census round. However, the linkage step of the PES data highlighted some evidence with respect over-coverage and further record linkage activities were carried out, matching PES data with all the administrative sources which contributed to the pre-census list. This complex linkage procedure allows to identify the main components of under- and over-coverage. The former ones were:

1. “non-response or kitchen garden”, farms included in the census list but hesitated as non-respondent or refusal or not eligible due their size (i.e. kitchen garden) after the census operation;
2. “in pre-census list”, farms that were in the pre-census list, but were classified as not eligible before the Census operations;
3. “in administrative archives”, farms stemmed in one of the original administrative sources but that have been excluded in the pre-census list;
4. “not present in any lists”, PES farms not linked with any units in Census, in pre-census list or in others available archives;

While the forth category represents under-coverage with respect to all the available information, the previous ones explain the under-coverage according to lists as less focused on farms as the number of the category increases.

As far as the over-coverage is concerned, the category “farm with multiple links” was used to represent the over-coverage risk, identifying those farms for which the linkage procedure proposed as correct link more than one unit in the census. Those multiple links (from n units in one file to m units in the other) couldn’t be solved according to any optimization algorithm (as in standard record linkage problems) because they represent actual mutual connections related to the land ownership or the farm operation conducted by several different relatives of the same family, on the same land area, at least on the basis of the available information.

Moreover, the category “farm demography” was introduced to measure the risk of linkage errors. In fact, strictly speaking the “farm demography” should not represent over-coverage, because continuity rules are respected in order to assure that the same unit has been identified. However, for these farms the linkage status is less positively defined, further investigations on different variables with respect to those utilized for the linkage were needed, in order to assess the continuity rules hold in despite of the strong changes in the demographic variables (names, organization, land ownership, land extension). So, according to the linkage point of view, the “farm demography” gives a measure of criticisms in identifying farms connected to the use of the administrative sources.

The previous phenomena can be summarized in the following tables, where figures on their impact are reported.

Table 1: *Percentage of under-coverage factors with respect to the total amount of under-coverage*

Cause of under-coverage	Relative Percentage
1. non response or kitchen garden	19.25
2. in pre-census list	5.52
3. in administrative archives	41.65
4. not present in any lists	33.58

Table 2: *Percentage of over-coverage and linkage errors with respect to the total amount of covered farms*

Over-coverage and linkage errors	Relative percentage on the total amount of covered farms
a. farm demography	5.51
b. farm with multiple links	1.91

Table 1 shows that the hardest component of under-coverage (farms not present in any lists) is just one third of the total amount. Most of the not-covered farms (41%) were remain in the administrative sources used to build the pre-census list, meaning that if the procedures adopted in forming the preliminary list is improved enough, the total census under-coverage will be halved. Conversely, the percentage of farms remained in the pre-census list is small (about 5%), while actual farms but differently assigned in the census list is a most considerable percentage (about 20%) with respect to the overall under-coverage. Finally, table 2 shows that the risk of linkage errors, represented by the "farm demography" that explain the difficulties in linking units connected to the same farms from the several administrative sources containing so different kinds of entities, seems bigger than the risk of over-coverage, explained by the "farm with multiple links".

The Table 2 provides measures of over-coverage and linkage errors manly related to the use of administrative data in preparing census list. These errors should be introduced in the selected estimator for the evaluation of the total amount of the interest population in order to reduce its bias. Nevertheless, as far as the 2011 Italian Agricultural PES is concerned, no adjustments were applied and these measurements were provided mainly to stress their importance in a future scenario where the traditional census would be substituted by a farm register built exploiting the administrative sources. In fact, it is important to underline the PES was not designed in order to measure and correct the over-coverage, but only to evaluate the under-coverage of the census list. Anyway, in the next paragraph, an exercise is proposed in order to evaluate the impact of linkage and over-coverage errors on the standard DSE results.

3.1 Adjusting for over-coverage and linkage errors: an exercise

In order to evaluate the effect of over-coverage, the census counts can be deflated by the estimated number of over-enumerated farms, obtained by means of the over-coverage risk represented by "farm with multiple links" reported in table 2. The approach is similar to those applied in UK and Israeli, with simplifications due to the reasonable assumption of absence of local over-coverage (farms are likely less and less moveable than people). In formula,

$$\hat{N}^{O}_{DSE} = \frac{(N_{1+} - \hat{O}) \times \hat{N}_{+1}}{\hat{N}_{11}} \qquad (2)$$

where the DSE estimator of the population total is corrected by the over-coverage error and the number of over-enumerated farms O, the PES totals and the units enumerated both by census and PES are sample estimates.

On the other hand, the adjustment for linkage errors can be obtained following the Ding and Fienberg (1994) proposal. In this context, the probability of missing a true link (i.e. the false non-matches errors, when records that really represent the same unit are erroneously left unmatched) can be considered negligible and approximated by zero (α=1, according to the Ding and Fienberg notation). Otherwise, the probability of false matches (when records referred to different entities are linked) can be evaluated by the risk of linkage errors represented by the "farm demography" (β=0.0551 in the Ding and Fienberg notation). The resulting "linkage error adjusted" DSE total estimator is:

$$\hat{N}_{DSE}^{L} = \frac{(N_{1+} + \hat{N}_{+1} - \hat{N}_{11})}{\hat{p}_{1+}^{L} + \hat{p}_{+1}^{L} - (1-\beta)\hat{p}_{1+}^{L}\hat{p}_{+1}^{L} - \beta\hat{p}_{1+}^{L}} \quad (3)$$

Moreover, the over-coverage and the linkage errors can be taken both into account, deflating the census totals of the estimated over-enumerated units and re-calculating the $\hat{p}_{1+}^{L}$ and $\hat{p}_{+1}^{L}$ as well. In this way, the following linkage and over-coverage unbiased estimator will be obtained:

$$\hat{N}_{DSE}^{L-O} = \frac{(N_{1+} - \hat{O} + \hat{N}_{+1} - \hat{N}_{11})}{\hat{p}_{1+}^{L-O} + \hat{p}_{+1}^{L-O} - (1-\beta)\hat{p}_{1+}^{L-O}\hat{p}_{+1}^{L-O} - \beta\hat{p}_{1+}^{L-O}} \quad (4).$$

In table 3, the resulting under-coverage ratios corresponding to these different estimators are reported, as well as the percentage relative difference with respect to the standard DSE estimate.

Table 3: *The coverage ratio estimates and percentage relative difference with respect to the standard DSE estimate*

	Under-coverage ratio estimates	Percentage Relative Difference
$\hat{\tau}_{DSE}$	11.70	--
$\hat{\tau}_{DSE}^{O}$	9.98	14.73
$\hat{\tau}_{DSE}^{L}$	11.44	2.21
$\hat{\tau}_{DSE}^{L-O}$	9.60	17.93

The table shows clearly that the adjustments for over-coverage and linkage errors work both in the same direction, decreasing the under-coverage rate. Moreover, even if the linkage errors risk seems bigger than the risk of over-coverage (table 2), their impact on the DSE adjustment is exchanged, the over-coverage adjustment being more effective than the linkage one. Finally, it seems important to remark that in this adjusting estimation exercise the measures of over-coverage and linkage errors were derived both from the PES, that was designed uniquely for evaluating the under-coverage. Due to the relevance of over-coverage issues when dealing with administrative sources, it could be preferable to achieve more reliable measures of this kind of error by means of explicit and specific methodologies, as a dedicated survey (like in US) or detailed analyses on a designed sample for quality assessment.

4. Concluding remarks and future works

This paper focalizes attention on quality issues in using administrative data, mainly stressing under-coverage, over-coverage and imperfect matching errors. Examples are reported, from the Post-Enumeration Survey of the 2010 Italian Agricultural Census. In this context the target is to estimate the unknown total amount of farm. The case is complicated by difficulties in recognizing the farm entity in the several administrative sources exploited for assisting the census, with consequent linkage problems in the resulting pre-census list. Other issues are related to changes and modification in the farm entities, the farm demography, also reflecting in linkage errors when comparing data sources. In the framework of capture-recapture models, generally adopted to evaluate the unknown total amount of a population, these facts represent removals of basic assumptions, i.e. the closeness of the population, the absence of over-coverage and the perfect matching hypotheses. Standard estimators should be adjusted in order to take into account the potential biases introduced when these assumptions do not hold, as already done in case of removal or relaxing the hypotheses of independence of captures and homogeneity of capture probabilities.

The analyses proposed in this paper try to recognize the main components of coverage errors so to identify possible solutions. Generally speaking, when administrative data are exploited for statistical purpose, strategies for minimising over-coverage are adopted, as well as for reducing matching errors. However, even if over-coverage is reduced there will likely be some unknown residual amount which the estimation methodology has to take account for. Moreover, minimising over-coverage risks increasing under-coverage and the robustness of the dual system estimation approach to departures from its assumptions tends to decline as under-coverage increases and this could risk unanticipated errors. It seems possible that the effect of matching errors and over-coverage could be in the same direction, leading to over-estimation of the population, due to the fact that even relatively small errors could lead to non-negligible biases. So further investigation in the estimation methodology is needed in order to adequately take account of these kinds of errors.

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THEMATIC SET

F33

USE OF ADMINISTRATIVE DATA FOR AGRICULTURAL STATISTICS

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ABSTRACT

A large proportion of the data being currently produced in developing countries comes from administrative sources, mainly as a by-product of activities of extension workers and other administrative processes and this situation is likely to stay for a long time because of resource and capacity limitations in many of these countries to conduct proper sample surveys. Also because of the growing need for very low geographical level data and for early warning and pre-harvest crop forecasting data to inform governments on the prospective food situation which is mainly derived from crop monitoring and other auxiliary information produced by field staff. Furthermore, data on livestock, fishery, forestry, land and water is usually derived from administrative reports prepared by subject matter specialists. In developed countries, budget restrictions, respondent burden and availability of new tools and methods are prompting many countries and institutions to undertake research in new ways of producing agricultural statistics with a more important role of administrativesources. However, several studies have underlined the limitations of data from administrative sources in terms of their low quality for a number of technical reasons. This session will present and discuss findings from research undertaken on the improvement and use improvement and of administrative data for a cost effective agricultural statistics system both in developing country and developed country context. Papers can focus on successful research or implementation of methods and tools for use of administrative data in agricultural statistics in a country.

LIST OF PAPERS

Role of administrative registers for agricultural statistics

S. Mnatsakanyan | National Statistical Service of the Republic of Armenia | Yerevan | Republic of Armenia

A. Safyan | National Statistical Service of the Republic of Armenia | Yerevan | Republic of Armenia

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Use of administrative data in agricultural production statistics compiled by Turkish Statistical Institute

F.S. Ozbek | Turkish Statistical Institute | Ankara | Turkey

I. Uzunpinar | Turkish Statistical Institute | Ankara | Turkey

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Using administrative registers for making a sample frame for agricultural statistics - Methodologies, techniques and experiences

A. M. Karlsson | Swedish Board of Agriculture | Jönköping | Sweden

A. Grönvall | Swedish Board of Agriculture | Jönköping | Sweden

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Administrative data and agricultural statistics – What strategy and methods should we adopt?

A. Wallgren | BA Statistiksystem AB | Vintrosa | Sweden

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Role of administrative registers for agricultural statistics

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ABSTRACT

The Government has three main missions: to ensure the internal and external safety of the society, to create necessary prerequisites for sustainable development of every member of the society and to ensure the minimal needs of those members of the society, who can't yet/no more to cover their needs by themselves. Authorities who carry out the realization of state mission are government bodies that have administrative power (ministries, administrations, etc.), local self-government bodies and government bodies that render public services (non-administrative). Tools for administrative influence (for administrative competences) are registration and calculation of rights and liabilities, activity endorsement, permissions, prohibitions and prevention, encouragement and destruction, regulation and control. There are other tools for administrative influence such as checking, correction, inspection, monitoring, discussions of disputes and solutions, enforcement of penalties and restrictions, privileges, reimbursements, and gratuitous assistance, etc. The main principles of forming the administrative registers are definitions of concepts and criteria, classifications (status, type of activity, production, and administrative territorial and other units), coding (common identification codes), individual addressable information (developed as a result of using administrative tools). The administrative registers are individual addressable databases that are used by state and local self-government bodies, and are the basis and effect for administrative influence. The administrative registers are used by bodies that create administrative registers (realization of their individual addressable administrative influence authority), other bodies that possess administrative authority (by identifying it with individual data from other administrative registers), statistical bodies (for providing public statistical services), scientific and educational institutions and individual researchers (for providing scientific and research and educational services).

The peculiarity of use of administrative registers by official statistics is that official statistics, as a provider of statistical information, is entitled to use and modify the information received from administrative registers in order to ensure their compliance and comparability with statistical definitions and classifications. The data that is received in this way cannot be transferred to the primary information holder (administrative register) or transferred to the third party for the purpose of using them for administrative purposes.
Given the fact that for agriculture as a type of economic activity there are specific factors such as measurements regulated by the administrative legislation like the land, machinery, other fixed assets (from the viewpoint of property registration on land, machinery, other fixed assets and relations on their taxation), subsidies to economic units (from the viewpoint of the relevant administrative registrations and monitoring), numbering and movement of the livestock, including diseases control, etc., so the use of administrative registers, as a source of E-based information is actual and urgent.
Use of administrative registers is also stipulated by the fact that agricultural technologies by their character require more detailed regulation and control by administrative bodies, therefore, and more disaggregated registrations that are crucial for complete statistical indicators with the higher degree of aggregation.

Keywords: Administrative bodies, administrative records, definitions, classifications.

1. Introduction

In Armenia, under the centralized planning of the economy, the official statistics was used as consolidated and fragmented information for authorities. Official statistics mainly played the role of administrative information systems for government agencies at all the levels. Such practice took place in the transition period until 1999, when the Eurostat developed and presented the scheme of a model law on statistics based on the UN Fundamental Principles of Official Statistics. Based on that model law the National Statistical Service of the Republic of Armenia (NSSRA) has developed the new law "On State Statistics" that has been adopted by the Armenian Parliament and came into force on 10th May 2000.

2. Formation of administrative registers in transition period

According to the above-mentioned law, the change of the functions of statistics from a "state accountant" to a role of an information supplier for the whole society, economy and authorities is a process that should proceed in parallel in the framework of official statistics and administrative information systems.
However, in conditions of liberal economy an old inertia, which took place in the administrative cycles, hampered the process of formation of administrative registers. The official statistics supplier's legal refusal to draw up administrative information has certainly accelerated the process of formation of administrative information systems in the country. Laws on social cards, population register, securities market and others have been adopted. Amendments have been made to laws regulating the powers of administrative bodies on formation and maintenance of administrative registers both by activity and certain functions. In particular, by functions of state registration (property rights register, entrepreneurship rights, shareholders and others).

Powers for establishing administrative registers have been assigned to the general state agencies. However, this process is not always smooth, even with the methodological support of the NSSRA. The main reason for the complications of the process of formation of national registers is the lack of registers at the level of communities and regions.
In Armenia, with a population of 3 million there are 915 communities, of which 866 are rural, most of which are very small. Because of lack of resources the majority of communities (local self-government bodies) are not able to organize and establish administrative registers. Based on the new edition of the Law "On local self-government" the process to delegate new and necessary powers to communities has started, which has created a basis for their consolidation and implementation of the full administrative registration system. In particular, since 2004, the authority to collect the property tax has been delegated to urban communities, and, since 2005, the process has been extended to rural communities. In 2005, the country's population register has been established and started from the involving of communities.

3. Challenges of formation of administrative registers at the community level in transition countries

Taking into account the above mentioned developments, the NSSRA has developed and tested a model "passports of communities and regions", which are the necessary minimum sets of basic indicators describing the administrative information system of these territorial units. The piloting process has revealed a number of unsolved problems, connected with:

- technical equipment,
- professional training,
- methodological support,
- organizational links with regional and nation-wide registers,
- identification problems on perception other administrative and statistical registers, etc.

According to the description and analysis of the current situation there are the following tasks in transition countries:

- a clear definition of statistical and administrative purposes and character of links between them,
- providing guarantees for non-involvement of official statistics in the conflict of administrative and similar interests,
- a clear legal distinction between statistical and administrative information,
- formation of a complete system of administrative information in the country,
- providing easy use of administrative information for statistical purposes,
- promotion of expanding the scope of the administrative information on the basis of modern information and communication technologies,
- developing methodologies and improving the quality of administrative information,
- developing and improving statistical methodology for the use of administrative records for statistical purposes.

4. General factors of formation of administrative registers in transition countries

There are the following factors that could help to solve the above-mentioned tasks:

- general accounting and statistical culture of the country,
- complexity of the payment and accounting system of the country,
- completeness of reforms in the country's management system,
- level and scale of the use of international standards and classifications in the payment and accounting system of the country,
- universality, accessibility and comparability of the methodology used at national and international levels,
- degree of complexity (simplification) of procedures and tools of state registration, licensing, permits, etc.
- level of self-regulation of local self-government bodies.

In conclusion, it should be emphasized that for countries in transition a starting point to solve the above mentioned problems, from the NSS RA` point of view, is an intensification of stimulating formation of administrative registers at the community level. This process has not just statistical and administrative value, but also political one. Strengthening the accounting capacity of communities will enhance their role as a source of administrative information, thus reducing the possibility of the temptation to use statistical data for administrative purposes that at the same time will improve the quality and integrity of the state administrative registers.
In general, this process will affect on the ability of the interactive character of administrative information, thus highlighting the problem of perception of information flows in both administrative and statistical systems. All this, in a long run will promote to improve the quality of information and to achieve a high level confidence in any information systems, and to form an information society.

5. The Government mission as a basis to form administrative registers

The Government has three main missions: to ensure the internal and external safety of the society, to create necessary prerequisites for sustainable development of every member of the society and to ensure the minimal needs of those members of the society, who can't yet/no more to cover their needs by themselves.
Authorities who carry out the realization of state mission are government bodies that have administrative powers (ministries, administrations, etc.), local self-government bodies and government bodies that render public services (non-administrative).
Tools for administrative influence (for administrative competences) are registration and calculation of rights and liabilities, activity endorsement, permissions, prohibitions and prevention, encouragement and destruction, regulation and control. There are other tools for administrative influence such as checking, correction, inspection, monitoring, discussions of disputes and solutions, enforcement of penalties and restrictions, privileges, reimbursements, and gratuitous assistance, etc.
The main principles of forming administrative registers are definitions of concepts and criteria, classifications (status, type of activity, production, and administrative territorial and other units), coding (common identification codes), individual addressable information (developed as a result of using administrative tools).

6. Main characteristics of administrative registers

The administrative registers are individual addressable databases that are used by state and local self-government bodies, and are the basis and effect for administrative influence.
The administrative registers are used by bodies that create administrative registers (realization of their individual addressable administrative influence authority), other bodies that possess administrative authority (by identifying it with individual data from other administrative registers), statistical bodies (for providing public statistical services), scientific and educational institutions and individual researchers (for providing scientific and research and educational services).

7. Peculiarity of using administrative registers for agricultural statistics

The peculiarity of using administrative registers by official statistics is that official statistics, as a provider of statistical information, is entitled to use and modify information received from administrative registers in order to ensure their compliance and comparability with statistical definitions and classifications. The data that is received in this way cannot be transferred to the primary information holder (administrative register) or transferred to the third party for the purpose of using them for administrative purposes.
Given the fact that for agriculture as a type of economic activity there are specific factors such as measurements regulated by the administrative legislation like the land, machinery, other fixed assets (from the viewpoint of property registration on land, machinery, other fixed assets and relations on their taxation), subsidies to economic units (from the viewpoint of the relevant administrative registrations and monitoring), numbering and movement of the livestock, including diseases control, etc., so the use of administrative registers, as a source of E-based information is actual and urgent.
Use of administrative registers is also stipulated by the fact that agricultural technologies by their character require more detailed regulation and control by administrative bodies, therefore, and more disaggregated registrations that are crucial for complete statistical indicators with the higher degree of aggregation.
According to the RA Law "On State Statistics" and based on the results of agricultural census conducted for the first time in Armenia in 2014 and usage of relevant administrative registers, the NSSRA will establish a statistical farm register for statistical purposes that could be used as a frame for sample surveys, as well as to complete survey data, and could be linked with state administrative systems, particularly land balance, livestock and machinery registers.
The NSS RA actively cooperates and has close partnership relations with administrative data providers to assure the data quality. According to the RA Law "On State Statistics" the NSS RA effectively coordinates administrative statistics. The NSS RA has concluded the Agreements with owners of administrative data on the access to and use of administrative data for statistical purposes. The NSS RA provides methodological support, including training materials to ministries and other public authorities to properly manage their administrative registers.

8. Conclusion

In countries in the course of management reforms, the capacities of administrative registers in the field of administrative records should be strengthened, including technical capacity and training, as well as interrelations among them and with the NSOs should be enhanced to use common identification codes, definitions and classifications.

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Use of Administrative Data in Agricultural Production Statistics Compiled By Turkish Statistical Institute

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ABSTRACT

Agricultural production data have been mainly compiled by Turkish Statistical Institute (TurkStat) through regional offices of Ministry of Food, Agriculture and Livestock (MFAL) in district detail. Many administrative sources are used in data collection for crop and animal production statistics by the agricultural engineers, veterinarians, and technicians in the province and district offices of MFAL. Current study presents information about the administrative data, and the statistical data network used for data compilation, the scope of the administrative data, and the data analyze methods used in producing agricultural statistics compiled by TurkStat.

Keywords: Administrative data, Agricultural production, Statistics, Turkish Statistical Institute

1. Introduction

It is needed to produce reliable and timely agricultural production statistics in order to monitor the developments of agricultural production sector, and to develop agricultural policies. In Turkish Statistical Institute (TurkStat), there are two kinds of data source used in agricultural production statistics (i) administrative data (e.g. yearly crop and animal production statistics) and (ii) vey data (e.g. monthly poultry statistics, milk and milk products statistics).

'Administrative data' is defined as the set of units and data derived from an administrative source (OECD, 2002). And, it is collected for administrative purposes by administrative sources, and not primarily intended for research or statistical purposes (Smith et al., 2004, ADLS, 2016). The administrative data has intensely used, and has ensured important advantages in producing agricultural statistics in Turkey.

Many data on animal production, crop production, production under protective cover area, organic farming, pesticides use, and fertilizer use are based on administrative records and agricultural technician's regional observations through Province and District Offices of the Ministry of Food, Agriculture and Livestock (MFAL) in Turkey.

[1] The opinions and contents of the article remains the responsibility of the author, not of the Turkish Statistical Institute.

Current study presents information about the administrative data, and the statistical data network (SDN) used for data compilation, the scope of the administrative data, and the data analyze methods used in producing agricultural statistics.

2. Scope and Method

Agricultural production data have been mainly compiled by TurkStat through regional offices of MFAL in district detail. Many administrative sources are used in data collection for crop and animal production statistics by the agricultural engineers, veterinarians, and technicians in the province and district offices of MFAL. These sources are Farm Registration System (FRS), Turkish Veterinary Information System (TURKVET), National Milk Recording System, National Red Meat Recording System, Agricultural Information System, Land Parcel Identification System, Greenhouse Registration System, Organic Farming Information System, Agricultural Fertilizer Register System, Agricultural Pesticides Register System, Ornamental Plants Register System, Sea Products Information System, Apiculture Registration System, Sheep and Goat Registration System, National Sheep and Goat Information System, Pedigree and Pre-pedigree Registration System.

FRS and TURKVET are the most comprehensive administrative sources in MFAL. FRS is an agricultural database, which the farms are registered by MFAL. The farmers should present requested documents to register to the system. The government promotes the farmers to register to the system (e.g. subsidies, grain purchases etc.)

TURKVET is a database based on the ear tags of animals. The system is formed by MFAL regional offices, and ensures to monitor the animals from birth to death.

Animal production statistics compiled by TurkStat consist of data on number of bovine animals, sheep and goats, poultry, meat, egg, milk, wool, hair and mohair production, apiculture, and sericulture. These data except for sericulture have been compiled via SDN system through regional offices of MFAL in district detail. Data on sericulture is compiled from Bursa Silk Cocoon Association of Agriculture Sales Cooperatives.

The data on crop production (sown area, harvested area, production, yield, number of fruit trees, fallow land), production under protective cover area have been compiled via SDN system through regional offices of MFAL in district detail same as in animal production. Moreover, organic farming and fertilizer use data have been compiled from MFAL through Organic Farming Information System and Fertilizer Sales data, respectively. Sugar beets production data has been compiled from Turkish Sugar Authority, tobacco production data has been compiled from Tobacco and Alcohol Market Regulatory Authority, and poppy (capsule and seed) data has been compiled from Turkish Grain Board (TurkStat, 2015).

Agricultural production statistics by theme compiled by TurkStat and administrative data used are presented in Table 1.

Table 1. *Agricultural production statistics by theme compiled by TurkStat, and administrative data used*

Agricultural production statistics by theme	**Data source**	**Administrative data used**
Agricultural Land and Forest Area	Ministry of Food, Agriculture and Livestock (MFAL)	• Farm Registration System • Agricultural Information System • Land Parcel Identification System
Production and Area of Crop Products	MFAL, Turkish Sugar Authority, Tobacco and Alcohol Market Regulatory Authority	• Farm Registration System
Crop Products Balance Sheets	Various	• Farm Registration System • Turkish Feed Manufacturers' Association Registers • Agricultural Cooperatives' Registers
Production for Land Under Protective Cover	MFAL	• Greenhouse Registration System
Organic Agriculture Statistics	MFAL	• Organic Farming Information System
Ornamental Plants	MFAL	• Farm Registration System • Ornamental Plants Register System
Agricultural Fertilizer Statistics	MFAL	• Agricultural Fertilizer Register System
Agricultural Pesticide Statistics	MFAL	• Agricultural Pesticides Register System
Number of Animals by Type	MFAL	• Turkish Veterinary Information System (TURKVET) • National Sheep and Goat Information System • Pedigree and Pre-pedigree Registration System.
Monthly Production of Milk and Milk Products	Survey	-
Number of Hen Eggs	Survey	-
Number of Animals Slaughtered and Production Quantity of Red & Poultry Meat	Survey	-
Animal Products (other)	MFAL	• Turkish Veterinary Information System (TURKVET) • National Milk Recording System • National Red Meat Recording System • Apiculture Registration System
Apiculture		• Apiculture Registration System
Sericulture	Bursa Silk Cocoon Association of Agriculture Sales Cooperatives	• Bursa Silk Cocoon Association of Agriculture Sales Cooperatives' Registers
Sea Products	Survey	• Sea Products Information System
Inland Water Products	MFAL	• Sea Products Information System
Aquaculture	MFAL	• Sea Products Information System

SDN is a data entry system, where the data are entered by the agricultural engineers, veterinarians, and technicians in the province and district offices of MFAL via electronic media. The MFAL technical personals use above-mentioned administrative records of MFAL in data entry.

In analysis of data in SDN, firstly the data provided by MFAL regional offices have been controlled by MFAL Central Office. And then TurkStat analyzed the data by using change ratios, consistency analysis, confidence intervals, and outlier detection. Then, TurkStat forms the list of suspected data, and re-sends to the MFAL in order to control suspected data (Fig. 1). After the data analyze process, the statistics have been published via Press Releases and statistical tables through web media.

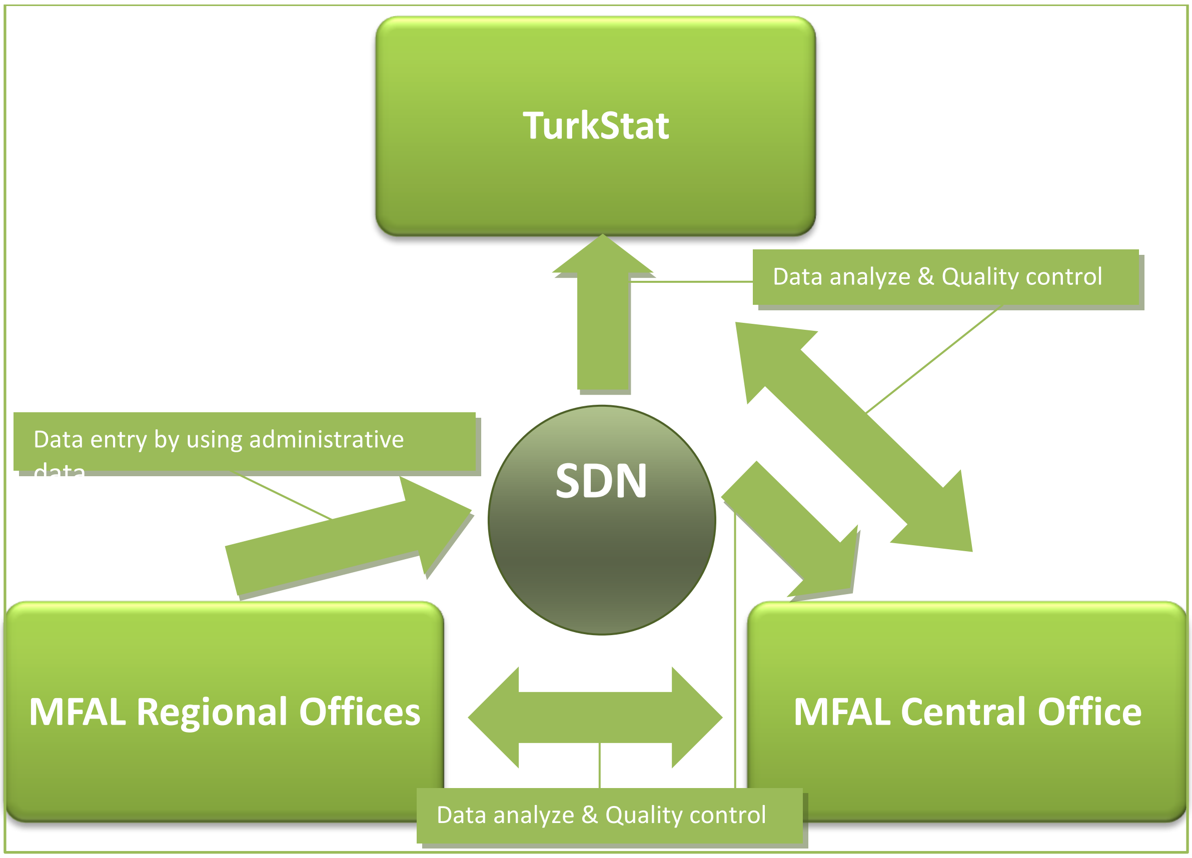

Figure 1. *Data flow in Statistical Data Network (SDN)*

TurkStat: Turkish Statistical Institute; MFAL: Ministry of Food, Agriculture and Livestock; SDN: Statistical Data Network

3. Conclusion

When the high number of farms in Turkey, about 2,2 million (MFAL, 2014), is considered, administrative data has an important role in agricultural production statistics. The use of administrative data ensures following advantages in producing statistics: simplicity, speed and frequency of updating; lower costs; wider coverage, completeness and disaggregation; and low-response burden (ADB, 2010). Administrative data has widely used in agricultural production statistics in Turkish Agricultural Statistics System because of these advantages. However, there are some disadvantages of using administrative data. Smith et al. (2004) summarized the disadvantages of administrative data as follows;

- Information collected is restricted to data required for administrative purposes
- Lack of researcher control over content
- Proxy indicators sometimes have to be used
- May lack contextual/background information
- Changes to administrative procedures could change definitions and make comparison over time problematic
- Missing or erroneous data
- Quality issues with variables less important to the administrator e.g. address details may well not be updated
- Metadata issues (may be lacking or of poor quality)
- Data protection issues
- Access for researchers is dependent on support of data providers
- Underdeveloped theory and methods

There are some of above-mentioned disadvantages in administrative data used in Turkish Agricultural Statistics System. Particularly, missing use of classification and of national address codes in the administrative registers, and lack of coverage in the administrative register systems. Development of these issues in administrative data is important to increase the quality of agricultural statistics. For the development of agricultural registers in Turkey, some additional works have been started since 2014 in the scope of establishing Agricultural Production Register System (APRS). In APRS, which uses quantified agricultural land parcel information, the main variables (agricultural production, land use, animal production, agricultural equipment etc.) of agricultural holdings have been obtained for the production year, and it is planned to revise the system annually (MFAL, 2016).

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USING ADMINISTRATIVE REGISTERS FOR MAKING A SAMPLE FRAME FOR AGRICULTURAL STATISTICS - METHODOLOGIES, TECHNIQUES AND EXPERIENCES

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ABSTRACT

Swedish official statistics in the agricultural area has since 1995 been based upon the extensive use of administrative data. However, in most cases it is not advisable to produce statistics direct from administrative registers. This paper reviews the methodologies and techniques used in order to ensure sufficient statistical quality when using administrative sources together with the Farm Structure Survey for the creation of the statistical farm register. The Farm register (FR) is used as a sampling frame for all agricultural statistics based on holdings.

In the paper we will show how the frame can be updated regarding the holdings constituting the frame as well as regarding the characteristics for example area of different crops, rented land and number of animals needed to stratify samples. The results show that integrating administrative registers with surveys is a cost-effective way of updating the frame while reducing the burden on respondents. Various aspects of the quality dimensions “accuracy”, “comparability” and “coherence” are the key issues for development in order to improve the quality when integrating registers and surveys. However if extensive, systematic work is integrating registers and surveys, the quality in these dimensions can be high. It is shown that there is at least as much need for work with improving quality, methodological studies and quality assurance for statistics based on administrative registers as for statistics based on sample surveys. When using administrative registers, the integration phase where data from several sources are integrated into a new statistical register is central for improving quality.

Keywords: register-based statistics, administrative registers,

1. Background and aim

At least from 1965 and onwards agricultural statistics in Sweden has been dependent on an updated Farm register (FR). The FR consists of all agricultural holdings in Sweden as well as variables needed for creating a typology consisting of type of farm, size of farm and region. The variables include different kinds of animals and crops, rented land and some general information about type of holding and the holder. The typology is used to stratify effectively and thus minimise the sample in almost all agricultural sample surveys. Up until 1996 the FR was updated by a yearly census where farmers were asked about all crops and animals.

When Sweden joined the EU in 1995 administrative registers of all farms applying for EU-subsidies where made available for statistical purposes. Subsequently several studies were made to see how the registers best could be used for agricultural statistics. Selander et al. (1998) and Wallgren & Wallgren (1999) for example compared IACS (the register for area-based subsidies) from 1996 with the objects in the FR from 1995. The results showed that 88 per cent of the objects matched, 4.9 per cent of the objects had multiple links between the registers and 6.9 per cent could not be found in IACS. Of the objects in the IACS register on the other hand, 2.9 per cent could not be found in the FR. As a result of the studies work the following years were focused on integrating the registers and FR. Several questionnaires were sent to subgroups of farmers asking them about keys in IACS.

In recent years Dias et al. (2016) has shown, with the example of Portugal, how alternative methodologies to a traditional population-census could be evaluated. They conclude that since there are advantages and disadvantages to all methods, it is important to make a systematic evaluation so that the trade-offs between options could be taken into account in the decision making process. It is stressed that registers might not have all the content needed; instead the registers may need to be combined with traditional surveys. The findings in the studies of Wallgren & Wallgren (1999) also showed that it is not possible to produce the FR directly from administrative registers. However they showed that administrative registers could be used for updating the objects in the FR as well as give information on some variables, for example crops.

As a result, starting in the year 2000 the FR was no longer updated with an annual full census, instead it was updated with an integrated use of registers and surveys in the years for which EU require the member states to conduct a Farm structure survey (FSS) according to regulation (EC) 1166/2008. In the years in-between, the FR is updated mainly from registers, together with information from a sample survey on animals. In recent years additional registers have been used, for example administrative registers on cattle, sheep, poultry and pigs.

When using an administrative register there is at least as much need for methodological studies and quality assurance as for statistics based on statistical surveys. However, the quality deficiencies and the approaches to investigate and resolve them differ. Several studies, for example Wahlgren & Wahlgren (2014), Laitila et al. (2011), Daas et al. (2009, 2010) and Agafitei et al. (2015) have discussed quality frameworks for using administrative registers for statistical purposes. This includes the quality of the register itself, the possibilities of integrating administrative registers into statistical registers and how to document the quality of the statistics produced. There is also a discussion about which part of the process to focus on. Holmberg (2015) summarises that there is an ongoing theoretical development on how to assess the quality of administrative data, but that more work is needed for example regarding linkage errors and cowerage errors.

The framework by Daas et al. (2010) is recommended by EU (2016) for assessing the quality of administrative registers. In 2016 the framework was used for evaluating registers for FSS 2016 (SJV, 2016)

1.1 Aim of the paper

This paper will describe how the FR in Sweden is updated using administrative registers in combination with some census data. The quality achieved by using the administrative registers in combination with a statistical survey will be compared to what quality could be achieved by updating FR using only a census and using only administrative registers. The framework recommended by Eurostat (2016) presented by Daas et al. (2010) will be used to highlight the quality in the administrative registers.

The quality will be described according to the quality criterias stipulated in regulation (EC) No 223/2009 on European statistics. Furthermore aspects of cost-effectiveness, privacy and response burden will be addressed.

2. Updating the Farm register (FR)

Figure 1 shows that the overall method for creating the FR is to make a maximal sampling frame (2) with combining the objects in the FR from the latest FSS year (1a) by all new possible objects that can be found in registers (1b). Next a questionnaire is sent out to the maximal sampling frame (3), and a current FR is made (5) by combining the information in the maximal sampling frame with information from the questionnaire (4). In the end the variables needed for the typology are added.

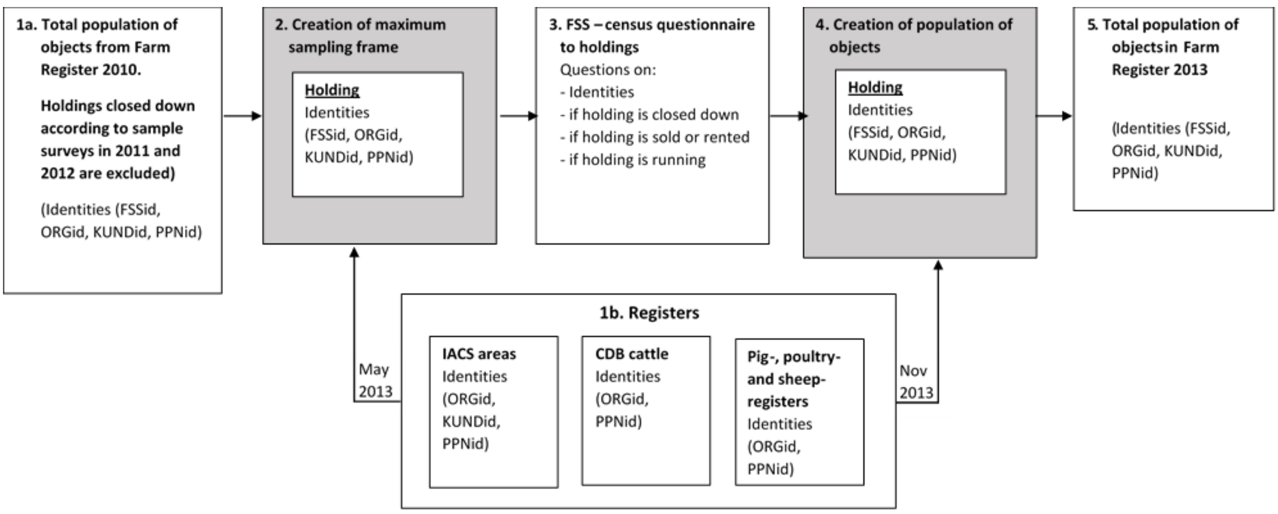

Figure 1: *Creation of the Farm register 2013.*

The target population of the farm register is the same as the target population of FSS. The variables of animals and crops in FR are also defined in the same way as the variables for animals and crops in FSS. I.e. producing the FR means doing a large part of the work needed for FSS.

2.1 Creating the maximal sampling frame

In the beginning of 2013 the total population was taken from the 2010 Farm Register. The indicators related to the source as described in the hyper-dimensions of (Daas et al., 2010) are used to describe the quality of the registers. The Swedish Board of Agriculture is the supplier of the data sources for all registers except the Business register (BR), where the supplier is Statistics Sweden. The Board is also the responsible NSO for agricultural statistics, so privacy and security rules are in place. Historically the registers have always been delivered in time. All persons and organisations in the registers as well as in the FR have a unique organisational number (ORGid). The ORGid is therefore always a linkable auxiliary key between registers.

The IACS register is highly relevant. It consists of all holdings applying for area based subsidies in May each year. In IACS about 60 codes for crops are included. It has unique keys (KUNDid) and the linkability is high. It has clear definitions and the information is well checked. However there is an under-coverage since about 10 per cent of the holdings do not apply for or are eligible for area based subsidies. Following the definition in FR a holding might contain several KUNDid. IACS could be used both for updating the register and for a large proportion of the variables.

The registers for poultry, pigs and sheep as well as the cattle database are aimed at tracing animals in case of an outbreak of a contagious animal's disease. Each production-place with these animals have a unique key (PPNid). The production-place is related to a person or legal entity with an organisational number (ORGid). One holding can relate to several production-places. The information in the registers differs. The poultry-and pig- registers mainly holds information on the number of animals that could be held at the production-place.

In the sheep-register additional information on the number of sheep in December are added by a questionnaire. There is a unit non-response of about 24 per cent. This register also has an over-coverage of about 20 per cent. It can be assumed that the over-coverage of the poultry- and pig-registers is the same. The under-coverage is small since the PPNid needs to be reported when animals are slaughtered. These registers could be used to update the objects in the maximal sampling frame but the quality is not sufficient for the variable values.

In the cattle-database each head of cattle has an identifier that is related to a production place (PPNid). There is, however, no distinction in the register between dairy-cows and cows for meat-production. Information from a second auxiliary register of milk deliveries is used to obtain the required information. It is assumed that if the holding delivers milk in the month of the reference day, the cows on the holding are all dairy cows. This approach will result in a small over-estimation of dairy cows and subsequently an underestimation of cows for meat-production. However a sample survey conducted in 2002 showed that the error was less than 1 per cent. The cattle database is therefore used both for updating the objects and for the variables needed for cattle.

The use of registers means that the postal questionnaire sent to the farmers did not have to include questions on crops and cattle since this information is available from registers. Only questions on the number of horses, poultry, pigs-, and sheep were included. Since there could be multiple to multiple objects in the different registers, the order of merging is decided by specific rules. Each holding in FSS has a set of related keys (for example Orgid and KUNDid). The keys are ordered by their quality. If there are multiple possibilities of linking, the key ordered the highest i.e. with the best quality is used first.

The linkages made in the spring 2013 showed that 64 036 objects could be linked to the registers while 11 689 holdings in the FR 2010 could not be found in registers. 3 004 of them had not been found in registers 2010 either and 8 685 are holdings that existed in registers 2010 but not 2013. Information from sample surveys done in 2011 and 2012 indicate that 800 holdings had closed down during the period. 868 additional holdings were found in the cattle register, IACS or the pig-, poultry-, and sheep registers. 934 horticultural enterprises in the business register were added to find horticultural holdings that might fit into the frame. In the end the maximal sampling frame amounted to 77 527 holdings. By creating the sampling frame this way there will be an over-coverage in the frame. The under-coverage is assumed to be small as long as the holdings were present in 2010.

When the questionnaire was created it included questions regarding what keys (ORGid, KUNDid, PPNid) that were related to the holding and whether it was sold, rented out, closed down or still running. If the holding was sold or rented out it was asked who was now running the farm. It is assumed that most of the 8 685 holdings that could no longer be found in the registers are no longer farmers, but some of them are likely to be the same as the 868 holdings that were found in registers but not in the register from 2010. This together with the linkage process could mean that the same holding might get more than one questionnaire. Whether this has occurred is therefore a question in the questionnaire. The questionnaire also includes questions on animals and rented land, variables that could not be found in the registers. The variables grazing land and arable land are included as a reference to the area of rented land.

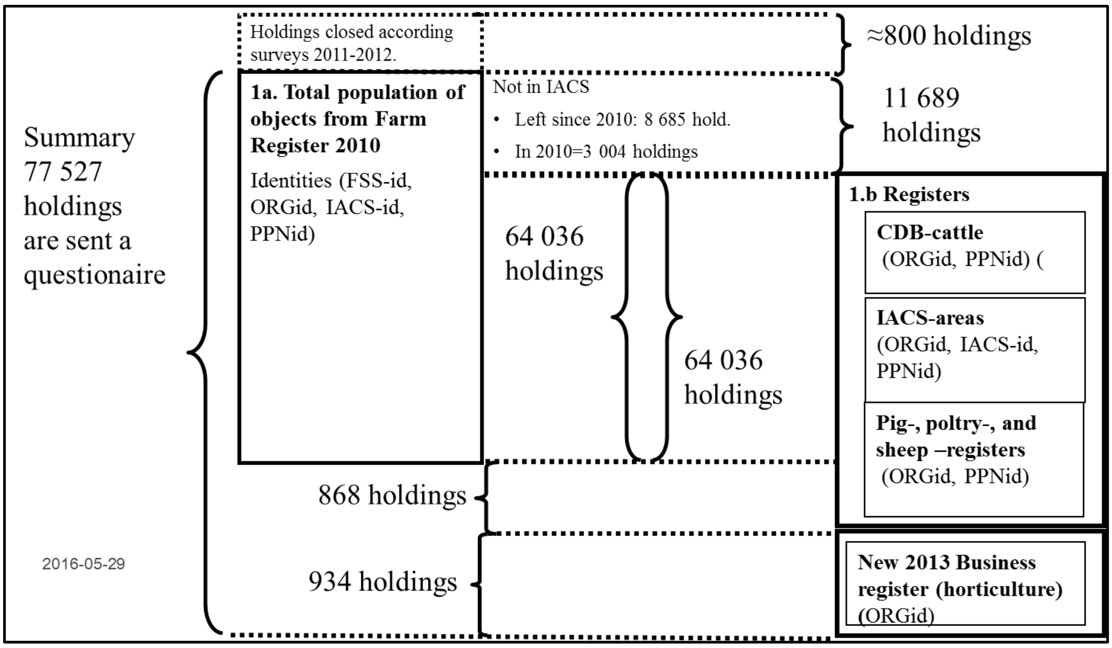

Figure 2. *Creation of the maximal sampling frame.*

2.2 Results from 2013

In November when the answers from the questionnaire were processed, updated data was gathered from the registers and related to the reference time. The information from the questionnaire and the registers was matched and the population of objects for 2013 was created. In the questionnaire the set of keys and the quality of the keys related to the holding were updated. The linkage was then made using the same principles as when creating the sampling frame. The linkage resulted in 67 126 holdings in the FR for 2013.

613 duplicates were found. The duplicates were mostly holdings in FR 2010 that were not found in registers included in the group “left since 2010”. The duplicates were due to linkage errors.

The holdings in the group “left since 2010” were mainly growing crops. Out of the 8 684 holdings 3 125 had been closed down and 3 626 had been taken over by another holder. I.e. only 16 per cent were still farmers so there is a large over-coverage in this group. Out of the 3 004 holdings in the group “In 2010” 989 holdings had closed down and 541 had sold the farm to someone else. I.e. 58 per cent were still running the holding. It could be concluded that those holdings that for several years are running their business without applying for subsidies continue to do so.

The results regarding the horticultural register showed that 30 per cent were still running their holdings. 574 holdings had closed down and 77 had sold it to someone else. For the holdings in this group it is more common to close down the business than letting someone else continue it. Out of the holdings in the pig-, poultry-, and sheep groups about half were still running their holdings and out of the large group that matched with IACS 98 per cent were still running their holding.

When the population was created, the variables were connected to the objects using the established links of keys. The information on areas and crops given in IACS as well as information about cattle given in the cattle register are considered to have high quality since the information is subject to extensive controls. For example, the holding is requested to give information about the total area of arable land in hectares as well as the total area of rented arable land in hectares. If the total area of arable land differs from the summarised areas of arable land used for different crops in IACS, the IACS figure will be used. As a result, the answers in the questionnaire were only used to calculate the share of rented arable land at the holding. The divergent answers could also be a sign that the creation of objects had not been fully successful. Consequently the information was used to improve the creation of objects.

3. Comparing quality between registers, census and multiple source

Every 10:th year a full census needs to be made meeting the target-population of FSS according to regulation (EC) 1166/2008. The census includes the variables in the FR. The alternatives which are interesting to compare are different methods for updating the FR in the two times during the 10 year period when the FSS is stipulated to be made as a sample survey. The three alternatives compared are a:

1. combination of census and registers i.e. the current method described in section 2,
2. register based approach, using registers in combination with the FSS-sample survey,
3. full census based method using a census and not any of the registers available.

3.1 Cost-effectiveness, privacy and response burden

Privacy and the principle that information given for statistical purposes should not be used for administrative purposes are fundamental when producing statistics (Eurostat 2016). On the other hand, administrative registers may be used for producing statistics. In Sweden, the Official Statistics Act (2001:99) addresses data disclosure and the Secrecy Act (1980:100) addresses the confidentiality of individual information. In the case of the FR, individual data from administrative registers are protected by the Secrecy Act (1980:100) when used for statistical purposes, regardless of whether the data would be public or not from the body responsible for the administrative register.

Using administrative registers is also a way of reducing the burden on respondents. At our user-meetings the Union of Swedish Farmers states that it is favourable to share information between governmental bodies in order to make it possible for farmers to only provide the same information once. The hours spent filling out the present set of questionnaires are calculated to 5 800 hours. If no administrative registers where used the questionnaire would also need to have information on all animals and all crops and the total number of hours spent could be calculated to 9 600 hours. If only administrative registers were used the time would be 0. However compared both to the current method used and the full census the quality of the register would be lower. The samples for surveys in the years 2014-2020 would need to be larger. We have calculated those extra hours to 9 500 hours. This includes larger samples for the sample surveys of crops, rented land, fertilisers and the census 2020. Over the 10 year period the difference between register-based statistics and the current method regarding response-burden is low.

The total cost for the current method used in 2013 was 750 000 euro. The cost for a full census through postal questionnaires could be estimated to 1 100 000 euro and for producing the statistics solely from registers to 450 000 euro. However there would be an additional cost for the larger samples in the years 2014-2020. Producing statistics from administrative registers is cost-effective in relation to postal questionnaires. From a cost-effectiveness point of view it can be seen that a large proportion of the cost is due to handling paper questionnaires. In 2013 only 20 per cent answered using the web service. I.e. the most obvious way of saving money would be to persuade farmers to answer through the web.

3.2. Quality criteria

Relevance refers to the degree to which statistics meet current and potential needs of the users. The updated FR is harmonised with the target population and some of the variables in FSS. I.e. the needs from EU-legislations are met. The FR also can be used to disseminate statistics for small regions or groups as well as combining data in new ways without restrictions. It could be assumed that a full census would meet the same quality criteria. If the FR were updated only by registers it would still fulfil the needs from EU-legislation regarding FSS. However since animals would be sampled it could only be used for producing statistics on NUTS3 sometimes NUTS2 level.

Accuracy refers to the closeness of estimates to the unknown true values. For register-based surveys, key issues are integration errors as well as how well the definition of objects and variables in the registers correspond with the required definitions in the statistics. The problems of matching different sources should not be underestimated. There is a risk for over-coverage in the FR. Parts of the same holding or the same areas could be counted several times. It is possible that a landowner, who is no longer cultivating his land and who belongs to the 8 685 holdings that could not be found in the register, answers the questionnaire on the basis of the land that he owns without cultivation. At the same time, the tenant of the same land who has applied for subsidies also states that he uses the land. Using only a census would lead to an under-coverage of the FR since the holdings not applying for subsides might be lost and new holdings more difficult to find. Using only registers for creating objects might also lead to an under-coverage since holdings not in the subsidy systems would be excluded.

For *timeliness* i.e. the period between the availability of the information and the event or phenomenon it describes there are no differences between approaches. Wallgren & Wallgren (2014) stress that timeliness is often a problem when using administrative registers. However in the case of IACS and the cattle-database this is not a problem. IACS data are available in May the reference year and the cattle-database is updated constantly.

Punctuality which means if release dates are kept, *accessibility and clarity* that has to do with the user's possibilities to access and compare data and *coherence* i.e. if the information is put together and presented in a logical way present no differences between alternatives.

Concerning *comparability*, or the possibility to compare results over time, problems might occur. Statistics based on administrative registers are dependent on changes that the statistical bodies may not be able to predict. For example, the change in the CAP in 2005 meant that the holders applying for subsidies in 2005 would be eligible for subsidies in subsequent years. The changes in the CAP affected the statistics in several ways, for example the number of holdings increased. Two explanations to this increase could be found. Firstly it was thought that small farms that had not been eligible for subsidies now applied for subsidies and were consequently incorporated into the population of holdings. The change in administrative rules thus improved the quality of the FR, correcting a previous under-coverage. Secondly, it could be assumed that some landowners applied for subsidies although the land in practice was cultivated by a neighbouring holder, leading therefore to over-coverage in comparison with the definitions in the FR. This problem would be the same for the register based approach but would not occur for the alternative based on full census.

The quality in terms of comparing results from registers and surveys are high because of the wide-ranging work done to merge different registers. In this sense the quality would be lower in the two other alternatives.

1. Conclusion

To conclude the use of registers is cost-effective and reduces the response burden for the holdings. Regarding the quality criteria of relevance, there are advantages to integrating registers with surveys and censuses when collecting data for the FSS. On one hand, in solely register-based surveys, the register may not cover the requested variables. On the other hand, in solely statistical surveys, the questionnaire would be expensive and cause a high response burden. Regarding the dimension of timeliness, the registers used for the FSS are updated and available earlier than results from a survey or census would be. When comparing the accuracy of the results, there are several aspects to consider. However, integrating registers and surveys as well as only using a statistical survey is considered to give accurate results. The coherence and comparability is assumed to be the highest when registers and surveys are integrated because of the wide-ranging work done to merge different registers. The availability is good in all three alternatives.

The paper shows that different aspects of accuracy are the key issues to consider in order to improve the quality when integrating registers and surveys in the FSS.

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Administrative Data and Agricultural Statistics – What Strategy and Methods should we adopt?

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ABSTRACT

Agricultural surveys traditionally consist of censuses and sample surveys. The *sample surveys* commonly use stratified cluster sampling or stratified multiple-stage cluster sampling designs to select sampling units as farms or households from an area frame. The Farm Census is often based on a frame that is based on the agricultural households in the Population and Housing Census.

Many countries have started to use administrative registers with microdata to produce social, economic and agricultural statistics. The countries in northern Europe started the transition from a traditional, area frame-based statistical system into a completely register-based system in the 1960s. Since 1997 Eurostat has been in favor of the member countries' increasing use of administrative registers for statistical purposes.

In a register-based system, all sample surveys are based on frames that have been created with statistical registers. In addition, for a *census* such as the Farm Census, the Farm Register is used as a frame and questionnaires are sent to all farms to gain additional information that is not already in the register. A third kind of survey is based entirely on available microdata in the system of statistical registers. The traditional Population and Housing Census is replaced by a number of such *register surveys* that are based on statistical registers created by the national statistical institute. The statistical registers can be used to create an integrated register system, where microdata can be combined and used efficiently. Consistency and coherence are important quality dimensions that can be measured and improved through the systems approach.

Expert judgements or *eye estimates* are often used in Agricultural Routine Data Systems to produce agricultural statistics in developing countries. Unfortunately, this kind of data is often called *administrative data* as in FAO (2015e). The methods used for expert judgements have nothing in common with the methods used for censuses, sample surveys or register surveys. Administrative data originates from administration of separate units as persons or enterprises – expert judgements are not used in this way and should not be called administrative data. In contrast to administrative data, data collected in Agricultural Routine Data Systems do not represent something new in agricultural statistics.

The *Global Strategy to Improve Agricultural and Rural Statistics* by the World Bank, FAO and the UN (2011), was launched to modernize and improve agricultural statistics in developing countries. One important goal is that agricultural statistics should become an integrated part of the national statistical system. Another part of the strategy is for administrative data to play a more important role in the production of agricultural statistics than today. FAO has therefore published a number of working papers on *Improving the Methodology for Using Administrative Data in an Agricultural Statistics System* (FAO 2015a–e).

This paper discusses the long-term strategy for developing agricultural statistics to achieve integration with the national system and the more efficient use of administrative data. The ultimate goal is to create a statistical Farm Register that can be regularly updated with administrative sources. Note that administrative registers are also being used for non-agricultural statistics. Parallel to the work with improving agricultural statistics, national statistical systems are becoming increasingly register-based. When the Population and Household Census is replaced with statistical registers, the preconditions for a Farm Census will be completely different – the Population Census can no longer be used as a frame for agricultural surveys.

Keywords: Integrated statistical systems, Farm register, Coverage errors, Multiple frame approach

1. Agriculture and the rural population in a register-based system

This section describes how statistics on agriculture and the rural population are produced in a country where statistics production is based on registers. Statistics on agriculture are based on the Farm Register, but the Farm Register is only one of many registers used for statistics production. The Population Register and Business Register and the registers that have replaced the population and housing census constitute an integrated system.

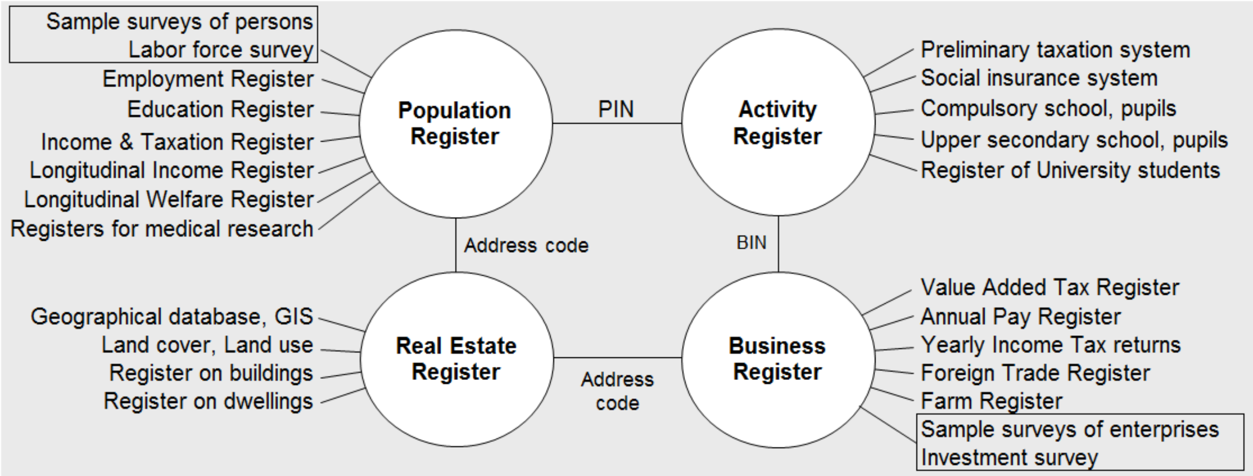
1.1 The key features of a register-based system

In a traditional system based on area frames, the *location* of a statistical unit is the factor that determines if a unit is sampled and interviewed or not. A sampled person's name or identity is not important for the production of statistics. Consequently, information regarding the identities of units is not used in the production process. Countries with register-based production systems use *identity numbers* in all surveys: all censuses, sample surveys and register surveys. The Population Register, the Business Register and the Farm Register are used to create frames, and the statistical units are identified by unique numbers that are used in the production process. In sample surveys and censuses, the identities are used to contact the respondents by mail or telephone. In register surveys, microdata from different registers is combined to create the required data set for the specific survey. These combinations are created by record linkage using the identity numbers as matching keys.

In a national statistical system with a coordinated register system, all microdata in the system can be integrated. In a coordinated system, the populations in the different registers are consistent regarding coverage, and variables in different registers do not have contradicting values. This is what we mean by *an integrated statistical system*. Of course, perfect consistency is difficult to obtain. However, if coverage problems and variable inconsistencies are tolerable, we can say that the system is an integrated system. Integration of microdata will become possible without disturbing problems regarding lack of consistency between populations and variables.

Chart 1 illustrates a register-based production system. The basis is the register system consisting of four base registers (circles) defining the *populations* in the system and a number of statistical registers with important statistical *variables*. The lines in the chart illustrate the important *links* between units in different registers. We have added two sample surveys – the Labor Force Survey and the Investment Survey. These two sample surveys are only examples; all sample surveys can be linked to the register system.

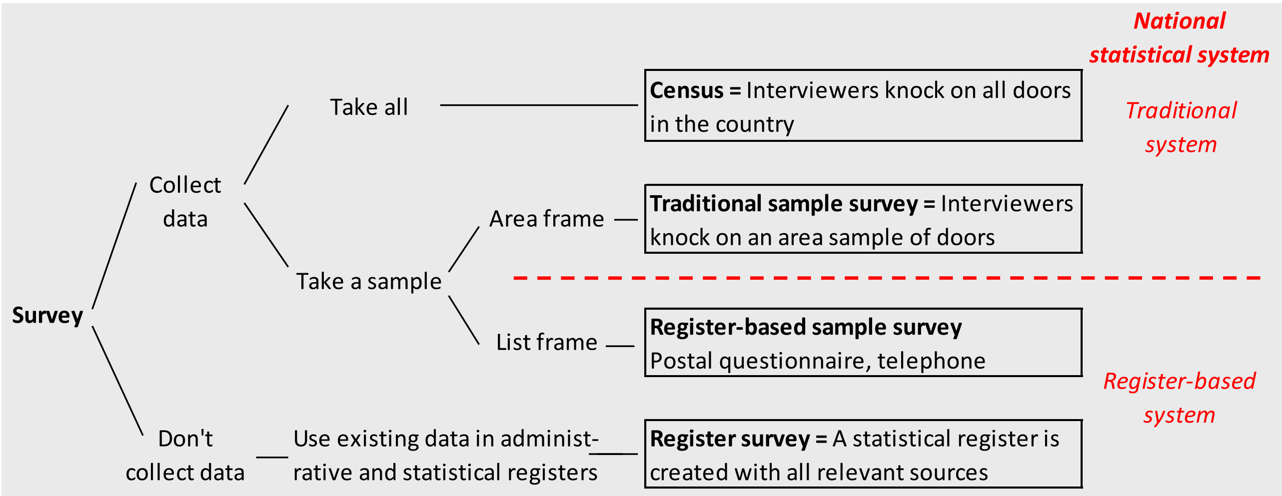
Chart 1. A register-based production system – the register system and sample surveys



PIN = Identity numbers of persons BIN = Identity numbers of enterprises

Chart 2 illustrates the different survey methods used in traditional and register-based production systems. In a register-based system the censuses are replaced with statistical registers, and sample surveys are not based on area frames. This explains why a register-based system is much more cost efficient than a traditional system.

Chart 2. Survey methods in traditional and register-based statistical production systems



1.2 The Farm Register in a register-based system

The population of the Farm Register is determined using one or more administrative registers. The Integrated Administrative and Control System (IACS) is a yearly source in countries that are members of the EU. Instead of conducting a census every tenth year with a census population that will soon be outdated, the IACS system generates a new register population every year.

The Farm Register and the Business Register should be consistent. All holdings in the Farm Register should be linked with enterprises in the Business Register. The holdings are local kind of activity units (LKAU) in the Business Register. The enterprises in the Business Register that are linked to the holdings should be active within NACE 1. There should be no other enterprises with NACE 1 as one of its economic activities in the Business Register.

1.3 Opportunities and problems with a register-based system

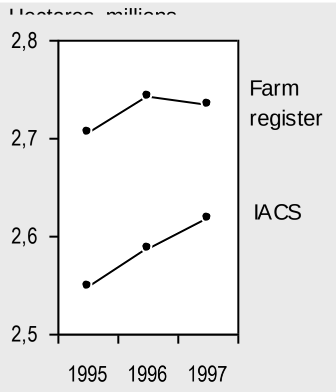
All registers in the system can be used to describe agriculture and the rural population, and there is no extra cost or response burden related to this way of gaining information. If the Farm and Business registers are consistent in the way described in Section 1.2, all administrative data linked with enterprises in the Business Register can be used to describe the agricultural sector.

All registers in Chart 1 contain information regarding agricultural enterprises and/or persons working for agricultural enterprises as self-employed or employed. The households related to these persons can be described as well as the households living in rural areas. With the GIS-system that is linked to the Real Estate Register, the rural regions can be defined freely without using administrative borders.

In Wallgren and Wallgren (2010) we discuss methodological issues and quality problems related to the Farm Register in a register-based statistical system. In a decentralized national system, agricultural statistics and economic statistics can be produced by different statistical institutes. If these institutes do not cooperate, the Farm and Business registers will be inconsistent and this will create problems for the National Accounts, for instance.

Selander et al. (1998) discuss the problem of undercoverage in the IACS register. If this undercoverage is not handled, the consequences can be misleading statistics. This is illustrated in the example in Chart 3, taken from Wallgren and Wallgren (2014). Even if coverage is rather high, variations in coverage will destroy time series patterns.

Chart 3. Undercoverage in an administrative register, the IACS-register



Farmed area of arable land, millions of hectares			
	IACS	Farm Register	Coverage
1995	2.548	2.707	94.1%
1996	2.587	2.743	94.3%
1997	2.618	2.734	95.8%

Change in per cent between years		
	IACS	Farm Register
95/96	1.5%	1.3%
96/97	1.2%	–0.3%

Selander et al. suggest that the population of holdings is divided into three parts, and coverage errors should be reduced by combining register data for the first part with statistical questionnaires for the other parts. This is actually a kind of multiple frame approach:

1. IACS 1 is the part of IACS that consists of the holdings that have reported the entire area of arable land divided among different crops.
2. IACS 2 is the part of IACS where there is no complete crop data in IACS, though there is information for register keeping.
3. The holdings that are outside the IACS system. This third part consists of the holdings that have not applied for subsidies. This part of the population can be monitored by using administrative data from registers with business data.

In Sweden in 1995, IACS 1 comprised some 69,000 holdings, IACS 2 comprised some 6,000 and the non-IACS population some 20,000. The lines of demarcation between the different parts of the population may be changed as a result of a change in agricultural policy.

Some general conclusions can be made based on this IACS example.

- A register-based system is dependent of the administrative systems that generate the administrative data. The coverage problems related with these administrative systems must always be analyzed and monitored over time. Changes in the administrative systems can produce changes regarding coverage.
- The example also illustrates that a multiple frame approach should be used to reduce coverage errors. Undercoverage can be reduced by combining many administrative registers (‘frames’). This is an option in countries with many administrative registers available to the statistical institute.
- Coverage errors can be reduced by combining registers with list-based sample surveys or area samples. In the IACS example, list based samples or censuses covering the second and third part of the population will reduce undercoverage errors. In developing countries, combining registers with area sampling may be necessary to reduce the coverage errors related to the registers.

In Wallgren (2016b) we use the dual frame approach to discuss two problems:

- First, residential addresses are often not updated in administrative population registers in many countries. This means that it is difficult to use administrative population data for regional statistics. In countries with strong urbanization, this will lead to overcoverage of rural register populations and undercoverage of urban register populations.
- In addition, a difficult but important problem is the informal sectors that exist in many countries. Family farms in many countries can belong to this informal sector. Only the formal sector will be found in the administrative sources and these administrative registers must be combined with area samples that cover both the formal and informal sectors.

These two problems are common in developing countries. The problems must be solved so that these countries can modernize their traditional census-based statistical systems into register-based systems. The final solutions of these problems will require many years of applied methodological work.

As a rule, we assume that an area sample has no coverage errors. For the case when we work with flow data, such as production etc., the area sample must also cover all time. In the Swedish Labor Force Survey, we ask *“what did you do last week?”*. To cover all time with the LFS, a new sample is interviewed every week during the calendar year. Thus, we must cover all weeks during the year, quarter or month to be able to assume that we have no coverage errors in the area sample. In contrast, administrative registers cover all time; births and deaths are registered continuously and, for instance, taxation systems measure income night and day during the entire year.

Our aim with this paper is to describe the long-term strategy that should be used when developing countries start to use administrative registers for statistical purposes. When we discuss how administrative registers can be used for agricultural statistics, we must at the same time understand that non-agricultural statistics are becoming increasingly register-based. This will change the preconditions for agricultural and rural statistics. Therefore, the transition processes that will change both agricultural and non-agricultural statistics should be considered together. Agricultural statistics must be an integrated part of the national system and should not be discussed and developed separately.

2. What strategy and methods should developing countries adopt?

This section illustrates that starting to use administrative registers for statistics production implies many new 'non-statistical' activities that are necessary for success. We discuss here the modernization of the national statistical system from a traditional census-based system with no statistical registers into a register-based system. This will be a general discussion describing how administrative registers can be used to create an integrated system of statistical registers. The discussion is based on our experiences from visits to a number of countries in Latin America and the Caribbean during 2011–2016.

If the system for agricultural statistics is to be fully integrated with the system for social and economic statistics, the Farm Register should be an integrated part of the register system. The statistical system should describe statistics on crops and livestock as well as rural regions and households that are dependent on agricultural activities.

2.1 Microdata with identities

All administrative registers contain *identities*. The registered transactions include the identity of the administrative unit responsible for the transaction and/or the identity of the unit that is administrated. These identities are the most important variables in a register-based statistical system. With the identities we can check quality issues as for example coverage and we can combine records for the same unit from different sources. The identities link the different parts of the system together and it becomes possible to create an integrated system and produce consistent statistics.

We also need access to *microdata* to enable work with administrative registers in a methodologically efficient way. In many countries the national statistical institute, NSI, receives only aggregate administrative data from the ministries due to a desire to protect the confidentiality of citizens and enterprises. However, quality assurance and quality improvements will then become difficult and in many cases impossible; and it will not be possible to combine data from different sources so that relations between variables can be studied.

The conclusion is that the statisticians at the NSI must gain access to administrative microdata with identities of good quality. The goal is to have identity numbers so that deterministic record linkage can be used in all statistics production. In addition, those who work with agricultural statistics should have access to microdata with identities. These identities can link together different sources with agricultural data and link agricultural registers with registers in the general system.

2.2 Survey design includes work with improving administrative systems

Many countries in Latin America have reformed their national registration systems so that almost all newborn receive their identity numbers soon after the birth. The situation is worse in other countries: there can be one old system of identity numbers, a new system for adults, one system for children and another system for persons born abroad. In addition, some persons may not have registered and consequently have no identity numbers.

Administrative systems that do not generate data of good administrative quality cannot be used for statistical purposes. When the administrative system is improved, both administration and statistics production will be improved – this is a win-win situation. The national registration system with identity numbers, registration of births, deaths and migration is the most important administrative system for statistics production. If this system is not robust, there will be no identities that can be used to identify farmers, family farms and households; and register-based rural statistics will not be possible.

In many of the countries we visited, the NSIs are actively working to improve the national registration system and the cadaster. All births and deaths should be registered and migration within the country must be registered to make regional statistics possible. Emigration must also be measured; otherwise, there will be overcoverage in the population register. These improvements require political support and sometimes new legislation. This is high-level survey design – the preconditions for all statistical surveys in the country are improved.

We have seen an example where an old, very bad system was replaced by a new system for criminal statistics. In the old system microdata with identity numbers were created by many persons working for two ministries, the police and the correctional authorities. The information could be recorded through hand-writing or with different IT-systems, and different authorities used different codes for classification. Registering information in the old system was difficult and retrieving information was almost impossible. The new system developed by the NSI is based on one form and will standardize and simplify reporting. Retrieving information is now easy. The administration of crime reporting, victims and criminals has been improved and microdata for the production of crime statistics is now available.

2.3 Protection of confidentiality

When a country changes the national statistical system from a traditional into a register-based system, new methods must be developed to protect confidentiality. Identities can be handled and should be handled in such a way that confidentiality is protected *at least as well* in the new register-based system as in the traditional system.

One unit at the NSI, consisting of a small group of persons, should be responsible for receiving all microdata that is stored in an input database with very restricted access. At this unit, names and addresses are removed and official identity numbers are replaced by anonymous numbers. After this work has been completed, the anonymized data is stored in the output database and those who need access to data for statistics production can use it for their purposes. Record linkage is carried out with the anonymous numbers if information in different statistical registers must be combined.

Providing microdata with identities to the NSI will be something new for ministries and other authorities. In many cases old attitudes must be changed. If the ministries understand how the NSI works to protect confidentiality, it will be easier for the NSI to gain access to the data.

2.4 Centralization, cooperation and legislation

Centralization is not as important in a traditional statistical system as it is in a register-based system. In the production system in Chart 1, we want the register populations to be consistent. The populations in different registers must be compared when checking for consistency. When the registers are created, other registers must be used in a systematic way. This work is simplified if all registers are stored together at the same statistical institute. A natural and important role for the NSI will be to create and maintain the system of statistical registers.

Thus, the transition from a traditional system into a register-based system will actualize a more centralized national system. We recommend that the NSI be responsible for all registers that replace the population and housing census and all registers that are used for the National Accounts.

Politicians, ministries, other administrative authorities and the NSI must work together to develop register-based statistics. This cooperation is necessary to improve the administrative systems. Cooperation between the NSI and the authorities that deliver administrative registers will be a permanent task in a register-based system. Old legislation must be replaced with new laws that define that the NSI should have access to microdata and that protect confidentiality.

Regional register-based statistics require that that all persons’ residences are georeferenced and that all job activities are georeferenced. In all Nordic countries it is mandatory that a person's place of residence (dwelling) is registered and that all employers report at which local unit (establishment) each employee works. These two laws were passed by each Nordic parliament to make the register-based population and housing census possible.

2.5 Quality assessment

Problems related to field work, sampling errors and nonresponse are our main concerns when working with sample surveys. In register surveys we have no fieldwork, no sampling errors and we do not ask any questions and we do not have any nonresponse. This probably explains why many people feel bewildered when they start working with administrative registers – how shall we now work with quality assessment?

The understanding of field work and how it determines quality issues in a sample survey corresponds to the understanding of the administrative system that has generated the administrative register. The staff must develop this new competence by studying the administrative system, by having discussions with persons at the administrative authority and by spending time analyzing microdata from the source.

Instead of computing sampling errors, we should analyze coverage problems and other inconsistencies. We do this by comparing coverage at the micro level in different sources describing similar populations. If we combine two registers with record linkage, the mismatch gives us a measure of the differences in coverage (if we have good identity numbers, mismatch is caused by coverage differences). If we combine sources with similar variables, we can also study inconsistencies between variables in different sources. When we find inconsistencies regarding coverage and/or variables, the next step is to try to understand why we have these differences. This is difficult but necessary. Finally, we should correct the errors we have found and reduce the inconsistencies.

There is one important difference between sample surveys and register surveys. In sample surveys we cannot see the errors, we know that we have sampling errors and nonresponse errors but can only give an interval for the probable sampling error. In register surveys, however, many errors can be seen if microdata is analyzed. Here are two examples:

- We found that 16% of the persons between 20–24 years had different residences in the University Register and the Population Register. This is an example of inconsistent variable values. The Population Register can be corrected and improved with this information from the University Register.
- We found that the turnover of *Manufacture of pharmaceutical preparations* was underestimated by 17% due to undercoverage in the SBS, the Structural Business Statistics Survey. This is an example of inconsistent populations. The SBS can be corrected with the information we used.

Each administrative register should be evaluated for statistical purposes prior to use. However, administrative registers are often evaluated one by one and this may lead to wrong conclusions. This is because an administrative register can be used in many ways – for one use the register may be good, for another use the register may be bad. In addition, registers can be combined. Each register may appear to be bad when analyzed separately, but the register based on the combination can still be good. Systematic check of input data quality is discussed in Wallgren and Wallgren (2014, p 273ff). The main purpose is to find out *how* an administrative register should be used. Every new source should be considered as a methodological challenge.

3. Creating a system for agricultural statistics based on registers

FAO (2015e) describes the situation regarding agricultural statistics in some African countries. Three survey methods are used today:

- An agricultural *census* of agricultural holdings is interviewed perhaps every tenth year. This gives detailed statistics for small areas but the information is not timely.
- An *area sample* of agricultural holdings is interviewed. This gives timely information but not for small areas.
- A specific form of statistical survey where statistical data is collected regarding *eye estimates*[1] made by farmers and/or *expert judgements* made by regional officers. This gives timely information for small areas, but the content is not as detailed as in the census.

According to Ssekiboobo (2015), *administrative registers "are rarely used in developing countries because of quality and coverage issues."* This means that register surveys are not used in African countries today, but if we want to modernize national statistical systems as many countries in Latin America do, then administrative registers must become available and be used for statistics production. If the present administrative systems are not sufficiently good, then the first step in the modernization process is to improve the registration systems as discussed in Section 2.2.

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[1] This kind of survey is called *administrative data*, both by the FAO (2015a-e) and by Ssekiboobo (2015). It is a kind of statistical survey that only can be used for agricultural statistics – everyone can look at fields and can judge if the crop looks good or bad. These judgements can be collected and used for statistics based on eye estimates. For other kinds of statistics, it is impossible to make eye estimates – e.g. labor market statistics require the established kinds of sample surveys or register surveys.

It is confusing to call these *eye estimate surveys* for administrative data. We must be careful with our statistical terms – when we work with developing national statistical systems from traditional systems into register-based we must use the term *administrative register* in the correct manner. We ask our colleagues working with agricultural statistics: *Please, do not to destroy this term!* In Wallgren and Wallgren (2014, Chapter 2, particularly on page 28) we discuss the nature of administrative data.

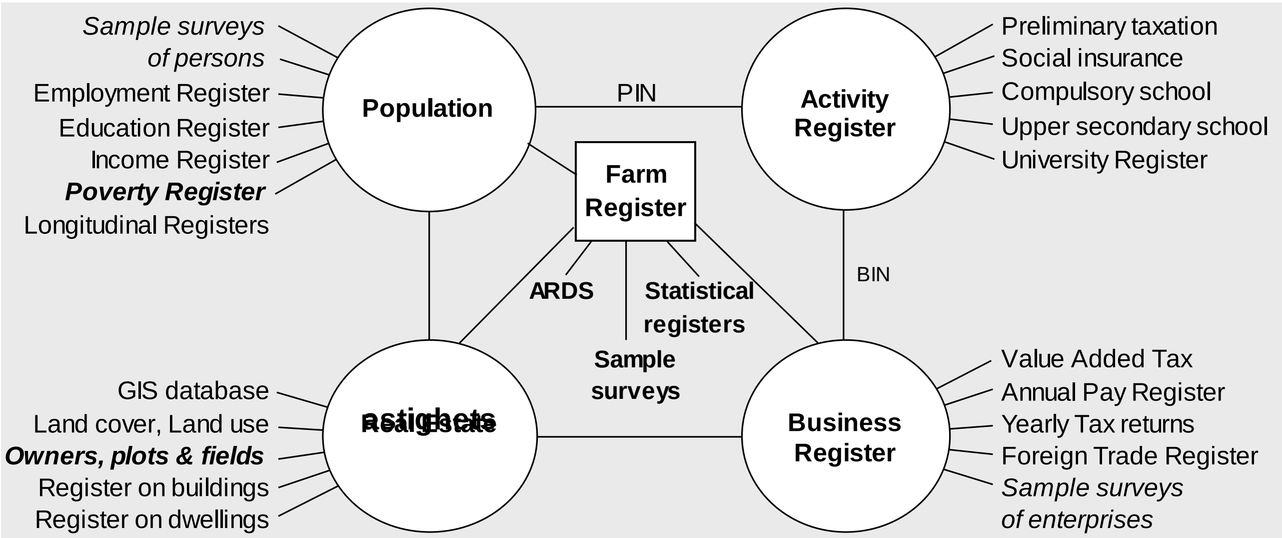
3.1 The Global Strategy and the register system

The Global Strategy by the World Bank (2011) states that agricultural statistics should be an integrated part of the national statistical system. This is an important aspect that is not discussed in FAO (2015a-e). For us, the term *integrated system* is a statistical term with a specific meaning: *Populations and variables should be consistent and estimates should be coherent.* Chart 1 (and also Chart 4) illustrates the production system with base registers, other statistical registers and sample surveys. The following quotations come from the Global Strategy (our italics):

> The integration and underlying methodology … considers the quality dimensions, which include relevance and *completeness,* accuracy, timeliness, accessibility, *coherence, and comparability.*
>
> The process of improving agricultural statistics will begin with the integration of agriculture into the national statistical system. This integration will be accomplished by the development of a master sample frame for agriculture to ensure relevance and completeness; its use *in implementing a coordinated data collection program to produce timely and accurate data that are coherent and comparable*;
>
> One of the shortcomings of current statistical systems in both industrialized and developing countries is that data are collected by sector, using different sampling frames and surveys. The division of data by sector leaves no opportunity to measure the impact of an action in one sector on another. In some cases, different organizations produce statistics for the same items, with different results, which confuse the data users.
>
> Surveys are often conducted on an ad-hoc basis … *It is therefore difficult to integrate data from various surveys for in-depth analysis with cross tabulation of variables.*
>
> *Integrated statistical systems can resolve many of these problems by avoiding duplications of effort, preventing the release of conflicting statistics, and ensuring the best use of resources. Concepts, definitions, and classifications become standardized, allowing more systematic data collection across sources.*

The master sampling frame in the Global Strategy corresponds to the Farm Register in Chart 4. All sample surveys of holdings are based on the Farm Register and sources with crop areas, etc. are linked to the Farm Register. Thus, all data collection regarding agricultural variables is coordinated when the Farm Register is used in this way. As the Farm Register is linked to the Population and Business Registers, agricultural statistics can become an integrated and consistent part of the national system. Micro integration is possible, which makes *"in-depth analysis with cross tabulation of variables"* possible according to the quotation from the Global Strategy.

Chart 4. A register-based production system – the agricultural parts highlighted



The conclusion is: If you want an integrated statistical system that includes agricultural statistics, then the statistical method to achieve this goal is to create a system[2] of consistent registers according to the model in Chart 4.

[2] The eye estimate surveys denoted with ARDS (Agricultural Routine Data System) in Chart 4, can be included in this system if these surveys use data from agricultural holdings and contain identities of the holdings or holders.

3.2 Building the system step by step

The transition from a traditional statistical system based on censuses into a register-based system will take many years. The pioneer country was Denmark that managed to make this transition during 1968–1981. Austria managed to change into a completely register-based system during 2001–2011. The transition in Sweden was slower. The necessary legislative changes took many years, and the changes of the national registration of persons required much work with standardizing of addresses and the creation of a dwelling register. The Swedish transition took place between 1967 and 2011. This section provides an outline of the transition into a system for agricultural statistics that uses administrative registers.

The first step

In an integrated system, *identity numbers* play a very important role. The first step should therefore be to create a national registration system with good identity numbers. Newborns should be registered and receive their national registration number in connection with the birth. These personal identity numbers (PIN) should be used in all administrative systems. The identity numbers of holders can be used to identify holders or holdings in agricultural censuses and sample surveys and in administrative systems regarding agriculture.

The second step

The statistical Population Register is the most important part of a register-based statistical system. It is also important for agricultural statistics to have access to a Population Register with rural and agricultural households. The second step should therefore be to develop a *statistical Population Register*, which can be based on the administrative population register and supplemented by other sources to improve coverage and the quality of residential addresses. These addresses must have sufficient quality; otherwise, regional statistics will be impossible. Wallgren and Wallgren (2015) describes some of our experiences from Latin America.

The third step

The role of the base registers is to define statistical units and populations in the statistical system. The third step should therefore be to develop the Real Estate Register or Cadaster, the Business Register and the Farm Register. The Activity Register is also essential – all job activities are needed for the *Employment Register*, and all study activities are necessary for the *Education Register*. These two registers are important parts of the register-based population and housing census.

For register-based agricultural statistics, we need a Farm Register with all holdings and administrative registers with information regarding holdings. Within the European Union, three administrative sources can be used: the IACS-register, the Cattle Register and the Business register. In developing countries, a register can exist with big and/or commercial farms, but there is no register with small family farms. An inventory of sources with microdata regarding farms or farmers should be carried out. Cooperation between ministries can be important – other ministries than the Ministry of Agriculture may have data that includes farming households.

We can give one example from Latin America: The Ministry of Interior created a register to administrate support to poor households. The register covers between 60% – 95% of the population, with the highest coverage in poor rural regions. Here we suggest *integrated data collection* so that the Ministry of Interior will include questions when creating their register to identify agricultural households. This information can then be used by the Ministry of Agriculture and as a source for a Farm Register. Today, the Farm Census is often based on a frame based on the agricultural households in the Population and Housing Census. In the future, this integrated data collection can replace this way of using the Population and Housing Census.

Agricultural statistics as an integrated part of the national system

When a country has established a system with national identity numbers for persons (PIN) and if there is a population register with information on where people live and together with whom, then the preconditions for statistics production have been greatly improved. It will now be possible to create statistical registers and produce register-based statistics on persons.

All administrative systems concerning persons and households should use identity numbers PIN. Then data from these systems can be used for statistics production. Also all surveys as population censuses, all area frame based sample surveys of households, all register-based (list based) sample surveys of persons and all register surveys[3] with data on persons should include the identity numbers PIN. Then these surveys can be developed into an integrated statistical system that produces coherent statistics.

If we want to make agricultural statistics an integrated part of the national system, there must be a national system with registers that we can link to the agricultural registers. We assume therefore that the statistical Population Register exists and that family farms can be linked to this register with the identity numbers PIN of the holders. Commercial farms can be linked to the Business Register with business identity numbers BIN. If there exists a Real Estate Register, then the holders and holdings can be linked to the fields and plots they own via the identity numbers PIN and BIN. A Farm Register should be developed that can be linked to the registers in the national system. This is the necessary precondition that must be fulfilled is we want that agricultural statistics based on registers should be integrated with the national statistical system.

3.3 Agricultural surveys in an integrated system

In Chart 5 we give a short description of different sources with identities and agricultural data and how they can be used to create an integrated system of agricultural surveys. All relevant sources should be used to create a statistical Farm Register with as good coverage as possible. The Farm Register should also include basic classification variables as address, size and kind of farm.

Chart 5. Sources used to create a Farm Register and agricultural statistical registers

Source		Identity number	Survey
1.	Population census with identity numbers PIN and a variable that indicates holders	PIN	Statistical Farm Register
2.	Register to administrate support to poor households with identity numbers PIN and a variable that indicates holders	PIN	Statistical Farm Register
3.	Agricultural Routine Data System, field staff is used to improve and update the Farm Register	PIN, BIN	Statistical Farm Register
4.	Administrative Farm Register with commercial farms	BIN	Statistical Farm Register
5.	Agricultural Routine Data System, field staff is used to report holding identities together with holding level data	PIN, BIN	Statistical Registers with crop areas, production etc.
6.	Administrative registers with different content: Tax data for holders and holdings Land ownership Agricultural production and inputs Data from manufacturers and distributors Data from farm associations	PIN, BIN	Different statistical registers Can also be used to improve the Statistical Farm Register

[3] A *register survey* is a survey where data from existing statistical registers and administrative registers are combined to create a new statistical register for specific statistical purposes.

Population census

If a country does a traditional population and housing census (perhaps for the last time), this census should be used not only to improve the Population Register but also to improve the Farm Register. Identity numbers, PIN, of all persons should be included in the census and also questions that identify holders and holding households. This information together with the residential address can be used to establish a first version of the family farm part of the Farm Register.

Register to administrate support to poor households

In Latin American countries, many ministries create their own registers with population data to administrate their different political programs. In one country we found six different registers with population data for different purposes. If some of these ministries include questions to find holders and holding households, then this kind data can be used to create the family farm part of a Farm Register.

Agricultural Routine Data System

FAO (2015e) describes the Agricultural Routine Data Systems, ARDS, that are common in many developing countries. There are many problems with these systems: the staff is not always motivated, there is lack of training and the reports are not standardized etc. However, the ARDS is an old and well established kind of statistical system that has field staff all over the rural parts of the country. We think that the ARDS gives opportunities that can be used in a register-based statistical system. But to become an integrated part of the new statistical system, the ARDS should include identities of the holders and collect microdata from holdings. Today the ARDS staff aggregates data from holders into village data. These aggregated data are then transferred to wards and regions etc. We suggest that gradually the ARDS changes from collecting the aggregated data that is used today into collection of microdata with identities of holders. This microdata can then be used to create registers with agricultural data.

The field staff working with the ARDS can also report changes in the stock of holdings. In this way the quality of the Farm register will be maintained. The knowledge that the field staff has regarding the farm population should be used to improve and update the Farm Register.

Administrative Farm Register with commercial farms

A register with commercial farms should be one of the sources that should be used to create the statistical Farm Register. There are as a rule also administrative sources with tax data and other economic information that are important for agricultural statistics. These sources can be combined with business identity numbers BIN for enterprises. One BIN identity can however be linked with more than one holding.

Administrative registers with different content

When the statistical Farm Register has been established, available administrative registers can be used to create new statistical registers with agricultural and rural information. The populations should be created with the Farm Register and the administrative registers will be used as sources of the variables in these new registers.

When the administrative system that generates the administrative data is old and bad, the data will have poor quality. The NSI should in such cases take the initiative so that the bad system is replaced with a modernized system. This requires cooperation with administrative authorities as we explained in section 2.2.

4. Conclusions

Administrative data and agricultural statistics – what strategy and methods should we adopt? The following two quotations come from Wallgren and Wallgren (2015) and are based on our experiences from Latin America.

> "Administrative systems in the public sector generate vast amounts of data that is stored in administrative registers. These registers is a resource that can be used for statistics production. This resource is growing in volume and as the administrative systems gradually improve, the quality of the administrative data that is generated by these systems will become increasingly better."
>
> "If administrative registers are used for statistics production, costs can be saved and quality can be improved. Censuses can be replaced by register surveys, and new kinds of regional and longitudinal statistics can be developed. The national system can be changed into an integrated statistical system with consistent and coherent statistical registers and sample surveys. During the transition period, it may be necessary to combine the register-based statistics with estimates from area samples."

According to the Global Strategy (World Bank 2011), agricultural and rural statistics in developing countries must be improved and become an integrated part of the national statistical system. When a country starts to use administrative registers for statistics production, more and more statistical registers are developed. With identity numbers, all registers and surveys can be linked and become parts of an integrated system that can be used to produce coherent statistics.

In this paper, we have tried to give an overview of the strategy and methods that should be used in this transition process. Many countries in Latin America are working in this direction and we think that within five years some of these countries will have improved their national systems considerably.

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THEMATIC SET

F34

INTEGRATING AGRICULTURAL AND HOUSEHOLD SURVEYS

Session Organizer
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ABSTRACT

One of the central tenets of the Global Strategy to Improve Agricultural and Rural Statistics is the recognition of the need for greater integration of different agricultural data sources. Of particular interest are the analytical advantages of an integrated survey system and the ways in which household and farm surveys can be linked through various methods and techniques. As countries, particularly in the developing world, are faced with increasing pressure to collect more and better information at lower costs, this linkage between household and farm surveys becomes more important. Enhanced integration can be seen as a double win both in cost-efficiency as well as analytical potential. The session will explore different ways in which survey integration can be pursued, including by (1) using common master sampling frames and/or spatial sampling units and by designing "smart" samples enabling a closer correspondence between household and farm units, (2) encouraging thematic overlapping, allowing for better "cross-walking" between surveys through scalable imputation techniques, and (3) supporting geo-referencing of the different data sources. Submission of empirical applications of innovative methods of particular relevance to agricultural farming systems and statistical capabilities of developing countries are encouraged.

LIST OF PAPERS

The multifunctional farm household enterprise: using farm microdata to assess the rural economy impacts generated by farmer-operated off-farm businesses

S. Vogel | USDA Economic Research Service | Washington, DC | USA
R. D. Bollman | Rural Development Institute, Brandon University | Brandon, Manitoba | USA and University of Saskatchewan | Saskatoon, Saskatchewan | Canada
DOI: 10.1481/icasVII.2016.f34

Comparative analysis of cross sectional and panel data collection for agricultural statistics in Malawi: does an integrated vehicle provide an effective framework?

I.P. Pangapanga | Lilongwe University of Agriculture and Natural Resources | Lilongwe | Malawi
L.T. Pangapanga | Research for Development-Smart Projects | Lilongwe | Malawi
DOI: 10.1481/icasVII.2016.f34b

Demographic and social characteristics of the agricultural producer´s households

S. Pérez | INEGI | Aguascalientes | Mexico
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The agricultural integrated survey (AGRIS): rationale, methodology, implementation

F. Fonteneau | FAO | Rome | Italy
DOI: 10.1481/icasVII.2016.f34d

The Multifunctional Farm Household Enterprise: Using Farm Microdata to Assess the Rural Economy Impacts Generated by Farmer-Operated Off-Farm Businesses

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ABSTRACT

Rural development specialists working with agricultural statistics confront the tension between collecting data for the purposes of measuring farm sector performance versus that of assessing farm household well-being. While it is recognized that the activities of the farm enterprise and farm household generate a broad spectrum of market relationships in their local economies – linkages found in capital markets, commodity production, household consumption, and alternative income-generating activities on and off the farm, most agricultural data collection systems focus primarily on commodity production and just the basics of farm household structure (Bollman, 1998). The survey instrument that embraces the dual mission of collecting data on the farming enterprise and on farm households can allow specialists to study a broader complement of farm-rural economy linkages (Johnson, et al, 2008). Such a survey generates a more comprehensive quantitative assessment of the farm household as a multifaceted enterprise and its linkages to the rural economy (Vogel, 2012).

In this case study, we exploit microdata on farm household activities drawn from U.S. and Canadian national agricultural surveys to shed light on the impact of farmers who simultaneously operate off-farm businesses on their local communities– a farm/rural interface often overlooked by agricultural economists and rural development specialists alike. These entrepreneurial farmers provide additional employment and growth opportunities separate from commodity production for

their rural economies. Hence, instead of depending on the local communities' resilience for their household well-being, they contribute to it.

We use the Agricultural Resource Management Survey jointly administered by the Economic Research and the National Agricultural Statistic Services of the U.S. Department of Agriculture and the Farm Financial Survey administered by Statistics Canada. Given the sufficiently detailed data on these farmer-operated off-farm businesses, we are able to use the input/output modeling toolkit to recover estimates of nonfarm value added, sales, and employment generated by them. With respect to the rural economy, we find that the share of a rural county's employed nonfarm labor force linked to these off-farm businesses increases the further they are located from the urban core. Thus, the business acumen of these farm portfolio entrepreneurs is an even more valued intangible asset for communities in more remote rural areas.

For developing economies with large farming populations, data on the full complement of farm household enterprise activities can provide opportunities of regional development specialists to analyze the potential breadth of farm-generated development pivots.

Keywords:, off-farm businesses, farm microdata, entrepreneurship, rural resilience.

1. Introduction

In the current global economy, some elements in the development processes in agriculture remain intertwined with those of the rural economy, while other relationships have attenuated. in part to the increasing scale and concentration of farm operations and in part to the economic diversification of many rural economies, the farm links to the local economic base have weakened while the majority of farm households in many countries have at least one household member in non-farm employment. Farmers who simultaneously operate off-farm businesses provide additional employment and growth opportunities for their rural economies.

The activities of the farm *family enterprise* – farm production, farm household consumption plus all other household income-earning activities generate distinct market relationships, but most agricultural data collection systems focus primarily on family *farm enterprise* and just the basics of farm household structure (Bollman, 1998, Johnson et al., 2008). The survey instrument that collects data on these market relationships generates a more comprehensive quantitative assessment of the farm household as a multifaceted enterprise and its linkages to the rural economy (Vogel, 2012).

This case study shows how using farm sector microdata for rural development purposes is able to uncover additional contributions made by a small segment of U.S. and Canadian farm families to their communities' well-being. By simultaneously operating both farm and off-farm businesses, these farm families appear to use their comparative advantage in being able to organize resources across multiple enterprises when new business opportunities arise. A large body of case study research classifies these multifunctional farm families as "portfolio entrepreneurs" (Carter and Ram, 2001; Seuneke, et al., 2013).

In the local economy, off-farm business income serves a dual purpose. First, from the farm household's perspective, off-farm business income represents an additional, potentially lucrative source of household income. In section 2,
Survey (ARMS) jointly administered by the Economic Research and the National Agricultural Statistic Services of the U.S. Department of Agriculture and the Farm Financial Survey (FFS) administered by Statistics Canada to examine the incidence and distribution of these farm portfolio entrepreneurs (FPEs).[1] Second, from the perspective of the local economy, off-farm business income represents profit income derived from these FPEs marshaling local resources in producing nonfarm goods and services, without which they may have been imported or not available at all. In

section 3, we use elements of the social accounting matrix modeling toolkit to estimate of their contributions to local output, nonfarm value added income, and employment.

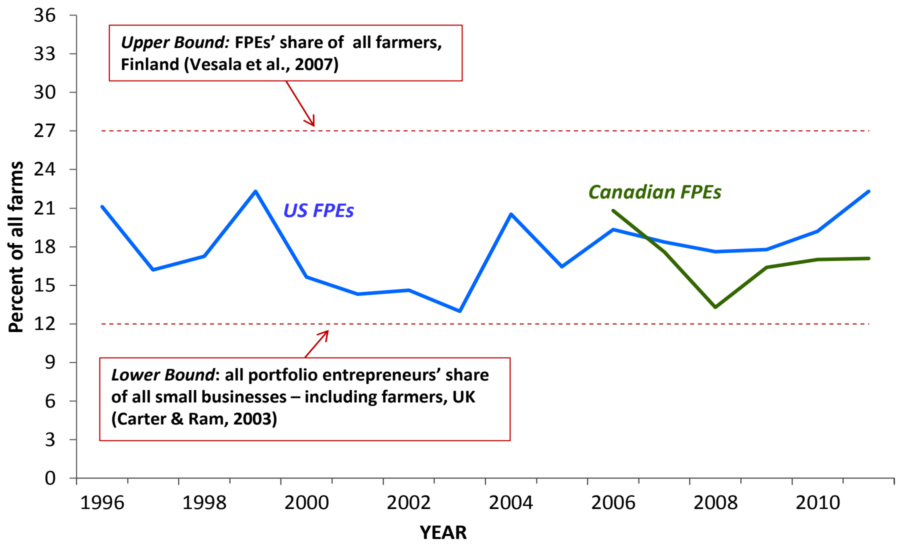
2. View from the Farm Gate: Characteristics of U.S. and Canadian FPEs

Why do farm households become portfolio entrepreneurs? For small farms generally, the ability to make a living solely from farming has declined over time as economies of size increasingly limit the profit potential of smaller operations. These multifunctional farm households rely on portable skills, multiple job-holding, and multiple enterprises as the basis for maintaining their household incomes. Farm households with excess resources at their disposal may operate a second enterprise if adjacent land or other key inputs become too costly or unavailable, or if nonfarm opportunities appear to be more profitable than intensive development of existing farm resources. For large commercial family farms with multiple operators, operating an off-farm business can provide an income and career path for extended family members, insuring that they remain part of the broader family farm business (Vogel, 2013).

Statistics on the incidences of farm and nonfarm portfolio entrepreneurship are uneven, ranging from 12 percent of all small businesses in England to 27 percent of Finnish farm households (Carter and Ram, 2003; Mikko Vesala, et al., 2007). Although ARMS collects data on off-farm business income annually, the data necessary for estimating farmer-operated off-farm business contributions to their local economy exist only for the years 2006-2012. For these years, FPEs reported the industrial sectors to which their businesses belonged, profit income, and how many workers their businesses employed. For the Canadian case, data on off-farm business income from the FFS was collected every two years prior to 1995 and continuously only for 2006-2011.

U.S. and Canadian FPEs represent a relatively small, enduring segment of all farm households, averaging 17.9 for the U.S. and 17.1 for the Canadian case (Figure 1). Vogel (2012) found that most of these farm families operated nonfarm businesses out of necessity, a small segment as part of family-enterprise growth and wealth generation strategies, and an even smaller portion as part of a transitional pathway into and out of farming. Compared to other types of small business entrepreneurs, farm and nonfarm portfolio entrepreneurs are more likely to rank their ability to organize resources and spot new opportunities as a greatest strength, more likely motivated by wealth creation, and to have invested more capital from both internal and external sources in their businesses (Westhead, et al., 2005).[2]

Figure 1. Incidence of Canadian and US farm portfolio entrepreneurship, 1996-2011



Source: USDA, ERS, ARMS, 1996-2011; Statistics Canada, FFS, 2006-2011.

In 2007, 395,583 U.S. farm households earned US $21.6 billion US off-farm business income and 39,243 Canadian farmers similarly earned CA $2.1 billion (Table 1).[3] The incidences of portfolio entrepreneurship by farm sales class among all U.S. and Canadian farm households also lie in the established range in Figure 1, suggesting that the human capital skills unique to farm portfolio entrepreneurship are universal and not directly linked to farm size.[4]

The distribution of farms across farm sales classes is different in the U.S. and in Canada – in 2007, the USDA ARMS survey reported that 58% of U.S. farms had sales under $10,000 whereas the Canadian 2006 Census of Agriculture showed that only 22% of Canadian farms had sales under $10,000. Thus, with a similar incidence of portfolio entrepreneurship in each sales class (Table 1), we find a much larger share of FPEs operating small farms in the U.S., compared to Canada. In 2007, 82 percent of U.S. FPEs were small farms with gross sales of less than $50,000, whereas only 48 percent of Canadian FPEs were classified as such. Medium-sized farms with sales between $50,000 and $249,999, and large farms with $250,000 or more in sales accounted for 52 percent of Canadian FPEs versus 21 percent of U.S. FPEs.

Table 1. Number of U.S. and Canadian FPEs and their off-farm business income, 2007

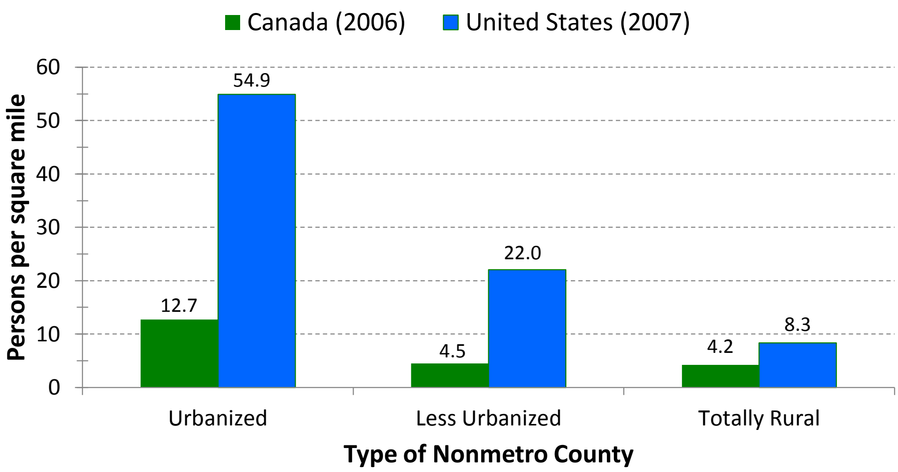
	*Farm Sales Class**			
	Less than $50,000	$50,000 up to $249,999	$250,000 or more	All
United States				
Number of farm portfolio entrepreneurs	325,617	41,864	28,102	395,583
Percent	82.3	10.6	7.1	100.0
Percent of all farms	19.5	14.8	13.7	18.4
Off-Farm business income (US $ millions)	17,028.0	3,053.3	1,538.0	21,618.9
Percent	78.8	14.1	7.1	100.0
Canada				
Number of farm portfolio entrepreneurs	19,008	12,450	7,785	39,243
Percent	48.5	31.7	19.8	100.0
Percent of all farms	16.0	17.4	20.0	17.1
Canada (CA $ millions)	1,091.0	600.7	427.8	2,119.9
Percent	51.5	28.3	20.2	100.0

*Farm sales classes were demarcated in U.S. dollars for U.S. FPE's and Canadian dollars for Canadian FPE's (2007 exchange rate: 1 USD = 1.07 CAD).

Sources: U.S. Department of Agriculture,Economic Research Service, 2007 Agricultural Resource Management Survey; Statistics Canada, 2007 Farm Financial Survey, and 2006 Census of Agriculture.

What underlying factor accounts for the disproportionately higher share of small farms among U.S. PFEs relative to Canada? Is it important to sustaining rural livelihoods? For the rural development specialist, a natural candidate is the role of population density. Figure 2 depicts average population densities for nonmetropolitan (rural) counties by the size of their urban populations in the 48 contiguous U.S. states (excluding Alaska and Hawaii) and in the Canadian provinces (excluding the Northern Territories). Nonmetropolitan counties with urban populations of 20,000-249,999 inhabitants are classified as 'urbanized', as 'less urbanized' for those with urban populations of 2,500-19,999 inhabitants, and 'totally rural' for those counties with less than 2,500 urban inhabitants. Within each of the three county types, population densities in US rural counties are 2 to 4 times higher than Canadian counties. In the Canadian counties, the centers of urban activities – be they small cities, towns, or villages – serve a much broader rural expanse than for corresponding U.S. counties. Regardless of the size of the urban center, higher population densities in rural counties may constrain farm-size expansion, but they can offer more opportunities for farm households to earn income in the nonfarm economy and more business opportunities for the entrepreneurial farm family.

Figure 2. Population Densities of Nonmetropolitan Counties by Type*



*2007 U.S. data excludes Alaska and Hawaii; 2006 Canadian data excludes the Northern Territories.
Sources: U.S. – USDA, Economic Research Service (2003 Beale county codes); U.S. Dept of Commerce, Bureau of the Census (2010). Canada – Statistics Canada., Census of Population, 2006

3. View from the local economy: economywide contributions of off-farm businesses

From a 'rural wealth creation' perspective, the long run sustainability of a rural community's well-being depends on promoting the economic activities that simultaneously augment its stocks of intangible resources. That is, fostering social and business networks, the capacity to innovate, and institutional malleability – social capital, intellectual capital, and cultural capital – can become important pivots in a rural community development strategy (Pender, et al., 2012). Case studies find that FPEs contribute to their communities' stocks of social and entrepreneurial capital. Our use of farm microdata complements these findings by quantifying the measureable economic impacts of their off-farm businesses.

The 2007 ARMS data allow us to distinguish between two types of FPEs based on whether or not they employ part-time or full-time workers. Off-farm businesses with no employees classified as sole proprietorships are referred to as "survival entrepreneurs" who may face few off-farm employment opportunities or possess limited financial or physical resources for farm enterprise growth. Off-farm businesses with employees are referred to as "growth entrepreneurs" contributing to a community's dynamic process of wealth generation (Markley and Low, 2012).

3.1. Industry Data and Methodology

To estimate the value of sales, labor income, and employment that, in theory, must exist to support the levels of U.S. and Canadian off-farm businesses incomes reported in Table 1, we assume that these businesses exhibit on average the same industrial characteristics as those operated by these countries' establishments not associated with a census-farm. This assumption lets us use the structural relationships embedded in the Canadian and U.S. benchmark input/output tables.[5]

For our simulations, we aggregated the 2007 ARMS data on off-farm businesses into 5 industrial classifications: (i) agricultural services, forestry and fishing, (ii) construction and manufacturing, (iii) utilities, wholesale trade, and transport, (iv) services, and (v) 'unclassified' or 'necessity' proprietorships. The Farm Financial Survey does not collect data on the type of industry to which Canadian off-farm businesses belong. As indicated below in Table 2, we assume that the distribution of Canadian off-farm businesses by sector is the same as in the U.S. We then use the input/output data regarding profit income, labor productivities and input usage for all firms in these sectors to estimate the contribution of Canadian off-farm businesses in each sector. Therefore, the differences between the two countries is generated by the differences within sectors as we assume a common weighting of the data across sectors to generate the national estimates of the contribution of off-farm businesses (Vogel and Bollman, 2012).

We used the fixed relationships between profit income and output embedded in a social accounting matrix (SAM) multiplier model to estimate the contributions to output, value-added income, and employment generated by off-farm businesses. Traditionally, after extracting the matrix of direct expenditure coefficients (**B**) from the data SAM, an exogenous shock to a particular group of industrial sectors or households ($\mathbf{\Delta x}$) multiplied by a matrix of SAM multipliers (**M**) yields economywide effects on sectoral outputs, factor incomes, and household incomes ($\mathbf{\Delta y}$),

(1) $$\mathbf{\Delta y} = (\mathbf{I} - \mathbf{B})^{-1} \cdot \mathbf{\Delta x} = \mathbf{M} \cdot \mathbf{\Delta x} .$$

Given that our farm microdata were collected on current-period enterprise activities, we assume that these off-farm businesses operate in the current period equilibrium. They did not generate any "new" derived demands for intermediate goods and labor services that would have been captured by the SAM multiplier **M**. Instead, we are only allowed to estimate the direct impacts of these off-farm businesses. Dividing the sectoral-level off-farm business incomes ($\boldsymbol{\pi}$) by their direct profit-income coefficients ($\mathbf{B}_{\pi}$) obtained from the 2002 U.S and the 2006 Canadian benchmark input-output tables yields estimates of sector-level output or sales for these off-farm enterprises (**x**),

(2) $$\mathbf{x} = \boldsymbol{\pi} / \mathbf{B}_{\pi} .$$

Given the estimates of total sales (**x**) for U.S. and Canadian off-farm businesses, we use the ratios of sectoral income and employment obtained from their respective input-output tables to estimate these business's contributions to their local economy's value-added income, labor income, and employment for the Canadian case. For the U.S. case, we report the 2007 ARMS employment estimates. As a robustness check, we found that the employment estimates for the U.S. case derived from equation (2) were within 6 percent of the 2007 ARMS employment estimates. Table 2 reports the contributions made by FPEs to their nonfarm economies.

3.2. Results

The summary measure of FPEs' contributions to their communities' well-being is value-added income, defined as the sum of labor and capital income plus indirect business taxes generated by their off-farm businesses. In addition to the value-added income generated by the farm operation, in 2007 off-farm businesses in the U.S. generated an estimated $111.6 billion in sales of goods and services, which resulted in an additional contribution of $54.6 billion to their communities' gross county products (Table 2). Similarly, Canadian farmers operating off-farm businesses generated $12.1 billion in sales, which resulted in $5.5 billion in additional value-added income accruing to their communities. The nonfarm businesses of FPEs paid out $19.7 billion in wages and salaries to 853,100 part-time and full-time employees in the U.S. and almost $2.9 billion in labor income to 68,200 employees in Canada.

For both countries, service sector businesses appear to generate the largest economic footprint in their local communities, accounting for about 55 percent of total value-added and labor income and the largest shares of employment linked to these businesses (Table 2). This outcome reflects the overall pattern of service sector enterprises driving the industrial composition of the two countries' rural and national economies.

Table 2. Contribution of FPEs to the off-farm economy

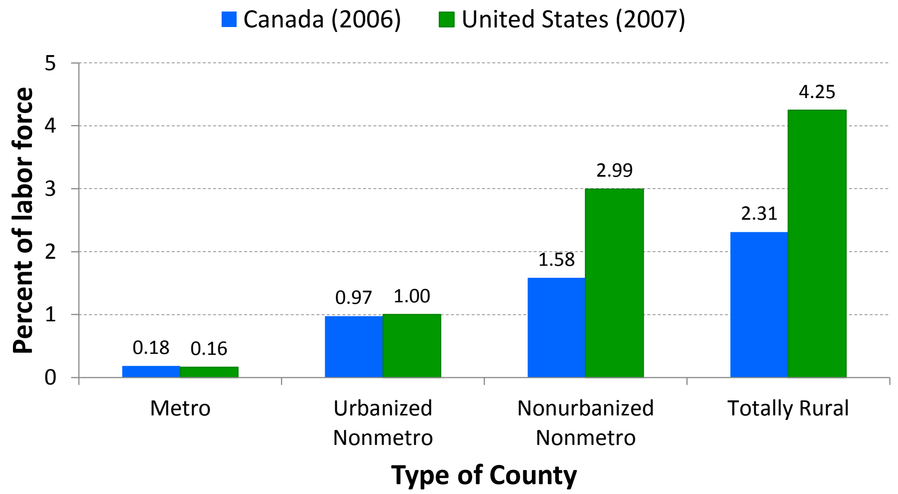
Item	All industrial sectors	*Industrial sector:* Agriculture, forestry, and fishing	Construction and manufac-turing	Infrastructure (utilities, wholesale trade, and transport)	Services	Unclassified proprietorships (with no employees)
United States		*Percent of total distributed across all categories*				
Off-farm business income (US $ milliions)	21,619	7.9	18.2	7.3	53.5	13.0
Sales (US $ milliions)	111,615	6.0	28.7	8.6	44.1	12.6
Value added Income (US $ milliions)	54,649	5.1	21.5	10.5	56.9	6.1
Labor Income (US $ milliions)	19,723	3.2	28.5	10.8	57.4	–
Jobs (number)	853,129	12.5	21.4	17.7	48.4	–
Canada		*Percent of total distributed across all categories*				
Off-farm business income (Can $ millions)	2,120	7.9	18.2	7.3	53.5	13.0
Sales (Can $ millions)	12,123	7.7	30.1	6.4	44.3	11.5
Value added Income (Can $ millions)	5,501	5.3	21.4	8.1	54.9	10.2
Labor Income (Can $ millions)	2,860	4.8	25.4	8.6	61.2	–
Jobs (Number)	68,194	9.8	19.4	7.2	63.6	–

This table's key finding points to the disproportionate contribution growth-oriented FPEs make to rural sustainability. These FPEs operating employer establishments generated 87 percent of all firm sales in the US and 88 percent in Canada, and contributed almost 94 percent of all value-added income from off-farm businesses in the US and 90 percent in Canada (Table 2). Yet, small in number, they make up in the U.S. case only 38 percent of all FPEs, and may represent key fixed-place human capital assets for local communities facing changing agricultural and rural economies (Vogel, 2012).

How important are U.S. and Canadian jobs directly tied to FPE off-farm businesses to the rural economy? In both countries, the share of local employment linked to these nonfarm businesses is higher in rural counties that are further from an urban core. In 2007 for both countries, jobs directly linked to off-farm businesses operated by farm households accounted for 0.2 percent of the employed labor force in metro counties and 1 percent in the urbanized nonmetro counties (Figure 3). In the U.S., the share of the total county labor force directly linked to FPEs' off-farm enterprises increased to almost 3 percent in less urbanized nonmetro counties to 4.3 percent in the completely rural counties. For the U.S. case, we observe when traversing the urban/rural continuum a 20-fold increase in the nonfarm employment directly linked to their farmer-run nonfarm employer establishments. In Canada, the shares of the total county labor force directly linked to these off-farm businesses increased to 1.6 percent in the less urbanizes counties to 2.3 percent in the completely rural counties. Similarly, for the Canadian case, we observe a 13-fold increase in the nonfarm employment linked to these farmer-run firms.

These findings suggest two additional stylized facts on the importance of farm portfolio entrepreneurship for rural communities. First, FPEs in the more remote rural areas play an increasingly important role in developing business opportunities. For these rural areas, attracting outside entrepreneurial resources is difficult. Hence, the place-based FPE's portfolio of intangible and tangible resources becomes a more highly valued development pivot, particularly in densely populated remote rural areas with large numbers of small farms. Second, the increase in the share of the total labor force tied to Canadian farmer-operated off-farm businesses is half that for the U.S. in the less urbanized nonmetro and totally rural counties. For the U.S., the county-level incidence of FPEs among all farmers is halved when the county's population density falls below 5 inhabitants per square mile (Vogel, 2012). For these Canadian counties, their population densities fall below this threshold, such that markets are too thin to support the same incidence of farm portfolio entrepreneurship observed in the more populous counties.

Figure 3. Percent of total county labor force employed directly by farm household operated off-farm businesses by type of county*



*2007 U.S. data excludes Alaska and Hawaii; 2006 Canadian data excludes the Northern Territories.
Sources: United States – U.S. Department of Agriculture, Economic Research Service (2003 Beale county codes); U.S. Department of Commerce, Bureau of the Census (2010). Canada – Statistics Canada., Census of Population, 2006

4. Conclusion

FPEs represent a small, but enduring segment of farm households in the U.S. and Canada, but agricultural economists or community development specialists have not recognized their importance to the rural economy. We found that for both the U.S. and Canada the share of local employment linked to these off-farm businesses is higher for rural counties that are more distant from an urban core. In these rural areas with limited resources, local communities increasingly rely on the FPEs as place-based contributors to its economic resilience. We found that the smaller shares of nonfarm employment supported by FPEs in Canadian rural counties relative to the U.S. were accounted for low population densities resulting further in thin markets and limited nonfarm entrepreneurial opportunities.

Rural development specialists working with agricultural statistics confront the tension between collecting data for the purposes of measuring farm sector performance versus that of assessing farm household well-being. In both the U.S and Canada, rural policy and rural programming largely emanate from the ministries of agriculture at both the national and state/province levels. Our study identifies and measures the contribution of FPEs to their local economies. In each country, the addition of a few more key questions to the ongoing farm surveys and censuses can improve our understanding of this and other rural development opportunities (Bollman, 1998). For countries in which separate household-level data on their rural economies is difficult or costly to collect, amended agricultural data collection systems allow the agricultural policymakers and researchers concerned with agricultural sustainability and the rural development policymakers and researchers concerned with rural community sustainability to explore the extent of the overlap between the two.

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[1] Our data comes from U.S. and Canadian farm surveys in which one business enterprise is a census-farm. In this paper a 'farm' refers to a 'census-farm'.
[2] Scholars of small business entrepreneurship classify as 'novice' entrepreneurs those farmers whose sole business is the farm operation, or 'serial' entrepreneurs if having operated another farm or nonfarm business prior to running their current farm operation.
[3] We used 2007 data to establish a pre-Great Recession benchmark. Figueroa-Armijos, et al. (2012) found that the Great Recession induced a decline in 'growth' entrepreneurship in U.S. rural areas and an increase in 'necessity' entrepreneurship due to employment losses and business enterprise failures.
[4] This research was based on an earlier ERS farm typology that has subsequently been revised (Hoppe and MacDonald, 2013).
[5] For a detailed discussion on the methodology, data development, calibration, and robustness tests, see Vogel and Bollman (2012).

COMPARATIVE ANALYSIS OF CROSS SECTIONAL AND PANEL DATA COLLECTION FOR AGRICULTURAL STATISTICS IN MALAWI: DOES AN INTEGRATED VEHICLE PROVIDE AN EFFECTIVE FRAMEWORK?

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ABSTRACT

This paper conducts a comparative analysis between cross sectional and panel component data collection methods for agricultural statistics in Malawi. The paper uses meta-analysis and / or revelatory case study approach to characterize a stand over cross sectional and panel data collection in Malawi. In this paper, we adopt a conclusion statement made by Deaton, Solon and Ashenfelter (1986) that, while there are genuine difficulties, there are good arguments for collecting panel data. Collecting panel data in Malawi is a sensible enterprise where both the dynamics and annual level statistics are generated. Despite advantages of a panel component in Malawi, they are very expensive as compared to cross section survey. We recommend a panel that is integrated in cross sectional data collection as is the case in the current Integrated

Household Survey design. This will not only improve and address data demands but also become cost effective for agricultural statistics stakeholders as would have been realized through a fully-fledged panel.

Keywords: Malawi, Cross Sectional, Panel Data Collection, Agricultural Statistics.

1. Study Context and Problem Statement

Agricultural development is an essential engine of growth in Malawi (GoM, 2012). It is also indicated as effective mechanism for combating food poverty. It often results in greater benefits accruing to the poorest segments of the population (National Statistical Office (NSO), 2014; Ravallion and Chen, 2007). It contributes about 40% to the Gross Domestic Product (NSO, 2016). Approximately 90% of households in Malawi depend on agricultural for their welfare security (NSO, 2015).

Success made in agriculture can only be tracked and attributed if consistent data is made available over time and in space. Prevailing data collections have produced conflicting agricultural statistics. Climatic change and weather related effects have led to high demand of agricultural statistics. World Bank (2010) argues that rapidly changing nature of agriculture in less developed countries especially in the errors of climatic change and the emergence of new issues make the available data and methods obsolete. Conversely, agricultural statistics are becoming expensive to collect, compile and analyze. Limited public finance and dwindling donor support of data collection exercises in agricultural sector is another obstacle that NSOcontinue to encounter. In other words, statisticians have to innovate new ways of achieving statistical demands in the agricultural sector in order to provide timely, relevant and consistentagricultural data (Binswanger, 2008). Innovations should at a minimumdisaggregate agricultural data into hard to reach population such as women, rural/urban and many others (International Development Committee, 2013).

Existence of serious weaknesses in agricultural statistics also persist throughout sub-Saharan Africa of which Malawi is not an exception (Carletto et al, 2010). Compliance to statistical standards in most of thesecountries remain low (FAO, 2008). Knowledge about agriculture and its impact on welfare and equity is limited by the lack of available, high quality, and consistent data on rural and gender disaggregated households. Althoughstudies have attempted to understand intra household dynamics, data is lacking to validate cases in terms of intra-household decision-making within agricultural activities (Koirala, Mishra and Sitienei, 2015).

On other hand, agricultural programming would be effectively realized and implemented if policy makers exploit data evidence based decisions. Of which data for informed decisions have to meet quality, timely, relevant and coordinated scopes (Binswanger, 2008). The Malawi National Statistical Office as a government department has this mandate and to exploit best practices that are innovative to ably capture agricultural data in a very cost effective manner and that meet quality dimensions aforementioned. One way would be to must partner with international organizations such as the World Bank, International Food Policy Institute (IFPRI and other institutions to have quality data in the agricultural sector. These institutions would provide an automated technical assistance that most government owned statistical offices lack.

In Malawi, NSO has embarked on this agenda through integrating household surveys with a huge agricultural component where most indicators are tracked. A data quality assurance framework has been developed and declares the needs of adopting a 10 year integrated household survey programme that streamline data collection activities (NSO, 2015).This would achieved both cost effectiveness and efficiency. Similarly, NSO has also reduced the time between panels to facilitate quick and comparable dynamic data of households' welfare in the country. Nonetheless, a rush decision to adopt a survey programme without a verified research would yield more costs than benefits. In this paper, we attempt to provide empirical responses conducting a comparative analysis of cross section, panel and integrated data collections in terms of their value for money, effectiveness and feasibility?

2. Rationale

Agricultural and rural development policies have gained in importance since independence (Moreddu, 2011). In Malawi, more complex information has been demanded to evaluate them (Matchaya, 2014). These new types of information that are at once more local, complex, multidisciplinary and integrated (Moreddu, 2011). Rural development and rural statistical indicators require information that goes beyond the agricultural sector, that is available at a disaggregated level, and which is comparable across area such as agricultural versus non-farm activities, males versus female plot managers (FAO, 2015). This requires significant resources sometimes to the detriment of basic agricultural information.The huge outcry of most Central Statistical Offices to become autonomy is not an issue of professional independence but of financial independence. This means existing data collection approaches may be finance demanding. In other words, a properly design data collection vehicle is critical for most National Statistical Offices for their continued existence and role in the economy.

3. Research Methodology

In this paper, we first adopt a meta-analysis (desk research) of cross section and panel data collection. In other words, we adopted a revelatory case study approach following Fitzgerald and Fitzgibbon (2014). We basically review publishable articles of the living standards measurement study team of the World Bank and World Class Universities that have provided a thorough discourse on data collection approaches.Survey reports that have been reviewed include Integrated Household Survey and Agricultural Production Estimate Surveys. Second, we have tried to interact with technocrats in agricultural statistics so that we derive experiential based understanding of cross section and panel data collection methods. We have lastly tried to relate such data collection approaches to Malawi.

4. Value for Money

Agricultural surveys,such as Agricultural Production Estimate Survey, Cost of Production and other, are determined based on national priorities within the limitations of cost and other constraints (World Bank, 2010).They capture quarterly information on a variety of topics, such as crop areas, yields, production, livestock, pesticides, etc. Carletto et al (2010) points out that such surveys usually collect information on structural characteristics; economic characteristics; labor force characteristics and share of income that goes to household. In the case of Malawi, an agricultural production estimate survey is, a traditional cross sectional survey, conducted quarterly to capture the whole agricultural value chain that is from land preparation, planting and harvesting (MoA, 2016). Nonetheless, it provides data on production, area and yield quantities.

On the other hand, an Integrated Household Survey (Malawi IHS) or Integrated Surveys on Agriculture is more complex than traditional cross-sectional data. This is both analytically and in terms of actual data collection (NSO, 2012). It combines both a cross section and panel data collections. Panel survey sample component areregularly refreshed to maintain the national representativeness of the data (NSO, 2016). It collects a wide variety of indicators as compared to a traditional agricultural production estimate survey.

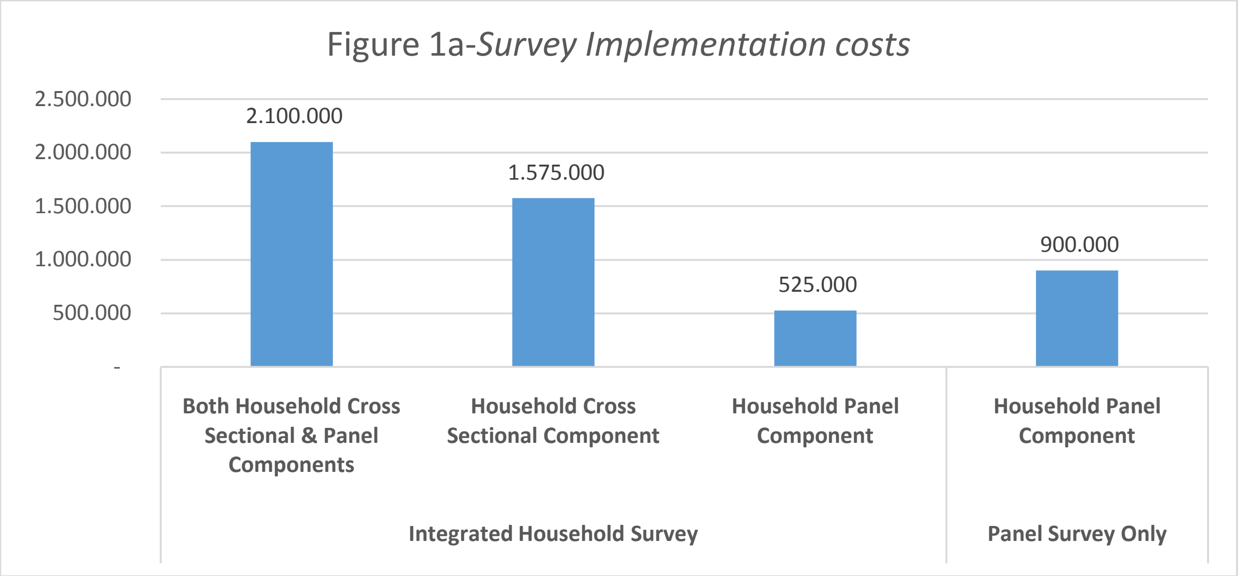
In other words, an integrated household survey fits well in the needs of the country. On average a panel embedded survey in Malawi collects almost all FAO minimum core indicators in agricultural sector. Agriculture questionnaires collects information on a core set of indicators that have been identified through a consultative process with several experts. Additionally, an Integrated Household Survey programmesupports the National Statistical Office (NSO) to generate nationally representative, household panel data with a strong focus on agriculture and rural development through technical assistance, hands on trainings and others.

Table 1: *Core minimum indicators stipulated by UN FAO*

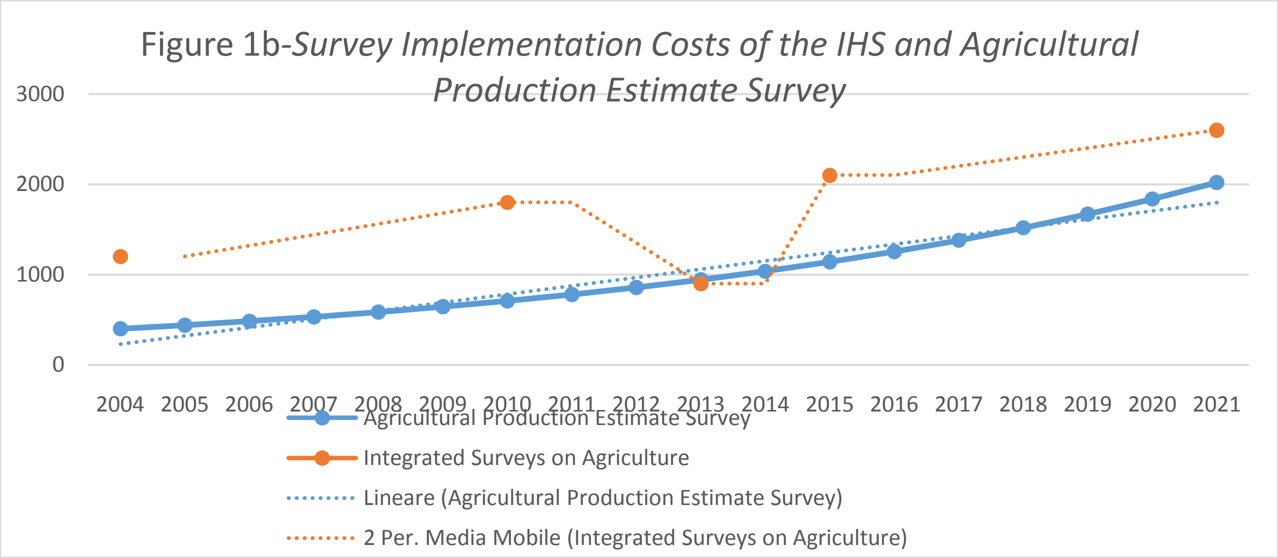
Indicators	FAO minimum core indicators	Integrated Surveys on Agriculture	Agricultural Production Estimate Survey
Geo-variables	√	√	
Garden and Plot Details (rainy/dry season)	√	√	√
Input (Coupon) Use (rainy/dry season)	√	√	√
Crop Cultivation (rainy/dry season)	√	√	√
Crop Sales (rainy/dry season)	√	√	√
Crop Storage (rainy/dry season)	√	√	√
Tree Crop Cultivation and Sales	√	√	√
Livestock	√	√	√
Access to extension services	√	√	√
Household demographics, Education, Health	√	√	X
Housing, Electricity and Sanitation	√	√	X
Food Consumption and Expenditure	√	√	X
Food Security and Anthropometrics	√	√	X
Non Food Expenditures	√	√	X
Assets and Household Ownership	√	√	X
Household Enterprises and Employment	√	√	X
Income, Credit/Loans	√	√	X
Safety Nets, Shocks and Copping Strategies	√	√	X
Internal and International Migration and Remittances	√	√	X

Sources: Ministry of Agriculture (2016); NSO (2014); FAO (2011); FAO (2008)

The Integrated Household Survey is expensive as roughly compared with the Agricultural Production Estimate Survey (APES) (see Fig 1a& 1b). A stand-alone household panel survey component costs more than an APESS. However, if we adopt an integrated household survey approach, the cost of a panel in an integrated household survey is just one quarter of the total cost of the survey.

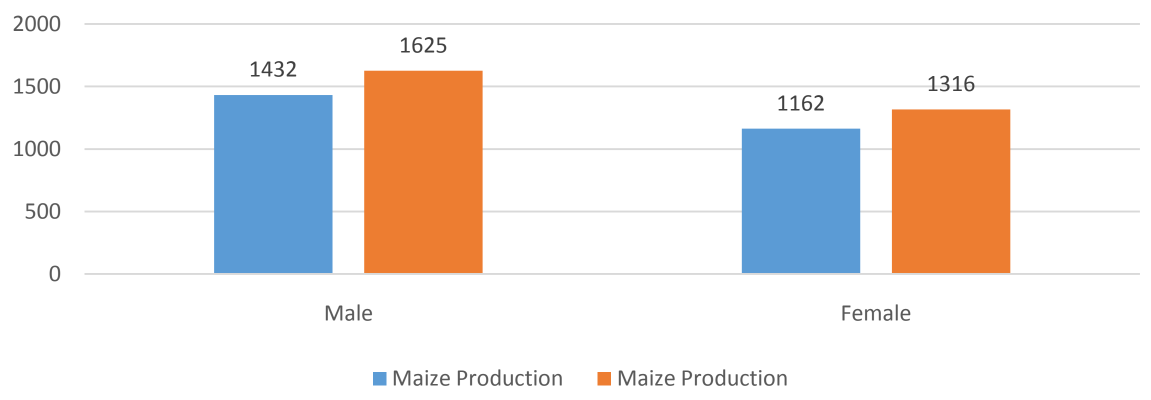


In terms of value for money, an integrated household surveys collects data on all types of household characteristics, not just households with agricultural holdings (Carletto et al, 2010). This allows for comparison between the different economic sectors and other important disaggregation.



Importantly, an Agricultural Production Estimate Survey supports annual decision with regards to areas under cultivation, production and yield. However, this does not permit the analysis of the relationship between the holding characteristics and the characteristics of the household and its members (MoA, 2016; NSO, 2014).

Figure 2-*Maize crop production by gender*



Agriculture is critical if countries are to achieve the poverty targets set forth by Development Goals within the agreed timeframe (World Bank, 2007). In Malawi, the majority of people suffering from food poverty are rural dwellers and other vulnerable groups,including women, who rely heavily on farm activities (GoM, 2015)). Thus, efforts to fight poverty must focus on rural areas and agriculture, and must be gender-sensitive (Carletto et al, 2010).

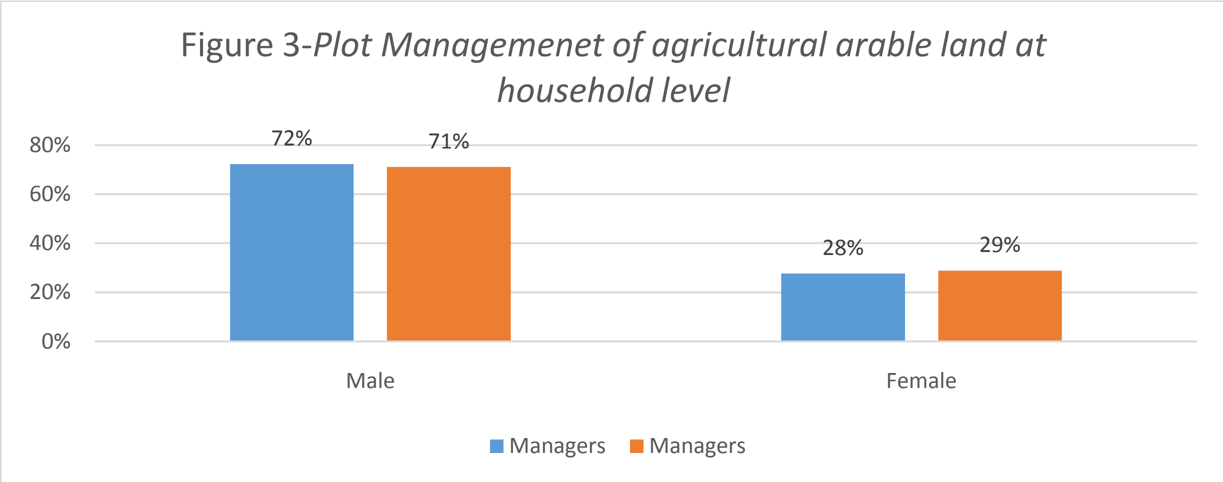
Table 2: *Agricultural characteristics by gender of household heads*

	Female Heads	*Male Heads*
land area in Ha	0.97	1.15
land value in Mk	48154	53200
land rent in Mk	3369	3700
seed in kg	14	20

Source: Koirola, Mishra and Sitienei (2015)

An Integrated Household Survey approach is implicitly therefore designed to meet this global development goals' call as it collects individual-level data by gender on control of household resources, decision-making and participation in agriculture and off-farm activities (see Figure 2 & 3). This provides researchers with a platform to conduct gender-specific analysis related to agriculture and off farm activities. From an

Integrated Household Survey approach we can assess the changes in household management between genders.



5. Advantages

First, research based on cross-sectional data helps to describe snapshots, and with repeated cross-sectional data, to measure broad trends at the macro level. However, they do not assist in understanding the dynamic aspects of the population change at the individual level (Wijesekere, 2009). This limitation portrays lack of capacity to discuss structural change and non-existence of data that could describe across individual and household characteristics. In 2013, a household panel in Malawi provided dynamics over various variables that could be correlated at individual and /or gender level (NSO, 2014).

Second, as the panel surveys have both cross-sectional and time-series elements; each wave is similar to a cross-sectional survey and when data for more than one wave have been collected then it will become a time series. Thus, panel surveys allow cross-sectional analysis of a particular issue of policy relevance as well as providing time-series analysis to assess trends, at the individual level, as opposed to aggregate-level analysis that is possible with cross-sectional data. More importantly, panel surveys provide opportunity to examine transitions between states–flow data to analyze change.

Third, like panel surveys, repeated cross-sectional surveys can collect information on the target population at different points in time, but without the assurance that the subsequent surveys will include the same population covered in the previous rounds. The advantage of panel surveys, therefore, is that they cover the same persons at different points in time, including split families or households, and add new members 'born into' the sample when they become in-scope according to the criteria used for sample management. This means a panel would still achieve dynamisms in human society (Wijesekere, 2009).

Panel data can further provide valuable information for policy-makers on an issue of policy significance that cross-sectional data cannot provide. At times panel data provide information that is quite different to that derived from cross-sectional analysis. In Malawi, for example, there are large differences in the estimates of the number of farm households between the Ministry of Agriculture (3.4 million farm households) and the National Statistics Office (2.47 million rural households), which in turn affects the accuracy and effectiveness of planning for the subsidized input program (School of Oriental and African Studies, 2008).

It is well known that cross-sectional data cannot resolve the issue of ambiguity in correlation and, more importantly, cannot confidently demonstrate the direction of causality (Davies, 1994:28). As panel surveys interview the same individual over different points in time, and panel data have a time order of measurement, they are suitable for assessing causality between variables (Hsiao, 2014). Panel data have the capacity to identify stability and change at the individual level. The causal association can be determined when the cause precedes the effect (or outcome of interest). Panel data have the advantage of convincingly identifying this. A detailed discussion of advantages of panel data collection can be found through work of Hsiao, 2014.

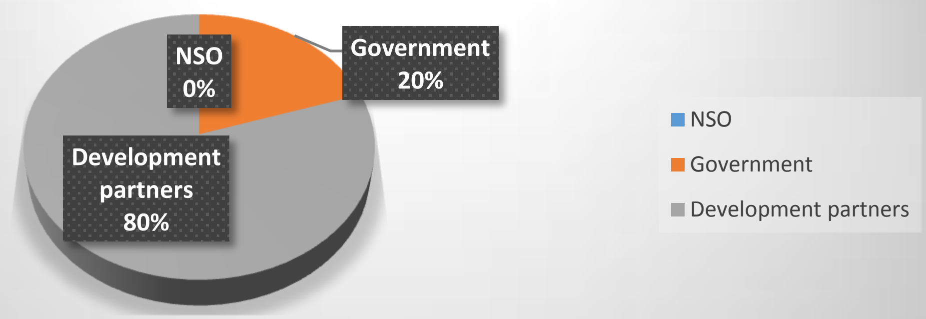
The current statistical system provides a fresh cross section of data each year for a new set of (randomly selected) agricultural holders. This format is very good, however, it does not enable policymakers to empirically assess the effectiveness of agricultural interventions over time or investigate medium- to long-term agricultural dynamics. For this, they need a subsample of agricultural holders to be surveyed repeatedly over a number of years(IFPRI, 2011).

Generally, an Integrated Household Survey improves the quality of household survey data; increases the capacity of statistical institutes to perform household surveys; improves the ability of statistical institutes to analyze household survey data for policy needs and provides policy makers with data that can be used to understand the determinants of observed social and economic outcomes (NSO, 2015).

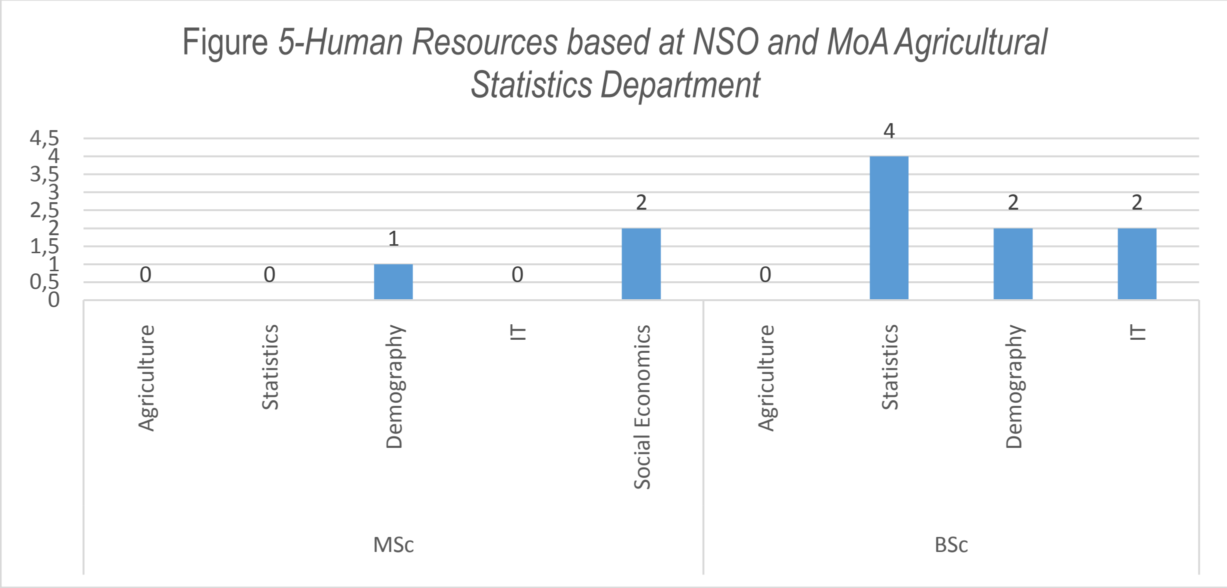
6. Limitations

Panel data collection demands financial and human capacity. Malawi, for which agriculture is a critical source of livelihoods, lacks the financial resources to generate survey data related to agriculture and off-farm activities (see Figure 4). It is noted that most agricultural survey collections are financially supported by development partners. This creates a threat for continued panel data collection in Malawi. For example, in 2015, an Integrated Household Survey failed to take off because of frozen development partner support. Even with sufficient financial resources, the NSO still lacks agricultural driven human resources to collect and analyze such data in a cost-effective and sustainable manner (see Figure 5).

Figure 4-*Financial Contribution towards implementation of household surveys*



Agricultural data are often collected in institutional isolation, with little coordination across sectors and little analytical value-added beyond the sector. For example, the Ministry of Agriculture collects agricultural data using a production estimate survey while the NSO collects agricultural data using an HIS or National Agricultural Census or Welfare Monitoring Survey. Carletto et al (2010) reports that there is disparity between number of households and yield reported by the MoA and the NSO due to institutional isolated survey designs and implementation. Lastly, there is also lack of analytical capacity that has created a vicious cycle of poor analysis undermining the demand for high-quality data. For example, Figure 5 shows that there is only one personnel with a Masters in Economics and one staff with Masters in Demography. These personals do not have agricultural background.



Author: Calculations

While panel data have numerous advantages over cross-sectional data they too are subject to limitations. The major limitation is the cost. Depending on the methods used to choose the samples, the cost of the first wave of a panel survey is expected to be not much different from that of the cross-sectional survey. Conducting subsequent waves in a Panel survey is expensive because it involves tracking all the original sample members who are in-scope for subsequent surveys.

Panel surveys are considered not as good as cross-sectional surveys at giving cross-sectional estimates if the subsequent waves of panel surveys are not representative of the population or subject to a high level of coverage errors, which are likely to accumulate over time (Deaton et al, 1986). Additionally, the response rates of subsequent waves could also be lower than those observed in cross-sectional surveys, partly because of dropouts from later waves and difficulty in tracing sample members.Obtaining exactly the right balance between overlaps and new households requires more detail on preferences than most investigators could be expected to provide for a multi-purpose survey, but the point remains that a rotating design of some sort will generally be better than either a pure panel or independent cross-sections.

7. Conclusion and Recommendations

The paper adopt a conclusion statement made by Deaton, Solon and Ashenfelter (1986) that, while there are genuine difficulties, there are good arguments for collecting panel data. Collecting panel data inMalawi is a sensible enterprise through generating both the dynamics and annual level statistics. However, they are very expensive. It would therefore be important for the panel component to be integrated into cross section household surveyvehicleas in the current Integrated Household Survey design so that there is reduction in costs of implementing a fully-fledged panel.

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Demographic and social characteristics of the agricultural producer's households

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ABSTRACT

The Food and Agriculture Organization of the United Nations (FAO), in its "World Programme for the Census of Agriculture 2010" and "Global Strategy to Improve Agricultural and Rural Statistics", recommends capturing the demographic and social characteristics of the household members of a producer that performs agricultural operations, regardless of whether it is the household´s predominant activity or only a secondary source of income.

Knowing the characteristics of the population that lives directly on agricultural or livestock activity, allows a better study of the conditions under which rural producers perform their duties, and provides more elements to perform various analyzes of its economic and social environment, thus contributing to the design of public policies and support programs.

In Mexico, projects that generate social-demographic statistics provide the country with a wealth of information on the characteristics of the population and, although these statistics account in particular localities with fewer people, they do not provide specific data on households located in rural areas, in which the persons responsible of the management and decision making of the agricultural and forestry production units live.

Therefore, taking advantage of the performance of the National Agricultural Survey 2014 conducted by the National Institute of Statistics and Geography (INEGI), a complementary chapter was included in the questionnaire, which guaranteed the collection of the producer´s data and of the people living in the dwelling. This yielded information on aspects such as kinship, age, gender, economic dependence, indigenous self-description, indigenous language, education and participation in farming or other economic activity.
This paper is aimed at presenting various shades of the agricultural producer´s household, such

as:

- Economic and social characteristics of the small, medium and large agricultural producers
- Characteristics of the production units run by women farmers
- Characteristics of the production units run by indigenous farmers
- Economic and social characteristics of the persons performing family agriculture
- Production units' social characteristics according to producer's schooling
- Characteristics of both households whose economic dependence comes entirely from farming as those households where agricultural production is a marginal activity.
    - Characteristics of rural households in the different regions of the country.

Keywords: sociodemographic, farming, livestock, support programs.

Introduction

The 2014 National Agricultural Survey

In this context, the National Institute of Statistics and Geography (INEGI), conducted the 2014 National Agricultural Survey (2014 ENA), which was conceived as a survey for exploiting data on the main species produced in the agricultural sector in Mexico.
2014 ENA is the second from a series of surveys that INEGI has raised as part of an agricultural information system that provides structural information and in both structure and the circumstances surrounding the sector to meet the data requirements of the primary sector, thus contributing to decision-making and to the definition of programs for the producers and country benefit.
Selected products for 2014 ENA are those that generate higher added value in the agricultural and forestry sector in Mexico and that are considered in the laws and programs that regulate objectives, priorities and policies for economic growth, and particularly for the Agricultural sector.
Thus, the final list for the survey includes 34 priority products:

> Agricultural products: white corn, yellow corn, forage maize, sugar cane, wheat grain, avocado, grain sorghum, beans, chili, alfalfa, tomatoes, potato, melon, watermelon, coffee, orange, grape, banana, lemon, mango, onion, pumpkin, zucchini, green tomato, cotton, apple, cocoa, rice, barley and soybeans.
>
> Livestock products: cattle, milk, pork, poultry and eggs.

As well as nine more products that are significant in some regions of the country:

> Agave in Jalisco; forage oats in Chihuahua, Mexico City, Durango, State of Mexico and Zacatecas; coconut in Colima and Guerrero; strawberry in Michoacan; guava in Aguascalientes, Michoacan and Zacatecas; nopal vegetables in Mexico City; pine in Chihuahua, Durango and Michoacan; forage sorghum in Coahuila, Nuevo Leon and Sonora; and blackberry in Michoacan.

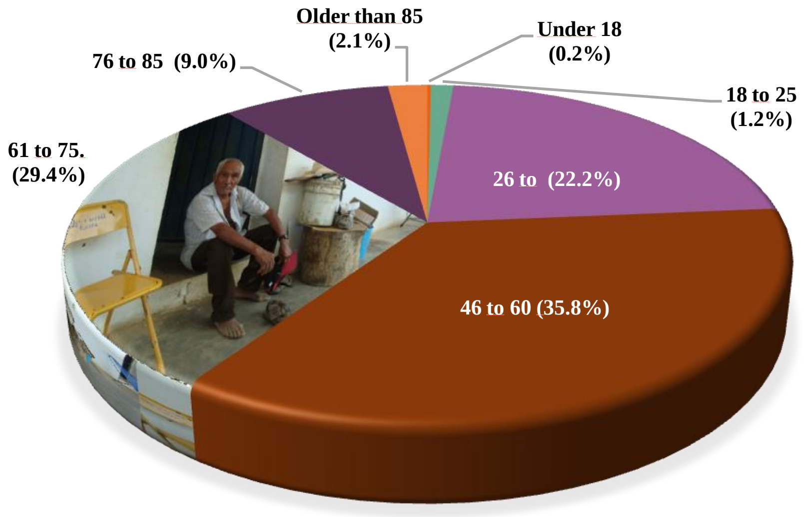
2014 ENA, estimated 3.8 million production units that cultivated or exploited from the above products. Final data are supported by the design of a probabilistic sample, except for four products (poultry, eggs, pine and blackberry), where a deterministic design was applied.

This survey provides information on the supply of food products; needs and employment opportunities in the field; the participation of women in farming and livestock activities; the destination of crops; technological innovations for production; degree dependence on fertilizers and other inputs; the needs of natural resources; water and irrigation systems benefits; seeds availability; use and deterioration degree of vehicles, tractors and machinery; financing; insurance; the main problems producers' deal with; and social and demographic characteristics of people living from agricultural production; among other topics.
Overall, the results of this survey provide a wide range of possibilities to know about quantitative and qualitative information from agricultural and forestry production units; specifically, the results of the 2014 ENA provide insight into typologies from the producer and the members of his household, such as kinship, age, sex, education, economic dependence, indigenous self-identification, indigenous language and participation in farming or other economic activity, as shown in the following sections.

Age and education of farm producers

Obtained data reflect one of the biggest current problems in the Mexican countryside, which is the producers' age: 76.3% are 46 or older, and from that percent, 40.5% specifically reported to be older than 60 years old; i.e. agricultural activities are not being undertaken by new generations, and that includes producers' children.

2014 National Agricultural Survey
Producer's age (%)



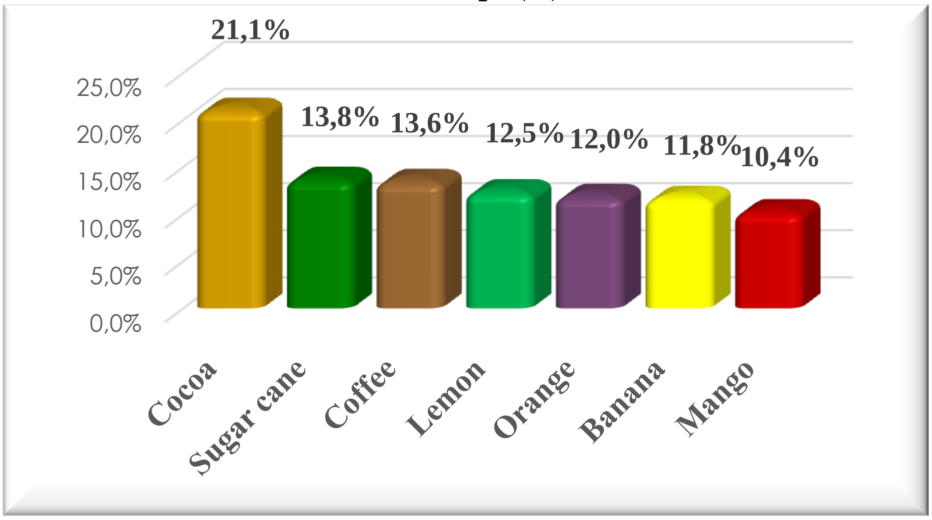
Concerning education level of the producer's and people living in farm households, most producers have an elementary education level (57.6%) and only 9% reported a high school education level or higher; in comparison, the percent of inhabitants of the country, not in the agricultural sector, shows a tendency to have higher education levels, since 17.7% achieved a high school education level or higher. By comparing these data with those of the total population, it can be determined that, in general, the education level of rural producers and their families is below the average of the total population, where

26.8% studied high school or has a bachelor's degree (according to the 2010 Population and Housing Census in Mexico).

Production units managed by women and participation of women

From surveyed production units, 11.3% are under women's responsibility. In the case of crops, according to production volume, participation of female producers stands out in obtaining cocoa, sugar cane, coffee, lemon, orange, banana and mango.

2014 National Agricultural Survey
Production units whose owner is a woman
Production volume according to total national production
Main crops (%)

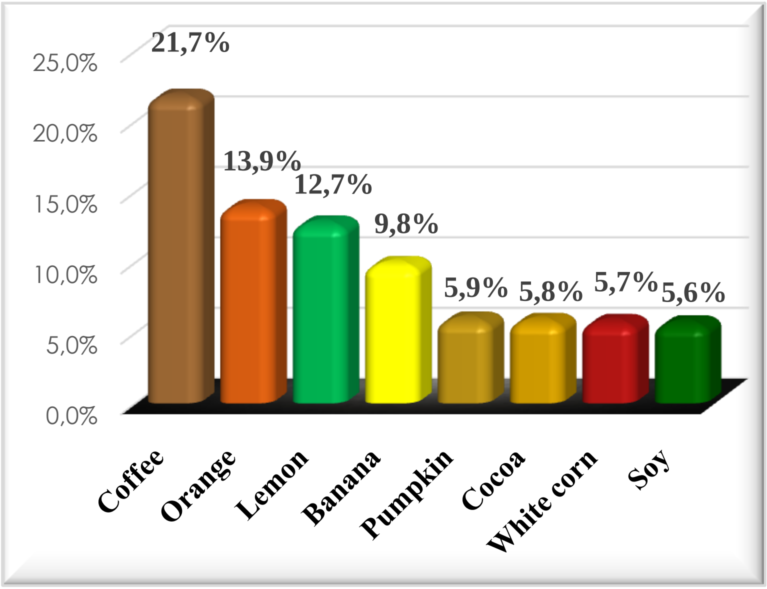


The participation in labor force in agricultural activities was of 17 women per every 100 male workers; female participation is higher in the farming activities (18.1%) than in cattle activities (15.8%).
It can be established that the participation of women in agricultural activities is significantly lower than the participation in not agricultural activities, where, in average, there are 44 women for every 100 persons employed (according to data from 2014 National Economic Censuses in Mexico).

Production units of indigenous self-identification

One of the concepts that was collected in 2014 ENA is the term *indigenous self-identification,* i.e. if the farmer considers himself indigenous because of his ethnicity or for preserving the customs and traditions of his ancestors.
The result indicates that 18% of the surveyed producers were self-identified as indigenuos, of which 81.8% stated speaking a native language.
Consequently, 18% of agricultural production surveyed units, are led by an indigenous producer, but that only represents 8.5% of production volume. The main crops they produce are coffee, orange, lemon, banana, squash, cocoa, white corn and soybeans.

2014 National Agricultural Survey
Production units whose owner identifies himself as indigenous
Production volume according to total national production
Main crops (%)



4.6% of bovine stock and 3.8% of pig stock nationwide, correspond to the production units whose holder identifies himself as indigenous.

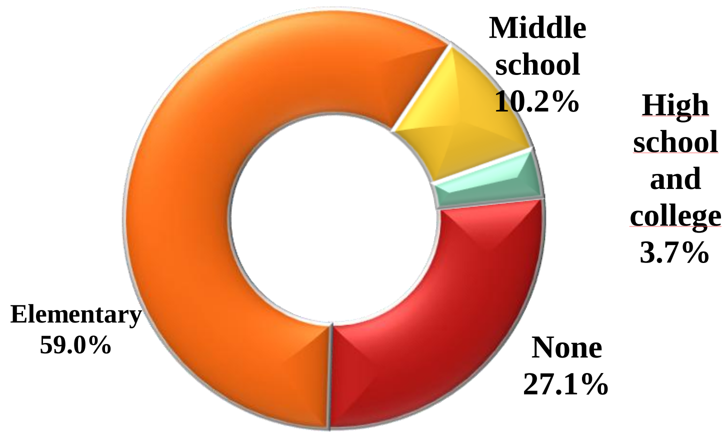
Regarding the destination of the production, 53.8% is destined to self-consumption (47.9% to cattle, 4.9% to the family and 1.0% to sowing seed), 43% goes to sales and 3.2% corresponds to losses for wastage.

2014 National Agricultural Survey
Production units whose owner identifies himself as indigenous
Production volume by destination (%)

	Destination of production	Indigenous production units	Total production units
	Sale	43.0%	73.4%
	Household consumption	4.9%	1.6%
Self consumption (53.8%)	Cattle consumption	47.9%	20.5%
	Seed for sowing	1.0%	0.9%
	Losses for wastage	3.2%	3.6%

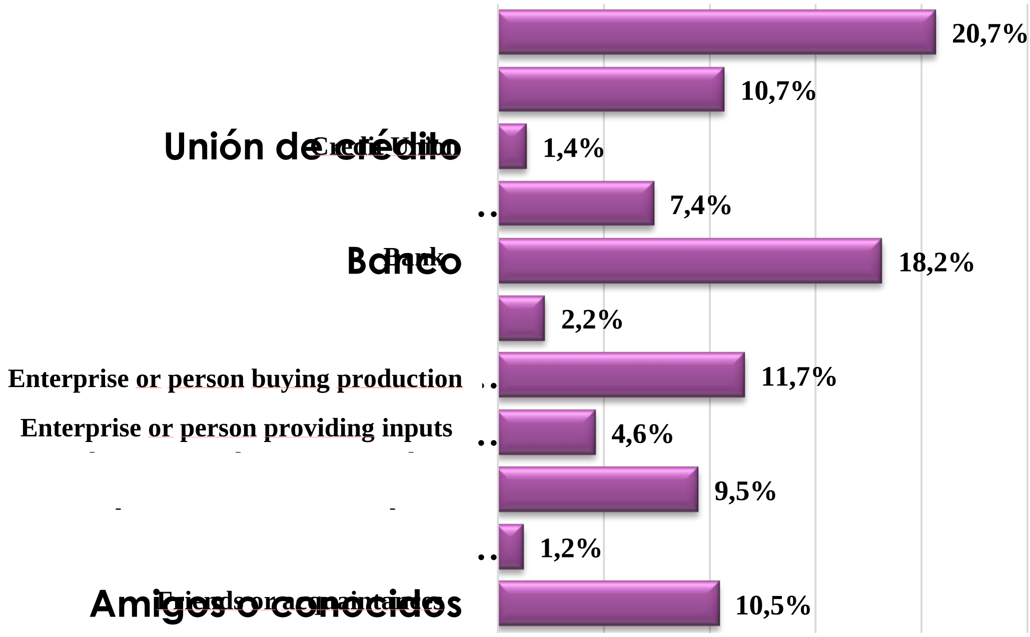
In production units led by indigenous, one of each five employed persons are women and four are men. As for schooling, 27.1% have no educational level, 59% have some elementary grade, 10.2% some middle school grade and only 3.7% reported to have studied high school, or college.

2014 National Agricultural Survey
Production units whose owner identifies himself as indigenous
Education and indigenous language speakers (%)



4.8% of the production units whose holder identifies himself as indigenous, obtained some type of financing for his agricultural activities with savings banks and banks as their main suppliers.

2014 National Agricultural Survey
Production units whose owner identifies himself as indigenous
Sources of credit or loaning
4.8% of indigenous production units obtained credit
(Percentage is 10.4% at national level)



Family Agriculture

A subject in which international agencies have special interest is "Family agriculture", in order to define public policies aimed at supporting these types of units (according to the Center of Studies for Sustainable Rural Development and Food Sovereignty of the Chamber of Deputies, family agriculture is defined as *agriculture that is performed predominantly with the work of the producer and his family*).
For 2014 ENA results, the units that reported only family labor without receiving a wage or salary were considered as family agriculture production units (all units that reported having hired any type of personnel for agricultural work were excluded).
Under this definition, 32.6% of the agricultural production units in Mexico perform family agriculture, which represents 9.9% of the production volume.
As for the products generated by these units, the cultivation of cocoa, beans, white corn, orange and coffee stand out. Also, 15.5% of bovine stock and 8.8% of pig stock are located therein.
As in production units under responsibility of indigenous, most of the production is destined to saleS (53.9%), while self-consumption represents 38.6%, (where cattle consumption predominates with 47.9%) . The wastage in this case represents 7.4%.

Another interesting aspect is the type of buyers, where intermediaries stand out (34.9% of total production), followed by the final consumer (17.2%) and packing and processing industries (5.4%). And to a lower extent, the sales to commodity markets, malls and supermarkets, among others.

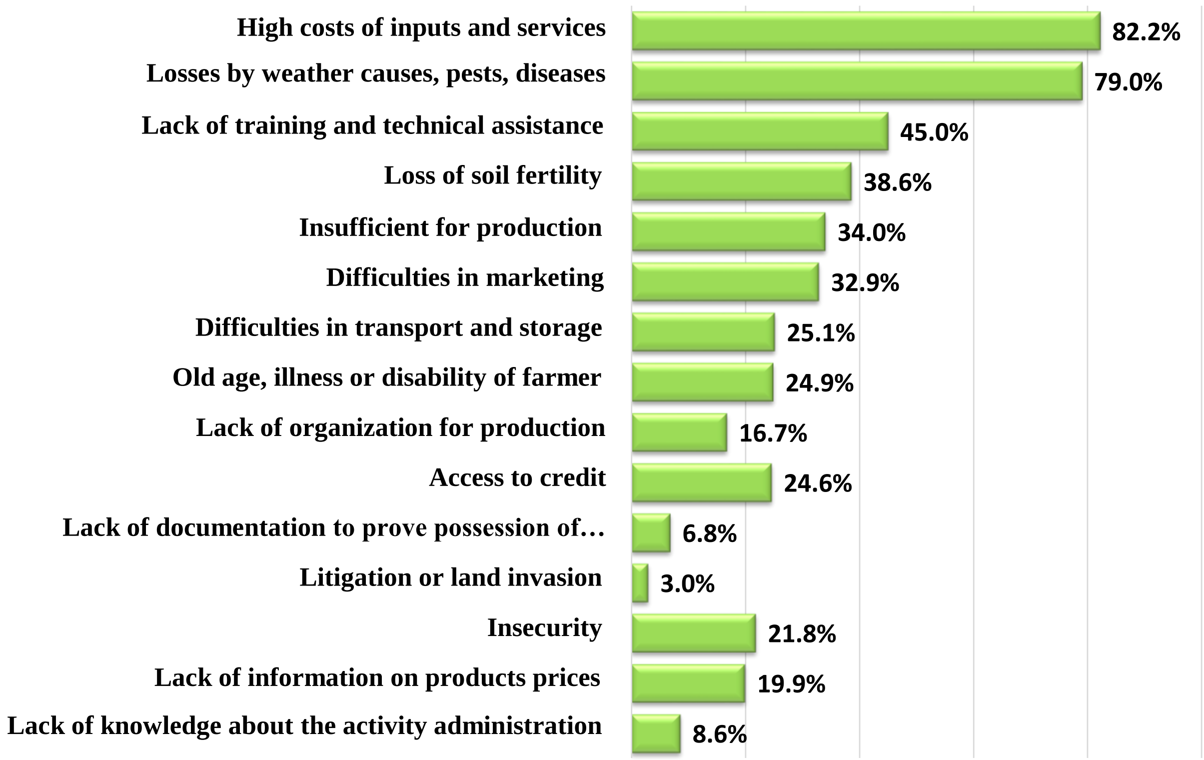
2014 National Agricultural Survey
Production units that perform family agriculture
According to sales of agricultural production (%)

Addressee of sold production	**Production units that perform family farming**	**Total production units**

Directly to consumer	17.2%	24.5%
Intermediary (broker)	34.9%	45.0%
Commodity markets	1.4%	2.6%
Malls or supermarkets	0.5%	0.8%
Packing or processing industries	5.4	5.0%
Other country	0.0%	0.1%
Other buyer	2.5%	2.6%

On another issue, 6.2% of the production units that perform family agriculture obtained some type of credit, mainly from savings banks.
It is worth noting that family agriculture production units reported that their main problems to carry out their agricultural and livestock activities are the high cost of inputs and services (82.2% of the units), losses due to weather causes, pests and diseases (79%) and lack of training and technical assistance (45%).

2014 National Agricultural Survey
Family agriculture production units
Problems presented during the development of the activities of agricultural production units (%)



Conclusion

ENA 2014 was created as survey that considers several matters of interest from institutions that regulate, assess and determine support programs for forestry and agriculture producers. Its results a wide range of possibilities, which allows us to know among other topics: particularities of women, farmers, important features of family agriculture and the conditions of production for indigenous producers. ENA 2014 provides significant indicators for public policy to be focused on supporting disadvantaged groups, by implementing practices that meet their needs.

References:

http://www.cedrssa.gob.mx

http://www.inegi.org.mx/est/contenidos/proyectos/encuestas/agropecuarias/ena/ena2014/

THE AGRICULTURAL INTEGRATED SURVEY (AGRIS): RATIONALE, METHODOLOGY, IMPLEMENTATION

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ABSTRACT

The Agricultural Integrated Survey (AGRIS) is a farm-based modular multi-year survey program. The AGRIS methodology is being finalized by FAO in the context of the Global Strategy to improve Agricultural and Rural Statistics. AGRIS complements other relevant initiatives such as the World Bank LSMS-ISA and aims to scale-up these global efforts. AGRIS implementation is just starting with partner countries.

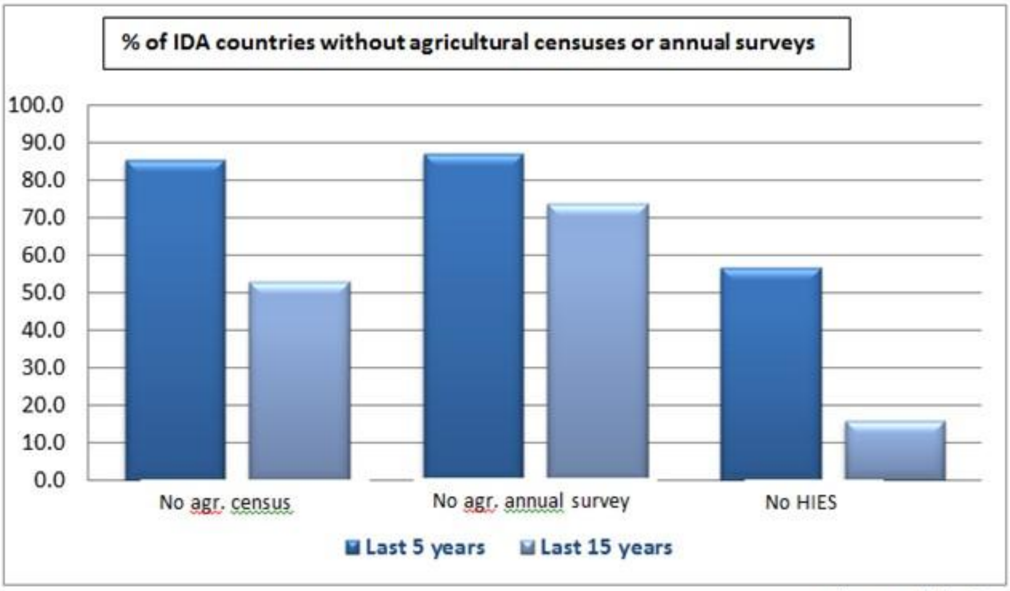
AGRIS is designed as a cost-effective way for national statistical agencies to accelerate the production of quality disaggregated data on the technical, economic, environmental and social dimensions of agricultural holdings. The data generated is meant to inform policy design and implementation, as well as improve market efficiency and support research. AGRIS constitutes an invaluable data source and provides the framework for designing, monitoring and evaluating any agricultural and rural policy or investment. AGRIS is designed to be particularly relevant for developing countries. Together with the agricultural census which it complements, a versatile agricultural market information system, and an appropriate use of remote sensing and administrative data, AGRIS is a cornerstone for the establishment of a comprehensive rural information system.

National agencies that are willing to design and implement a customized AGRIS will find in the AGRIS Toolkit the necessary resources in terms of (1) technical methodology, (2) specialized survey tools and instruments that use the latest knowledge and technology and cover the full range of survey steps, and (3) budget and institutional framework guidelines. Currently, FAO and its partners are scaling up a network of expertise, especially at regional level, to provide the necessary training, technical assistance and funding opportunities.

Keywords: agricultural integrated surveys, farm level data collection, modular approach, SDG, FAO guidelines

1. Rationale

3.1 The need for more, better, cheaper and faster statistical data in the agricultural and rural sector generally is widely recognized. While some progress on accessing existing information has been made in recent years, thanks to the traction of the open data movements, critical gaps on data production still remain in many countries. These gaps are largely explained by an absence of quality data collection, whether censuses or surveys. Some countries have yet to successfully leverage the technical and institutional innovations available for the industrialization of statistical production. Indeed, the majority of IDA countries1 have not conducted any agricultural annual surveys or censuses over the last 15 years, as shown in the table below:



(source: Author)

Figure 1: *The lack of agricultural surveys and censuses in IDA countries*

3.2 The Global Strategy to Improve Agricultural and Rural Statistics was endorsed in 2009 by the United Nations Statistical Commission, to address these concerns relating to poor data availability or quality, and the lack of capacity in developing countries. The Global Strategy is a coordinated effort to provide a conceptual and institutional framework for the production of data, to establish a Minimum Set of Core Data (MSCD) required to meet the current and emerging demands of national development policies, to develop cost-effective methodologies for data production and use, and to establish the necessary governance structures and capacities.

[1] http://www.worldbank.org/ida/borrowing-countries.html

3.3 As one of the main features of cost-effective methods, the Agricultural Integrated Survey (AGRIS) is designed to help national agencies accelerate the production of quality disaggregated data on the technical, economic, environmental and social dimensions of agricultural holdings[2]. AGRIS builds on the previous work of the Global Strategy and presents a unique opportunity to channel these methodological innovations, and to have a real impact on data systems on the ground.

3.4 The data generated by AGRIS is meant to inform policy design and implementation, improve market efficiency and support research. AGRIS constitutes an invaluable data source and provides the framework for designing, monitoring and evaluating any agricultural and rural policy or investment. The proposed generic set of AGRIS questionnaires will generate 65% of the MSCD data requirements. It will also provide basic data for monitoring the relevant SDGs. AGRIS provides essential and direct information for the following 6 SDG indicators: 2.3.1 / 2.3.2 / 2.4.1 / 5.4.1 / 5.a.1.a / 5.a.1.b. Additionally, AGRIS provides essential but indirect information for the following 16 SDG indicators: 1.1.1 / 1.2.1 / 1.2.2 / 1.3.1 / 1.4.1 / 1.4.2 /2.5.1 / 2.5.2 / 5.b.1 / 7.1.1 / 8.5.1 / 8.5.2 / 8.7.1 / 8.8.1 / 9.1.1 / 17.8.1. Finally, AGRIS is expected to generate the flow of quality data required to monitor regional policy frameworks, such as the African Union Comprehensive Africa Agriculture Development Programme (CAADP).

3.5 AGRIS, being a 10-year integrated survey program, lays the foundations for the creation of an efficient agricultural statistical system. Together with the agricultural census which it complements, a versatile agricultural market information system, and an appropriate use of remote sensing and administrative data, AGRIS is a cornerstone for the establishment of a comprehensive rural information system.

3.6 Without AGRIS, existing data gaps can only be filled by ad-hoc suboptimal mechanisms with high transaction costs. This would further increase the burden on people, agricultural holdings and data systems, and would not guarantee the data quality required by users. Ultimately, this would prevent any monitoring of these policy frameworks and would constitute an obstacle to the accountability and transparency required by functioning markets.

2. Methodology

2.1 The AGRIS methodology is being developed by FAO in the context of the Global Strategy. Some activities involve partner agencies, for example the World Bank and ILO. Research and testing is also conducted with national agencies on an ad-hoc basis.

[2] "An agricultural holding is an economic unit of agricultural production under single management comprising all livestock kept and all land used wholly or partly for agricultural production purposes, without regard to title, legal form, or size. Single management may be exercised by an individual or household, jointly by two or more individuals or households, by a clan or tribe, or by a juridical person such as a corporation, cooperative or government agency. The holding's land may consist of one or more parcels, located in one or more separate areas or in one or more territorial or administrative divisions, providing the parcels share the same production means, such as labour, farm buildings, machinery or draught animals." From FAO, WCA 2020.

Overall data collection strategy

2.2 AGRIS is synchronized with the Agricultural Census and operates over a 10-year cycle. AGRIS proposes to decrease the burden of conducting censuses by scheduling the collection of thematic data (e.g. non-structural data) over this time frame. This will contribute to a more regular flow of data, which would be more in line with the limited capacities currently in place for the production and use of statistics.

2.3 AGRIS consists of a collection of questions that can be classified in one of two main categories: a core section and a rotating section. The core section (also referred to as the ‘core’ or ‘core module’) focuses on a range of different themes that remain largely the same in each survey round. The rotating section (‘rotating modules’) is devoted to specific themes, the implementation frequency of which will vary among countries with different agricultural systems and data demand priorities.

2.4 The following table summarizes a possible modules flow for the four recommended modules: ‘economy’, ‘labour force’, ‘machinery and equipment’, and ‘production methods and environment’. The financial and human resources input required to sustain and implement such a set-up is relatively stable over the 10 year cycle, making it a viable set-up for a data producing agency. The targeted annualized budget for an IDA country for such a set-up is within the USD1m – 1.5m range. The flexible, modular nature of AGRIS makes it easy to modify this proposed setting and thus enhance its national relevance and its cost-effectiveness. Additional rotating modules may also be added to respond to additional specific data needs.

	Years	0	1	2	3	4	5	6	7	8	9	10
Agricultural Census		●										
AGRIS Core Module	AH Roster		●	●	●	●	●	●	●	●	●	●
	Crop production		●	●	●	●	●	●	●	●	●	●
	Livestock production		●	●	●	●	●	●	●	●	●	●
AGRIS Rot. Module 1	Economy				●		●		●		●	
AGRIS Rot. Module 2	Labour force			●				●				●
AGRIS Rot. Module 3	Machinery and equipment					●				●		
AGRIS Rot. Module 4	Production methods and environment				●			●				●

Figure 2: *Proposed AGRIS modules flow*

2.5 In order to provide timely information for market efficiency and decision making, data collection should be conducted several times during the year. This is particularly true for the Core Module in countries with several crop periods. Rotating Modules, in particular the Economy and Labour Force modules, could also require several waves of data collection in their years of implementation. Sub-sampling plans could be used to accommodate budget constraints, while producing more frequent data with different levels of statistical significance.

2.6 Survey-to-survey imputation methods can be a cost-effective way to fill some of the data gaps in the AGRIS scheme above, or between AGRIS and other relevant surveys (such as stand-alone labour force surveys). The key challenges for survey-to-survey imputation are that the two types of surveys (or modules) must be designed in a similar way (including questions asked), and the model parameters must not change over time.

Data collection mode

2.7 In the context of developing countries, improving data quality, and in particular accuracy and timeliness, remains a top priority. Face-to-face interviews carried out by professionals enumerators remain the best means of quality data collection. When required, data collection could include the use of self-reported log-books (or SMS log-books), for example in the case of multiple harvest seasons or livestock data (Core Module), or cost of production (Rotating Module 1). The use of CAPI technologies is recommended, to improve data quality and timeliness. Add-on devices to the mobile CAPI-enabled platforms could be used to perform a number of direct measurements – whether geocoding and plot area measurements (GPS), or measurements relating to the environment (leaf cover indices, soil and water characteristics, etc.). Mixed-mode data collection will be piloted to ascertain the benefits of surveying a panel of household holdings by phone and a panel of non-household holdings by means of web questionnaires. The systematic use of the GPS coordinates of the location of holdings and plots is recommended, to accelerate the ground-truthing of complementary remote sensing information systems.

Sampling

2.8 The AGRIS sample techniques and sample size will be decided by the implementing national agencies, based on the sample frames available, the capacities to design and implement complex sampling techniques and corresponding field work, the budget available and the ultimate data accuracy and disaggregation required.

2.9 Specific and detailed sampling guidelines and tools are provided in the AGRIS Toolbox (see paragraph 27 below). These tools are based on the advanced research conducted by the Global Strategy on Multiple Frame Sampling and on the Integrated Survey Framework.

2.10 Different theoretical and practical issues relating to frames exist, and, in many countries, still limit surveying options and eventually reduce data quality and usability. These issues range from generic issues, such as frame coverage (for list frames in particular) to more specific issues, such as the poor accuracy of livestock statistics based on area frames. Guidance upon these matters will be provided in the AGRIS Toolkit.

2.11 The AGRIS sampling strategy is versatile, to be able to meet the different national situations. In a nutshell, the strategy is articulated around the following elements:

- Stratified multistage random sample for farms from the household sector, based on a list frame when relevant or on an area frame (points or segments)
- Stratified simple random sample for farms of the non-household sector
- Panel sampling to enable longitudinal analyses
- Subsampling for rotating modules

2.12 Seasonality is a key dimension in agriculture. Right timing of data collection is of critical importance. The appropriate use of sub-samples and panels will allow AGRIS to capture some of the seasonality factors. Methodological options to administer data collection only once or several times a year are provided - both for the core and the rotating modules.

Topics covered and data items

2.13 AGRIS covers different technical, economic, environmental and social dimensions of agricultural holdings through its core module and its 4 rotating modules: ‘economy’, ‘labour force’, ‘machinery and equipment’, and ‘production methods and environment’. The following tables list the proposed data items for each module. The AGRIS Toolkit further details these data items and proposes corresponding generic questionnaires.

2.14 AGRIS collects sex-disaggregated data on key topics, through both the core and the rotating modules. This entails a more refined identification of male and female headed households, and will help to assess women's contribution to agriculture through labour and their access to and control of productive assets, resources and services.

2.15 Different series of generic questionnaires will be proposed for the AGRIS core module, to capture the variety of farming systems worldwide. The core module will collect data on the following topics:

<u>CORE MODULE</u>

1. Ide ification and general characteristics of the holding
2. emographics and social characteristics *[HS-AH only]*
Demographics Social protection : safety nets Social protection : transfers / gifts
3. olding housing infrastructure and key assets *[HS-AH only]*
4. ccess to markets and information
Access to agricultural markets Access to information
5. Pro ction Methods and Environment
6. abour
Labour input on the holding Work force availability
7. conomy
Access to finance
8. gricultural Productions
Crops: temporary crops Crops: temporary crops, next campaign Crops: permanent crops Livestock Milk, eggs and other animal productions Aquaculture and fisheries
9. Pro ction shocks and coping mechanisms

2.16 The four AGRIS rotating modules will collect data on the following topics:

<u>ROTATING MODULE 1: ECONOMY</u>

1. ans of production (no labour)

Land tenure Property of livestock Storage capacity
2. In me
Total income Income from agricultural activities Income from other gainful activities Subsidies/aid received
3. osts of production
Linked to crop production Linked to livestock production Salaries Insurance Linked to other gainful activities
4. M n commercial networks for the production
5. redit and access to financing
6. ccess to information and other issues

ROTATING MODULE 2: LABOUR FORCE

1. ousehold members' contribution to the agricultural holding (HH sector only)
Basic demographics information Participation in agricultural activities of the AH (incl. salary/wages; employment/own use production, etc.) Participation in diversification activities of the AH (incl. salary/wages; employment/own use production, etc.) Participation in other activities (incl. unpaid domestic activities, care, other activities related to own family AH) Managerial role in the agricultural activities on the AH
2. ousehold members' other working activities - diversification (HH sector only)
3. ired labour of the AH (HH and non HH sectors)
Basic demographic information Participation in agricultural activities (incl. salary/wages) Participation in diversification activities of the AH (incl. salary/wages) Wages / labour cost Work conditions (incl. decent work, informality, etc.)
4. ther labour force used in the AH (HH and non HH sectors)
Non-permanent employees (seasonal) Agricultural work carried out by a specialised company Other labour force

ROTATING MODULE 3:MACHINERY AND EQUIPMENT
(Types and quantities in use, access and ownership)

1. M hinery and Equipment - types & quantities in use, access & ownership
Manually operated equipment Animal powered equipment Machines for general farm use Tractors, bulldozers and other vehicles Land preparation and planting machinery and equipment Crop maintenance machinery and equipment Crop harvesting machinery and equipment Post-harvest machinery and equipment Livestock machinery and equipment Aquaculture machinery and equipment Energy production machinery and equipment Storage and marketing machinery and equipment Water management machinery and equipment
2. ontractors and services, activities
3. istribution of Managerial Decisions in the holding

ROTATING MODULE 4: PRODUCTION METHODS & ENVIRONMENT
(Quantities, types and areas)

1. Use of Natural Resources
Land use Energy sources Soil management Irrigation and drainage
2. Crops production systems and resources
Fertilizers Plant protection products Crops and seeds varieties and resources Rice cultivation, specificities Type of non-residential buildings
3. Livestock production systems and resources
Type of livestock production system Livestock types and resources Animal breeding and reproduction Animal housing, manure management, equipment and transportation of animals Veterinary products and use of traditional medical methods Feed and use of pastures
4. On farm processing of agricultural products and by-products
5. Organic farming (certified or in conversion to organic)
6. Agro forestry
7. Access to and use of services, infrastructure and natural resources
Agricultural extension services (incl. veterinary) Infrastructure (incl. IT, communications, access to market) Access to natural and common property resources
8. Greenhouse gas and environment
9. Adaptation to climate change and mitigation strategies
10. Waste Management

2.17 The AGRIS Toolkit provides additional resources to guide in the design and customization of the questionnaires. Specific guidelines will synthetize costs/benefits dimensions of different options for the sequencing of the rotating modules, for different farming systems.

Data access

2.18 When AGRIS is initiated at country level, a detailed release calendar will be published by the national agencies responsible, to announce the survey outputs available to each category of users, and under which conditions. This release calendar shall be user friendly and consistent with both the national dissemination policy in place and the international best practices (such as open data protocols).

2.19 FAO will maintain a DDI-compliant[3] AGRIS Central Catalog, in line with the practices of and tools made available by the International Household Survey Network4. In addition to all relevant metadata, questionnaires and survey outputs, the AGRIS Central Catalog will provide easy and safe access to anonymized microdata, for research purposes. The exact access terms for each survey dataset will be agreed between national agencies and FAO, and will fall under either of two categories: "public use file" and "licensed file". When anonymized microdatasets cannot be made available, the catalog will still provide detailed metadata at the variable level. The AGRIS Central Catalog will be connected to the national catalogs and to relevant international catalogs such as the World Bank Microdata Catalog or the IHSN Central Survey Catalog, for automatic harvesting and data exchanges. National agencies will have access to detailed usage statistics on their own products.

2.20 The AGRIS Central Catalog will be critical for ensuring long-term preservation of and access to AGRIS resources.

2.21 Partnerships with local universities will be recommended, to build the long-term capacity to understand and use complex microdatasets and the associated econometrics techniques. This is expected to increase statistical literacy, fuel research and inform civil society on policy choices.

The AGRIS Toolkit

2.22 The national agencies that are willing to design and implement a customized AGRIS will find, in the AGRIS Toolkit, the necessary resources in terms of (1) technical methodology, (2) the specialized survey tools and instruments that use the latest knowledge and technology, and that cover the full range of survey steps, and (3) budgetary and institutional framework guidelines.

2.23 The AGRIS Toolkit is being developed by FAO in consultations with partner agencies and external experts. These parties rely heavily on the research conducted and the guidelines produced within the framework of the Global Strategy. Customization of the generic survey tools to meet specific country data needs and statistical infrastructure is a prerequisite for a successful implementation. FAO and other partners can provide technical assistance and training in this process, as requested by national agencies.

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[3] www.ddialliance.org/

[4] www.ihsn.org

2.24 The AGRIS Toolkit includes the following resources [*(*): draft resource available]*:

AGRIS planning and design [GSBPM[5] 1.x, 2.x, 3.x]	
	Planning AGRIS - Data needs assessment guidelines - Survey plan template - Supply and equipment procurement - Budget calculation template - AGRIS pre-test guidelines - Memorandum of Understanding template - AGRIS Governance : example of terms of reference - Quality management checklist Questionnaires - Indicator lists and data items: core and rotating modules (*) - Core and rotating modules: generic questionnaires (*) - Flow of modules guidelines - Guidelines for the customization of AGRIS questionnaires Sampling - AGRIS sampling theory and practice (*) - Sample frames: design, use and maintenance (*) - Sampling do programs / syntaxes (R, STATA and SPSS) - Sample size and sampling error calculation simulations - Sample weight calculation simulations
AGRIS data collection [GSBPM 4.x]	
	- CAPI solution for tablets and smartphones: software and training package (*) - Instructions for interviewers - Instructions for supervisors - Fieldwork checklist
AGRIS data processing [GSBPM 5.x]	
	- CAPI solution: software and training package (*) - PAPI: AGRIS generic questionnaires data entry application - Manual for AGRIS data processing - Data quality guidelines - Tabulation do programs / syntaxes (R, STATA and SPSS)
AGRIS data analysis [GSBPM 6.x]	
	- Generic tabulation plan - Sampling errors calculations - Analyses for the core module and the rotating modules: guidelines
AGRIS data dissemination [GSBPM 7.x]	
	- Final report and presentations template - AGRIS dissemination strategy guidelines and release calendar - Generic dissemination policy and implementation protocols - Guidelines on engaging with journalists - Dissemination workshop series: agenda and templates - IHSN NADA software and guidelines (*)
AGRIS data documentation and archiving [GSBPM cross-cutting]	
	- IHSN Microdata Management Toolkit: software and guidelines (*)

[5] http://www1.unece.org/stat/platform/display/metis/The+Generic+Statistical+Business+Process+Model

3. Implementation

National implementation

3.1 AGRIS is designed as a national survey program, implemented by national agencies under an official mandate to produce statistical data.

Alignment with national priorities and capacity-building

3.2 In the context of developing countries with limited statistical capacity, the priority is to respond to the demands that have already been expressed. In particular, 12 African countries have identified the design and implementation of AGRIS as a priority[6]. Alignment with national priorities as identified in national statistical strategies[7] and work programs will continue to be an overarching principle of AGRIS' implementation. AGRIS will strengthen national systems and will provide an opportunity for the enforcement of national and international standards, thus eventually contributing to the enhancement of statistical capacity and literacy.

3.3 FAO will proactively promote AGRIS in countries where this approach can fill some of the identified data gaps. When financial and/or technical assistance is required, customized work programs will be designed.

3.4 All agencies that are willing to design and implement AGRIS are encouraged to use the resources available in the AGRIS Toolkit, and to customize them to their specific needs. Agencies are encouraged to share survey outputs so that these too can be shared also through the AGRIS Central Catalog.

International coordination: the GRAInS Partnership

3.5 In addition to its involvement in the Global Strategy, FAO works closely with relevant international organizations and interagency groups. In particular, FAO works closely with other relevant survey programmes, such as the World Bank LSMS-ISA. FAO is also a member of the Inter Secretariat Working Group on Household Surveys (ISWGHS).

3.6 A multi-agency survey hub is being established in Rome, Italy, to advance the common goal of facilitating the production and use of household and farm survey data for evidence-based policymaking by improving survey methods, generating high-quality data, and strengthening statistical capacities in low and middle-income countries. In this respect, on 13 November 2015, FAO, the International Fund for Agricultural Development (IFAD), and the World Bank signed a Memorandum of Understanding as a first step towards a broader alliance on agricultural and rural policy data.

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[6] Identification of technical assistance needs in agricultural statistics of African countries, Action Plan for Africa of the Global Strategy, GS/AfDB report, February 2015

[7] Examples of these strategies include the Strategic Plans for Agriculture and Rural Statistics which are being designed in the context of the Global Strategy, as well as the generic National Strategies for the Development of Statistics.

3.7 AGRIS will be implemented within the framework of the Global Rural and Agricultural Integrated Surveys (GRAInS) Partnership. GRAInS is a joint initiative of several key international agencies – including FAO and the World Bank – which are involved in the funding or methodological design of agricultural and rural surveys. The longer-term vision is for GRAInS to be formally established as a separate institutional entity and for a common financing instrument (e.g. a multidonor fund) to be created. This will enable the pooling of resources and thus attain a truly joint programme.

3.8 To achieve greater coordination and foster methodological coherence among related survey initiatives, including AGRIS and LSMS-ISA, as well as to promote methodological and technological advances in the collection, dissemination and use of agricultural data, the following are identified as common objectives of the GRAInS Partnership, which should catalyse joint or closely coordinated activities:

- to work towards the methodological and operational integration of the AGRIS and LSMS-ISA programs and to strengthen methodological standards in household and farm surveys in developing countries;
- to enhance the ability of international agencies, in close coordination with regional partners, to provide technical assistance to countries and build capacity in the design and implementation of integrated surveys on agriculture and the rural space;
- to develop and test technological innovations to promote the integration and usability of different data sources and reduce the cost of data collection, while improving quality and timeliness: examples include the enhanced application of sensors, mobile phones, GPS, satellite imagery, and various forms of Big Data, which may complement and add value to more traditional data collection methods such as household and farm surveys.

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THEMATIC SET

F35

SAMPLING STRATEGIES AND ESTIMATION METHODS FOR INTEGRATION IN AGRICULTURE STATISTICS

Session Organizer
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ABSTRACT

The collection of statistical data by integrating information from different sources, including both censuses and surveys, is increasingly a requirement for the production of statistics, with a view to expand knowledge capacity and to guarantee a higher quality of statistical data. At the national level, the need to cope with a growing demand for ever more information, interlinked by demo-socio-economic factors, is fundamental for decision and policy making at national and international levels, and entails a greater effort in terms of organization and budgeting for the conduct of large-scale statistical surveys. The efficient use of all available information to produce accurate and timely statistics, in the most appropriate and necessary areas, is therefore a fundamental challenge. Moreover, several recent development studies acknowledge the importance of agriculture for the national economies of developing countries and its key role for overall economic growth, increased incomes, poverty reduction and the fight against hunger.

The session is focused on defining sampling strategies allowing to foster data integration and producing consistent estimates in agricultural statistics, considering the different steps of a generic data process:

- Sampling design: the (i) How to collect consistent data for statistical populations including different statistical units (eg. Farms and households); (ii) how to ensure the integration of different surveys in the phase of sampling design; (iii) how
- Record linkage: how to link microdata having common statistical units;
- Sampling estimate: how to ensure consistency for survey data having different sampling designs, but with a common set of variables.
- This should enable the development of relevant means for achieving integration in the various circumstances that characterize developing countries.

LIST OF PAPERS

A spatially nonstationary Fay-Herriot Model for small area estimation –An application to crop yield estimation

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U. C. Sud | Indian Agricultural Statistics Research Institute | New Delhi | India
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Assisting total estimation in spatial populations

A. Vagheggini | University of Bologna | Bologna | Italy
F. Bruno | University of Bologna | Bologna | Italy
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THEMATIC SET

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Estimation strategies with different sources of information

S. Falorsi | Istat | Rome | Italy
A. Fasulo | Istat | Rome | Italy
F. Solari | Istat | Rome | Italy

DOI: 10.1481/icasVII.2016.f35c

Reconciliation of censuses and survey data during the next round of agricultural census

N. Keita | FAO | Rome | Italy
E. Ouedraogo | FAO | Accra | Ghana
U. E. Nyamsi | FAO | Accra | Ghana

DOI: 10.1481/icasVII.2016.f35d

Indirect sampling, a way to overcome the weakness of the lists in agricultural surveys

P.D. Falorsi | Istat | Rome | Italy
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DOI: 10.1481/icasVII.2016.f35e

A Spatially Nonstationary Fay-Herriot Model for Small Area Estimation – An Application to Crop Yield Estimation

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ABSTRACT

In agricultural survey data, relationship between study variable (e.g., crop yield) and covariates may not be same over the study area, this phenomenon is referred to as spatial nonstationarity. Small area estimates based on the widely-used area-level model proposed in Fay and Herriot (1979) assume that the area level direct estimates are spatially nonstationary. We propose an extension to the Fay-Herriot model that accounts for the presence of spatial nonstationarity in the area level data. We refer to the predictor based on this extended model as the nonstationary empirical best linear unbiased predictor (NSEBLUP). We also develop two different estimators for the MSE of the NSEBLUP. The first estimator uses approximations similar to those in Opsomer et al. (2008). The second estimator is based on the parametric bootstrapping approach. Results from simulation studies using spatially nonstationary data indicate that the NSEBLUP compares favourably with alternative area-level predictors that ignore this spatial nonstationarity. Both of the proposed methods of MSE estimation for the NSEBLUP seem to perform adequately. Developed small area estimation method is applied to produce district level estimates of crop yield in the State of Uttar Pradesh using the data on crop cutting experiments supervised under Improvement of Crop Statistics scheme (data collected with much reduced sample size, however, the quality of data is very high) and the secondary data from the Census. The results show a considerable gain in precision in estimates produced applying small area estimation. These estimates will provide invaluable information to policy-analysts and decision-makers.

Keywords: District level estimates, small area estimation, spatial nonstationarity, geographical weighted regression, Census

1. Introduction

Sample surveys are usually designed so that direct estimators for larger domains lead to reliable estimates, where by direct estimators here we mean estimators that use only the sample data from the domain of interest. However, direct estimation is typically inefficient for smaller domains where sample sizes can be small, and cannot be used when there are no sample units in the domain. Following standard practice, we refer to these smaller domains as 'small areas' or just 'areas' from now on. Indirect (i.e. model-based) small area estimation (SAE) techniques are now widely employed to produce estimates and measures of precision for these small areas. In this context, we differentiate between SAE methods based on unit-level models and those based on area-level models. In the former case these models are for the individual survey measurements and include area effects, while in the latter case these models are used to smooth out the variability in the unstable area-level direct estimates. Area-level modelling is typically used when unit-level data are unavailable, or, as is often the case, where model covariates (e.g. census variables) are only available in aggregate form. Fay and Herriot (1979) proposed an area-level SAE model (hereafter the FH model) that relates small area direct survey estimates to area-level covariates. The FH model is widely used because of its flexibility in combining different sources of information with different error structures, and can be described as follows. Let *i* index the *m* areas of interest and let y_i be an unbiased direct survey estimator of an unobservable population parameter (for example, the population mean) Y_i of a variable of interest *y* for area *i*. Let $\mathbf{z}_i$ be a vector of *q* auxiliary variables for area *i* that are related to the population mean Y_i. These variables are typically obtained from administrative and census records. The FH model is then defined by the two equations

$$y_i - Y_i = e_i \text{ and } Y_i - \theta - \mathbf{z}_i^T\boldsymbol{\lambda} = u_i, \quad (1)$$

where the first equation models the prediction error of the observed survey estimate y_i of the true area *i* population mean Y_i, while the second models the unobservable Y_i in terms of an overall mean θ and a linear combination of the components of the vector $\mathbf{z}_i$, and is such that the area effects u_i satisfy $E(u_i|\mathbf{z}_i) = 0$. Put $\mathbf{x}_i^T = (1, \mathbf{z}_i^T)$ with $p = q+1$ equal to the dimension of $\mathbf{x}_i$. Combining these two equations then leads to an area level linear mixed model of form

$$y_i = \mathbf{x}_i^T\boldsymbol{\beta} + u_i + e_i;\ i = 1, \ldots, m. \quad (2)$$

Here $\boldsymbol{\beta} = (\theta, \boldsymbol{\lambda}^T)^T$ is a *p*-vector of unknown fixed effect parameters, the area effects u_i are independently and identically distributed, with $E(u_i|\mathbf{z}_i)=0$ and $\mathrm{Var}(u_i|\mathbf{z}_i)=\sigma_u^2$, and the prediction errors e_i are independently distributed, with $E(e_i|\mathbf{z}_i)=0$ and $\mathrm{Var}(e_i|\mathbf{z}_i)=\sigma_{ei}^2$. The area effects and the prediction errors are assumed to be independent of each other within and across areas. An important additional assumption that is usually made is that the prediction variances σ_{ei}^2 are known.

Since the parameters $\boldsymbol{\beta}$ and σ_u^2 are the same for every area, they can be estimated using the data from all *m* areas. This is usually accomplished by 'stacking' the area level direct estimates to produce an overall area level mixed model of the form

$$\mathbf{y}=\mathbf{X}\boldsymbol{\beta}+\mathbf{u}+\mathbf{e}, \tag{3}$$

where $\mathbf{y}=(y_1,...,y_m)^T$ is the $m\times 1$ vector of direct survey estimates, $\mathbf{X}=(\mathbf{x}_1,\ldots,\mathbf{x}_m)^T$ is the $m\times p$ matrix whose *i*-th row is given by $\mathbf{x}_i^T$, $\mathbf{u}=(u_1,...,u_m)^T$ is the *m*-vector of random area effects and $\mathbf{e}=(e_1,...,e_m)^T$ is the *m*-vector of prediction errors. This model can be generalised by replacing **u** in (3) by **Du**, where **D** is diagonal matrix of dimension $m\times m$ of area-specific covariates that can be used to characterise heteroskedasticity in the area effects. In the interests of avoiding unnecessary notational complexity, we ignore this generalisation here. It is assumed that the vector of area effects **u** is distributed independently of the prediction errors $\mathbf{e}$, so that the covariance matrix of the vector $\mathbf{y}$ is given by $\mathrm{Var}(\mathbf{y})=\mathbf{V}=\sigma_u^2\mathbf{I}_m+\boldsymbol{\Sigma}_e$, where $\mathbf{I}_m$ is the identity matrix of order *m* and $\boldsymbol{\Sigma}_e=diag\{\sigma_{ei}^2;1\le i\le m\}$ is the known matrix of prediction variances. The parameters σ_u^2 and $\boldsymbol{\Sigma}_e$ are sometimes referred to as the variance components of (3). Under the assumption that **u** is Gaussian, σ_u^2 can be estimated using maximum likelihood (ML) or restricted maximum likelihood (REML). Let $\hat{\sigma}_u^2$ denote the resulting estimator of σ_u^2 and define the plug-in estimator $\hat{\mathbf{V}}=\hat{\sigma}_u^2\mathbf{I}_m+\boldsymbol{\Sigma}_e=diag\{\hat{\sigma}_u^2+\sigma_{ei}^2;i=1,\ldots,m\}$ of the covariance matrix $\mathbf{V}$. Under (3), the empirical best linear unbiased estimator (EBLUE) of $\boldsymbol{\beta}$ and the empirical best linear unbiased predictor (EBLUP) of $\mathbf{u}$ are then

$$\hat{\boldsymbol{\beta}}=(\mathbf{X}^T\hat{\mathbf{V}}^{-1}\mathbf{X})^{-1}\mathbf{X}^T\hat{\mathbf{V}}^{-1}\mathbf{y} \tag{4}$$

and

$$\hat{\mathbf{u}}=\hat{\sigma}_u^2\hat{\mathbf{V}}^{-1}(\mathbf{y}-\mathbf{X}\hat{\boldsymbol{\beta}}), \tag{5}$$

respectively. Under (2), the EBLUP estimate of Y_i is (Henderson, 1975; Fay & Herriot, 1979)

$$\hat{Y}_i=\mathbf{x}_i^T\hat{\boldsymbol{\beta}}+\boldsymbol{\delta}_i^T\hat{\sigma}_u^2\hat{\mathbf{V}}^{-1}(\mathbf{y}-\mathbf{X}\hat{\boldsymbol{\beta}})=\mathbf{x}_i^T\hat{\boldsymbol{\beta}}+\hat{u}_i, \tag{6}$$

where $\boldsymbol{\delta}_i^T$ denotes the i^{th} row of $\mathbf{I}_m$. Note that the corresponding EBLUP of the area effect u_i is therefore $\hat{u}_i=\hat{\gamma}_i(y_i-\mathbf{x}_i^T\hat{\boldsymbol{\beta}})$, where $\hat{\gamma}_i=\hat{\sigma}_u^2\left(\hat{\sigma}_u^2+\sigma_{ei}^2\right)^{-1}$ defines the shrinkage effect for area *i*. See Rao (2003, chapter 5) for further details.

In practice areas are unplanned domains, and so many of them have zero sample sizes. These areas are referred to as non-sampled areas. The conventional approach for estimating area means in this case is synthetic estimation (Rao, 2003, pp. 46), based on a suitable model fitted to the data from the sampled areas. Let $\mathbf{z}_{j,out}$ denote the vector of covariates associated with non-sampled area *j*, and put $\mathbf{x}_{j,out}^T=(1,\mathbf{z}_{j,out}^T)$. Under model (2), the synthetic EBLUP predictor for the unknown population value $Y_{j,out}$ of area *j* is then

$$\hat{Y}_{j,out}=\mathbf{x}_{j,out}^T\hat{\boldsymbol{\beta}} \tag{7}$$

where $\hat{\boldsymbol{\beta}}$ is given by (4). We refer to this predictor as SYN in what follows.

Model (2) implicitly assumes that direct estimates from different areas are uncorrelated. However the boundaries that define an area are typically arbitrarily set, and there appears to be no good reason why neighbouring areas should not be correlated. This can be the case, for example, with agricultural, environmental, economic and epidemiological data. It is therefore often reasonable to assume that the effects of neighbouring areas, defined via a contiguity criterion, are correlated. Cressie (1991), Singh *et al.* (2005) and Pratesi and Salvati (2008) extend the mixed model (3) to allow for spatially correlated random effects using conditional autoregressive (CAR) and simultaneous autoregressive (SAR) specifications for **u** (Anselin, 1992). These models allow for spatial correlation in the area effects, while keeping the fixed effects parameters spatially invariant. Under the area level version of this spatial mixed model, Singh *et al.* (2005) and Pratesi and Salvati (2008) define the spatial empirical best linear unbiased predictor (SEBLUP) for a small area mean and also derive an approximately unbiased estimator of the MSE of the SEBLUP.

An alternative approach to incorporating spatial information in SAE is to assume that the model for $E(Y_i|\mathbf{z}_i)$ varies spatially. There are currently two approaches to specifying such a model. The first uses a spatially varying surface to model the mean structure of (2). For example, Giusti *et al.* (2012) extend the unit level nonparametric spatial spline approximation of Opsomer *et al.* (2008) in order to define a spatially non-linear area level model. These authors then develop the corresponding area-level nonparametric empirical best linear unbiased predictor (NPEBLUP) for a small area mean. A key feature of this approach is that it assumes that the regression parameters associated with the model do not vary spatially. Instead, spatial variability is accommodated by adding spatially varying covariates to the model specification. There are situations, however, where this assumption is inappropriate, a phenomenon referred to as spatial nonstationarity, see for example Brunsdon *et al.* (1996) and the references therein. The second approach therefore replaces the global regression model (2) by one where the regression specification varies locally. Such a model can be fitted using geographically weighted regression (GWR), a method that is widely used for data exhibiting spatial nonstationarity (Brunsdon *et al.*, 1996, Fotheringham *et al.*, 2002). Note that the model underpinning GWR is a local linear model, i.e. a linear model for the conditional expectation of *y* given **z** at a specified location. Under GWR the data are assumed to follow a location specific linear regression function, with geographically defined weights used to estimate the parameters of this local regression function. We use the GWR concept to extend the FH model (2) to spatially nonstationary area level data. We refer to this extended model as a spatially nonstationary FH model, and investigate its suitability for SAE with area level data that exhibit spatial nonstationarity. Note that we have not provided simulation results, bootstrap approach of MSE estimation and many other analytical details in this paper. Readers are suggested to refer Chandra *et al.* (2015) for these details. The rest of paper is organized as follows. The nonstationary version of the area level linear mixed model and the estimator of a small area mean under this model are described in Section 2. Section 3 presents the theoretical expression for mean squared error of this predictor and an estimator for this mean squared error. Given that the approach is for the spatially nonstationary situation, a bootstrap procedure to test for the presence of spatial nonstationarity is also proposed in this Section. Section 4 presents an application of proposed method in a real data from agriculture survey to produce the crop yield estimates at small area level. Finally, Section 5 discusses concluding remarks.

2. A Spatially Nonstationary Area Level Model

Under (1), the parameters making up the vector $\boldsymbol{\lambda}$ are spatially invariant, i.e. the expected value of Y_i given $\mathbf{z}_i$ is the same at any two points in the study area that have the same set of values for this covariate. However, there are situations, for example in agricultural and environmental data, where this relationship is not constant, i.e. where there is spatial nonstationarity in the area level population parameters. In order to accommodate this situation, we now define a spatially nonstationary version of the FH model. To start, let the spatial location of area *i* correspond to the coordinates of an arbitrarily defined spatial location in the area, e.g. its centroid, which we denote by loc_i. Let $d(loc_i, loc_j)$ be an appropriate measure of the distance between the spatial locations of areas *i* and *j*, and define the spatial contiguity of these two locations to be $\omega_{ij} = \left(1 + d(loc_i, loc_j)\right)^{-1}$. Let $\mathbf{\Omega} = \left[\omega_{ij}\right]$ denote the positive definite $m \times m$ matrix of spatial contiguities defined by the loc_i. This matrix is assumed to be known. We consider a spatially nonstationary extension of the FH model (1) for area *i* of the form

$$y_i - Y_i = e_i \quad \text{and} \quad Y_i - \theta(loc_i) - \mathbf{z}_i^T \boldsymbol{\lambda}(loc_i) = u_i \tag{8}$$

where $\left(\theta(loc_i), \boldsymbol{\lambda}^T(loc_i)\right)^T = \left(\theta, \boldsymbol{\lambda}^T\right)^T + \boldsymbol{\gamma}(loc_i)$ and $\boldsymbol{\gamma}(loc) = \left(\gamma_k(loc); k = 1, \ldots, p\right)$ is a spatially varying multivariate random process of dimension p . Put $\mathbf{y} = \left(y_1, \ldots, y_m\right)^T$, $\mathbf{z} = \left(\mathbf{z}_1^T, \ldots, \mathbf{z}_m^T\right)^T$, $\mathbf{\Gamma} = \left(\boldsymbol{\gamma}^T(loc_1), \ldots, \boldsymbol{\gamma}^T(loc_m)\right)^T$ and $\mathbf{loc} = \{loc_1, \ldots, loc_m\}$, i.e. the set of locations for the *m* areas. Then

$$\mathrm{E}\left(\mathbf{\Gamma} | \mathbf{z}, \mathbf{loc}\right) = \mathbf{0}_{pm \times 1}.$$

Since a general specification for the covariance structure of $\boldsymbol{\gamma}(loc)$ is complex, we follow Datta *et al*. (1998) and assume a separable working model for the second order spatial moments of $\boldsymbol{\gamma}(loc)$. This is a model of the form

$$\mathrm{Var}\left(\Gamma | \mathbf{z}, \mathbf{loc}\right) = \mathbf{\Sigma} = \mathbf{\Omega} \otimes \mathbf{C} \tag{9}$$

where $\mathbf{C} = \left[c_{kl}\right]$ is a $p \times p$ covariance matrix that characterises the correlations between the components of $\boldsymbol{\gamma}$ at an arbitrary location loc and $\otimes$ denotes Kronecker product. Under (8) and (9),

$$\mathbf{y} = \mathbf{X}\boldsymbol{\beta} + \mathbf{\Psi}\mathbf{\Gamma} + \mathbf{u} + \mathbf{e} \tag{10}$$

where $\boldsymbol{\beta} = \left(\theta, \boldsymbol{\lambda}^T\right)^T$ and $\mathbf{\Psi} = diag\left(\mathbf{x}_i^T; i = 1, \ldots, m\right)$. Then

$$\mathrm{E}\left(\mathbf{y} | \mathbf{z}, \mathbf{loc}\right) = \mathbf{X}\boldsymbol{\beta}$$

$$Var\left(\mathbf{y} | \mathbf{z}, \mathbf{loc}\right) = \mathbf{V} = \mathbf{\Psi}\mathbf{\Sigma}\mathbf{\Psi}^T + \sigma_u^2 \mathbf{I}_m + diag\left\{\sigma_{ei}^2; i = 1, \ldots, m\right\} \tag{11}$$

$$\mathrm{Cov}\left(Y_i, \mathbf{y} | \mathbf{z}, \mathbf{loc}\right) = \mathbf{\Psi}_i \mathbf{\Sigma} \mathbf{\Psi}^T + \sigma_u^2 \boldsymbol{\delta}_i^T \tag{12}$$

where $\mathbf{\Psi}_i$ is the i^{th} row of $\mathbf{\Psi}$. The minimum mean squared error (MMSE) predictor of Y_i under (8) - (12) is the expected value of Y_i given **y**, **z** and **loc**. Under a Gaussian errors assumption, and assuming the inverse of **V** exists, this is

$$\tilde{Y}_i = \mathbf{x}_i^T \boldsymbol{\beta} + \mathrm{Cov}\left(Y_i, \mathbf{y} | \mathbf{z}, \mathbf{loc}\right) \mathbf{V}^{-1} \left(\mathbf{y} - \mathbf{X}\boldsymbol{\beta}\right). \tag{13}$$

The vector of MMSE predictors for the population values in **Y** is therefore

$$\tilde{\mathbf{Y}} = \mathbf{X}\boldsymbol{\beta} + \left(\mathbf{\Psi}\mathbf{\Sigma}\mathbf{\Psi}^T + \sigma_u^2 \mathbf{I}_m\right) \mathbf{V}^{-1} \left(\mathbf{y} - \mathbf{X}\boldsymbol{\beta}\right) \tag{14}$$

where **V** is defined by (11). The best linear unbiased estimator (BLUE) of $\boldsymbol{\beta}$ is then

$$\tilde{\boldsymbol{\beta}} = \left(\mathbf{X}^T \mathbf{V}^{-1} \mathbf{X}\right)^{-1} \mathbf{X}^T \mathbf{V}^{-1} \mathbf{y}, \tag{15}$$

and the best linear unbiased predictors (BLUPs) of $\boldsymbol{\gamma} = \left(\boldsymbol{\gamma}(loc_1)^T, \ldots, \boldsymbol{\gamma}(loc_m)^T\right)^T$ and $\mathbf{u}$ are

$$\tilde{\boldsymbol{\gamma}} = \mathbf{\Sigma}\mathbf{\Psi}^T \mathbf{V}^{-1} \left(\mathbf{y} - \mathbf{X}\tilde{\boldsymbol{\beta}}\right) \tag{16}$$

$$\tilde{\mathbf{u}} = \sigma_u^2 \mathbf{V}^{-1} \left(\mathbf{y} - \mathbf{X}\tilde{\boldsymbol{\beta}}\right). \tag{17}$$

The corresponding BLUP of the vector $\mathbf{Y}$ is $\tilde{\mathbf{Y}} = \mathbf{X}\tilde{\boldsymbol{\beta}} + \boldsymbol{\Psi}\tilde{\boldsymbol{\gamma}} + \tilde{\mathbf{u}}$. In particular, for small area *i*, the BLUP of Y_i , which we refer to below as the nonstationary BLUP, or NSBLUP, is

$$\tilde{Y}_i = \mathbf{x}_i^T\tilde{\boldsymbol{\beta}} + \left(\boldsymbol{\Psi}_i\boldsymbol{\Sigma}\boldsymbol{\Psi}^T + \sigma_u^2\boldsymbol{\delta}_i^T\right)\mathbf{V}^{-1}\left(\mathbf{y} - \mathbf{X}\tilde{\boldsymbol{\beta}}\right) = \mathbf{x}_i^T\tilde{\boldsymbol{\beta}} + \boldsymbol{\Psi}_i\tilde{\boldsymbol{\gamma}} + \tilde{u}_i . \qquad (18)$$

In practice the parameters σ_u^2 and $\mathbf{C}$ are unknown and have to be estimated from the data. Replacing these unknown parameters by their estimated values ^{2}
plug-in estimators by a 'hat', we obtain the empirical BLUE (EBLUE) of $\boldsymbol{\beta}$ as $\hat{\boldsymbol{\beta}} = \left[\mathbf{X}^T\hat{\mathbf{V}}^{-1}\mathbf{X}\right]^{-1}\left[\mathbf{X}^T\hat{\mathbf{V}}^{-1}\mathbf{y}\right]$ and the empirical BLUP (EBLUP) of Y_i as

$$\hat{Y}_i = \mathbf{x}_i^T\hat{\boldsymbol{\beta}} + \boldsymbol{\Psi}_i\hat{\boldsymbol{\gamma}} + \hat{u}_i . \qquad (19)$$

We refer to (19) as the nonstationary EBLUP, or NSEBLUP, of Y_i.

We now consider synthetic prediction for non-sampled areas under (10). Suppose that there are m_{out} of these non-sampled areas, indexed by *j*. We assume that the covariate vectors $\mathbf{z}_{out,j}$ and the spatial locations $loc_{out,j}$ (e.g. the centroids) of these areas are known. Let $\mathbf{z}_{out}$ and $\mathbf{loc}_{out}$ denote these auxiliary data. The spatially nonstationary predictor (denoted by NSSYN) of the vector of population values $\mathbf{Y}_{out}$ for the non-sampled areas is the plug-in estimator of the MMSE predictor of $\mathbf{Y}_{out}$ given **y**, **z**, **loc**, $\mathbf{z}_{out}$ and $\mathbf{loc}_{out}$,

$$\hat{\mathbf{Y}}_{out} = \mathbf{X}_{out}\hat{\boldsymbol{\beta}} + \boldsymbol{\Psi}_{out}\hat{\boldsymbol{\gamma}}_{out}$$

where $\mathbf{X}_{out}$ is the $m_{out} \times p$ matrix of covariates for the non-sampled areas,

$$\boldsymbol{\Psi}_{out} = diag\left\{\mathbf{x}_{j,out}^T; j = 1,\ldots,m_{out}\right\},\ \hat{\boldsymbol{\gamma}}_{out} = \hat{\boldsymbol{\Sigma}}_{out/in}\boldsymbol{\Psi}^T\hat{\mathbf{V}}^{-1}\left(\mathbf{y} - \mathbf{X}\hat{\boldsymbol{\beta}}\right), \text{ with } \hat{\boldsymbol{\Sigma}}_{out/in} = \boldsymbol{\Omega}_{out/in} \otimes \hat{\mathbf{C}} .$$

Here $\boldsymbol{\Omega}_{out/in}$ is the known $m_{out} \times m$ matrix of spatial contiguities between the non-sampled areas and the sampled areas. In particular, for non-sampled area *j*, we have

$$\hat{Y}_{j,out} = \mathbf{x}_{j,out}^T\hat{\boldsymbol{\beta}} + \boldsymbol{\Psi}_{j,out}\hat{\boldsymbol{\gamma}}_{out} \qquad (20)$$

where $\boldsymbol{\Psi}_{j,out}$ denotes the row of $\boldsymbol{\Psi}_{out}$ corresponding to this non-sampled area. We refer to the predictor (20) as the NSSYN predictor. In contrast to the SYN predictor (7), the NSSYN predictor uses the location data for the non-sampled areas to 'borrow strength' from neighbouring sampled areas, and so has the potential to improve conventional synthetic prediction for non-sampled areas. In particular, we expect that if in fact the population data exhibit spatial nonstationarity, then the NSSYN predictor (20) will exhibit less bias than the standard SYN predictor (7).

2.1 Parameter estimation

In what follows we restrict our development to the simple single parameter specification $\mathbf{C} = \eta\mathbf{I}_p$ for the matrix $\mathbf{C}$, where $\mathbf{I}_p$ denotes the identity matrix of order *p*. That is, the components of the random vector $\boldsymbol{\gamma}$ are uncorrelated at any particular location, with the parameter $\eta \geq 0$ reflecting the strength or 'intensity' of spatial clustering in the data, and $\eta = 0$ corresponding to the situation where the model is spatially homogeneous (no spatial correlation in Y_i). In this case there are just 2 parameters (η and σ_u^2) that need to be estimated. This can be done by maximising a restricted maximum likelihood under a Gaussian assumption. Put $\boldsymbol{\varphi} = \left\{\eta, \sigma_u^2\right\} = \left(\varphi_1, \varphi_2\right)$. Under (10), the restricted log-likelihood function is then

$$l\left(\boldsymbol{\varphi}\right) = const - \frac{1}{2}\log\left|\mathbf{P}^T\mathbf{V}\mathbf{P}\right| - \frac{1}{2}\left(\mathbf{P}^T\mathbf{y}\right)^T(\mathbf{P}^T\mathbf{V}\mathbf{P})^{-1}\left(\mathbf{P}^T\mathbf{y}\right) \qquad (21)$$

where $\mathbf{P} = \mathbf{V}^{-1} - \mathbf{V}^{-1}\mathbf{X}(\mathbf{X}^T\mathbf{V}^{-1}\mathbf{X})^{-1}\mathbf{X}^T\mathbf{V}^{-1}$ and, for $s = 1,2$

$$\frac{\partial l(\boldsymbol{\varphi})}{\partial \varphi_s} = -\frac{1}{2} tr\left(\mathbf{P}\mathbf{V}_{(s)}\right) + \frac{1}{2}\mathbf{y}^T \mathbf{P}\mathbf{V}_{(s)}\mathbf{P}\mathbf{y} \tag{22}$$

with

$$\mathbf{V}_{(1)} = \frac{\partial \mathbf{V}}{\partial \varphi_1} = \frac{\partial \mathbf{V}}{\partial \eta} = \boldsymbol{\Psi}\left(\boldsymbol{\Omega} \otimes \mathbf{I}_p\right)\boldsymbol{\Psi}^T \tag{23}$$

$$\mathbf{V}_{(2)} = \frac{\partial \mathbf{V}}{\partial \varphi_2} = \frac{\partial \mathbf{V}}{\partial \sigma_u^2} = \mathbf{I}_m . \tag{24}$$

The restricted ML estimate of $\boldsymbol{\varphi}$ can be obtained by setting the system of equations (22) to zero and solving for $\boldsymbol{\varphi}$. This can be done using a Fisher scoring algorithm as follows:

1. Compute the distance matrix $\boldsymbol{\Omega}$ between the centroids of the areas and define a starting value for $\boldsymbol{\varphi}$.
2. Use the current values of $\boldsymbol{\varphi}$ to calculate $\boldsymbol{\Sigma}$ and $\mathbf{V}$.
3. Update $\hat{\boldsymbol{\beta}}$ and **P**.
4. Calculate the value $\hat{\boldsymbol{\varphi}}$ such that the components of (22) are zero.
5. Return to step 3 and repeat the procedure until the estimates converge, i.e. when difference between the estimated model parameters $\hat{\boldsymbol{\beta}}$ and $\hat{\boldsymbol{\varphi}}$ obtained from two successive iterations is less than a very small value.

R code (R Development Core Team, 2010) that implements this algorithm is available from the authors.

3. Mean Squared Error Estimation

3.1 Analytic mean squared error estimation

Analytic estimation of the mean squared error (MSE) of the EBLUP (6) is usually carried out using the estimator of Prasad and Rao (1990). A corresponding analytic approach to estimating the MSE of the NSEBLUP (19) is developed below. After some algebra, we can show that the prediction error of the NSBLUP is

$$\tilde{Y}_i - Y_i = \mathbf{b}_i(\tilde{\boldsymbol{\beta}} - \boldsymbol{\beta}) + \mathbf{h}_i\left\{\boldsymbol{\Sigma}_H \mathbf{H}^T \mathbf{V}^{-1}\left(\mathbf{y} - \mathbf{X}\boldsymbol{\beta}\right) - \boldsymbol{\zeta}\right\}, \tag{25}$$

where $\mathbf{b}_i = \mathbf{x}_i^T - \left(\boldsymbol{\Psi}_i \boldsymbol{\Sigma} \boldsymbol{\Psi}^T + \sigma_u^2 \boldsymbol{\delta}_i^T\right)\mathbf{V}^{-1}\mathbf{X} = \mathbf{x}_i^T - \mathbf{h}_i \boldsymbol{\Sigma}_H \mathbf{H}^T \mathbf{V}^{-1}\mathbf{X}$, $\mathbf{H} = \left[\boldsymbol{\Psi}\ \ \mathbf{I}_m\right]$, $\boldsymbol{\zeta} = (\boldsymbol{\gamma}^T, \mathbf{u}^T)^T$ and $\boldsymbol{\Sigma}_H = \begin{bmatrix} \boldsymbol{\Sigma} & \mathbf{0} \\ \mathbf{0} & \sigma_u^2 \mathbf{I}_m \end{bmatrix}$. Put $\boldsymbol{\varphi} = \left\{\eta, \sigma_u^2\right\}$. The MSE of the NSBLUP is then

$$E\left(\tilde{Y}_i - Y_i\right)^2 = M_1(\boldsymbol{\varphi}) + M_2(\boldsymbol{\varphi}), \tag{26}$$

where

$$M_1(\boldsymbol{\varphi}) = \mathbf{h}_i \boldsymbol{\Sigma}_H \left\{\mathbf{I}_{pm+m} - \mathbf{H}^T \mathbf{V}^{-1} \mathbf{H} \boldsymbol{\Sigma}_H\right\} \mathbf{h}_i^T$$

and

$$M_2(\boldsymbol{\varphi}) = \mathbf{b}_i \left(\mathbf{X}^T \mathbf{V}^{-1} \mathbf{X}\right)^{-1} \mathbf{b}_i^T .$$

Similarly, we can express the prediction error of the NSEBLUP (19) as

$$\hat{Y}_i - Y_i = \hat{\mathbf{b}}_i(\hat{\boldsymbol{\beta}} - \boldsymbol{\beta}) + \mathbf{h}_i\left\{\hat{\boldsymbol{\Sigma}}_H \mathbf{H}^T \hat{\mathbf{V}}^{-1}\left(\mathbf{y} - \mathbf{X}\boldsymbol{\beta}\right) - \boldsymbol{\zeta}\right\}, \tag{27}$$

with $\hat{\mathbf{b}}_i = \mathbf{x}_i^T - \mathbf{h}_i \hat{\boldsymbol{\Sigma}}_H \mathbf{H}^T \hat{\mathbf{V}}^{-1}\mathbf{X}$. Following Opsomer *et al.* (2008), and again using $\boldsymbol{\varphi} = \left(\varphi_1, \varphi_2\right)$ to denote the variance components, define **S** to be the matrix with rows ($s = 1,2$)

$$\mathbf{S}_s = \mathbf{h}_i \left(\frac{\partial \boldsymbol{\Sigma}_H}{\partial \varphi_s} \mathbf{H}^T \mathbf{V}^{-1} + \boldsymbol{\Sigma}_H \mathbf{H}^T \frac{\partial \mathbf{V}^{-1}}{\partial \varphi_s} \right)$$

where $\frac{\partial \boldsymbol{\Sigma}_H}{\partial \varphi_1} = diag\left(\boldsymbol{\Omega} \otimes \mathbf{I}_p, \mathbf{0}_m\right)$, $\frac{\partial \boldsymbol{\Sigma}_H}{\partial \varphi_2} = diag\left(\mathbf{0}_{pm}, \mathbf{I}_m\right)$ and $\frac{\partial \mathbf{V}^{-1}}{\partial \varphi_s} = -\mathbf{V}^{-1}\mathbf{L}_s\mathbf{V}^{-1}$ with $\mathbf{L}_s = \frac{\partial \mathbf{V}}{\partial \varphi_s}$. Here $\mathbf{L}_1 = \boldsymbol{\Psi}\left(\boldsymbol{\Omega} \otimes \mathbf{I}_p\right)\boldsymbol{\Psi}^T$ and $\mathbf{L}_2 = \mathbf{I}$. Note also that the 2×2 Fisher information matrix $\boldsymbol{\Phi}$ with respect to $\boldsymbol{\varphi}$ contains elements $\phi_{rs} = 0.5 \times tr(\mathbf{P}\mathbf{L}_r\mathbf{P}\mathbf{L}_s)$. Replacing the unknown variance components in $\mathbf{S}$ and $\boldsymbol{\Phi}$ by their restricted maximum likelihood estimates then leads to the following estimator of the Prediction MSE (PMSE) of the NSEBLUP

$$\begin{aligned}\widehat{PMSE}\left(\hat{Y}_i\right) &= M_1(\hat{\boldsymbol{\varphi}}) + M_2(\hat{\boldsymbol{\varphi}}) + 2M_3(\hat{\boldsymbol{\varphi}}) \\ &= \mathbf{h}_i \hat{\boldsymbol{\Sigma}}_H \left\{\mathbf{I}_{pm+m} - \mathbf{H}^T \hat{\mathbf{V}}^{-1} \mathbf{H} \hat{\boldsymbol{\Sigma}}_H\right\} \mathbf{h}_i^T + \hat{\mathbf{b}}_i \left(\mathbf{X}^T \hat{\mathbf{V}}^{-1} \mathbf{X}\right)^{-1} \hat{\mathbf{b}}_i^T \\ &\quad + 2\left(\mathbf{y} - \mathbf{X}\hat{\boldsymbol{\beta}}\right)^T \hat{\mathbf{S}}^T \hat{\boldsymbol{\Phi}}^{-1} \hat{\mathbf{S}} \left(\mathbf{y} - \mathbf{X}\hat{\boldsymbol{\beta}}\right).\end{aligned} \tag{28}$$

The asymptotic behaviour of (28) can be developed along the same lines as set out in Opsomer *et al.* (2008). In particular, we then have

$$E\left[\widehat{PMSE}\left(\hat{Y}_i\right)\right] = PMSE\left(\hat{Y}_i\right) + o\left(m^{-1}L_m^2\right)$$

provided that regularity conditions described in Chandra *et al.* (2015) are met. The mean cross product error (MCPE) matrix defined by the vector $\hat{\mathbf{Y}}_{out} = \mathbf{X}_{out}\hat{\boldsymbol{\beta}} + \boldsymbol{\Psi}_{out}\hat{\boldsymbol{\gamma}}_{out}$ of values of the NSSYN predictor (20) is estimated in a similar fashion. Noting that

$$\begin{aligned}E(\mathbf{D}\mathbf{D}^T) &= \boldsymbol{\Psi}_{out}\left\{\boldsymbol{\Sigma}_{out/out} + \boldsymbol{\Sigma}_{out/in}\boldsymbol{\Psi}^T\mathbf{V}^{-1}\boldsymbol{\Psi}\boldsymbol{\Sigma}_{out/in}^T - 2\boldsymbol{\Sigma}_{out/in}\boldsymbol{\Psi}^T\mathbf{V}^{-1}\boldsymbol{\Psi}Cov\left[\boldsymbol{\gamma}, \boldsymbol{\gamma}_{out}\right]\right\}\boldsymbol{\Psi}_{out}^T \\ &= \boldsymbol{\Psi}_{out}\left\{\boldsymbol{\Sigma}_{out/out} - \boldsymbol{\Sigma}_{out/in}\boldsymbol{\Psi}^T\mathbf{V}^{-1}\boldsymbol{\Psi}\boldsymbol{\Sigma}_{out/in}^T\right\}\boldsymbol{\Psi}_{out}^T\end{aligned}$$

where $\mathbf{D} = \boldsymbol{\Psi}_{out}\boldsymbol{\Sigma}_{out/in}\boldsymbol{\Psi}^T\mathbf{V}^{-1}\left(\mathbf{y} - \mathbf{X}\boldsymbol{\beta}\right) - \boldsymbol{\Psi}_{out}\boldsymbol{\gamma}_{out}$, this estimator is given by

$$\begin{aligned}\widehat{MCPE}\left(\hat{\mathbf{Y}}_{out}\right) &= \boldsymbol{\Psi}_{out}\left\{\hat{\boldsymbol{\Sigma}}_{out/out} - \hat{\boldsymbol{\Sigma}}_{out/in}\boldsymbol{\Psi}^T\hat{\mathbf{V}}^{-1}\boldsymbol{\Psi}\hat{\boldsymbol{\Sigma}}_{out/in}^T\right\}\boldsymbol{\Psi}_{out}^T \\ &\quad + \mathbf{X}_{out}\left(\mathbf{X}^T\hat{\mathbf{V}}^{-1}\mathbf{X}\right)^{-1}\mathbf{X}_{out}^T + \hat{\sigma}_u^2.\end{aligned} \tag{29}$$

Here $\hat{\boldsymbol{\Sigma}}_{out/out} = \hat{\eta}\boldsymbol{\Omega}_{out/out} \otimes \left(\mathbf{1}_p\mathbf{1}_p^T\right)$ and $\boldsymbol{\Omega}_{out/out}$ is the $m_{out} \times m_{out}$ matrix of distances between the non-sampled areas.

3.2 Bootstrap procedure for mean squared error estimation

This Section describes an alternative procedure for estimating the MSE of the NSEBLUP based on the parametric bootstrap procedure of Gonzalez-Manteiga *et al.* (2008). Note that the MSE estimator defined by this procedure is consistent provided the model parameter estimators are consistent. The steps of this parametric bootstrap procedure are as follows.

1) Given $\mathbf{y}$, maximise the restricted log-likelihood (21) using the method described in Section 2.1. Let $\hat{\boldsymbol{\varphi}} = \left(\hat{\eta}, \hat{\sigma}_u^2\right)$ and $\hat{\boldsymbol{\beta}}$ denote the resulting estimates.
2) Given the estimates obtained in step 1, generate a vector $\mathbf{t}_1^*$ of length *pm* corresponding to a realisation from the $N\left(\mathbf{0}, \boldsymbol{\Omega} \otimes \mathbf{I}_p\right)$ distribution. Construct the bootstrap vector $\boldsymbol{\gamma}^*\left(loc\right) = \hat{\eta}^{1/2}\mathbf{t}_1^*$.
3) Generate a vector $\mathbf{t}_2^*$ whose elements are *m* independent realisations of a *N*(0,1) variable, independently of the generation of $\mathbf{t}_1^*$. Construct the bootstrap vector $\mathbf{u}^* = \hat{\sigma}_u\mathbf{t}_2^*$.

4) Calculate the bootstrap realisation $\mathbf{Y}^* = \mathbf{X}\hat{\boldsymbol{\beta}} + \boldsymbol{\Psi}\hat{\boldsymbol{\gamma}}^* + \hat{\mathbf{u}}^* = \left(Y_1^*,\ldots,Y_m^*\right)^T$ of the population quantities of interest.
5) Generate a vector $\mathbf{t}_3^*$ whose elements are *m* independent realisations of a *N*(0,1) variable, independently of the generation of $\mathbf{t}_1^*$ and $\mathbf{t}_2^*$, and construct the vector of random prediction errors $\mathbf{e}^*$ where $e_i^* = \sigma_{ei} t_{3i}^*$.
6) Construct the bootstrap vector $\mathbf{y}^* = \mathbf{Y}^* + \mathbf{e}^* = \mathbf{X}\hat{\boldsymbol{\beta}} + \boldsymbol{\Psi}\boldsymbol{\gamma}^* + \mathbf{u}^* + \mathbf{e}^*$ of direct estimates.
7) Using these bootstrap values $\mathbf{y}^*$, as well as the values of $\mathbf{X}$ and **loc**, calculate the bootstrap estimators $\hat{\boldsymbol{\beta}}^*$ and $\hat{\boldsymbol{\varphi}}^*$ using the method described in Section 2.1.
8) Combining the formula (19) with these values of $\hat{\boldsymbol{\beta}}^*$ and $\hat{\boldsymbol{\varphi}}^*$, calculate the bootstrap value $\hat{Y}_i^*$ of the NSEBLUP.
9) Repeat steps 2 - 8 B times. In the *b*-th bootstrap replication, let $\hat{Y}_i^{*(b)}$ be the bootstrap NSEBLUP in area *i*. The bootstrap estimator for the MSE of the actual NSEBLUP $\hat{Y}_i$, see (19), for area *i* is then

$$MSE_{boot}\left(\hat{Y}_i\right) = B^{-1}\sum_{b=1}^{B}\left\{\hat{Y}_i^{*(b)} - \hat{Y}_i\right\}^2 . \qquad (30)$$

3.3. A diagnostic for spatial nonstationarity

Following Opsomer *et al.* (2008), we describe a bootstrap procedure to test the hypothesis $H_{0\eta}:\eta=0$ versus the one-sided alternative $H_{1\eta}:\eta>0$. This involves first calculating the value $\ell_\eta = 2\left(\ell_1 - \ell_0\right)$, where ℓ_0 denotes the restricted log-likelihood under the null $H_{0\eta}$ and ℓ_1 denotes the corresponding value under the alternative $H_{1\eta}$. The level of significance of ℓ_η is then calculated via a parametric bootstrap. That is, if we put $\hat{\sigma}_u^2$ and $\hat{\boldsymbol{\beta}}$ equal to the estimates of σ_u^2 and $\boldsymbol{\beta}$ obtained under the null, then we generate bootstrap realisations of **y** as $\mathbf{y}^{*(b)} = \mathbf{X}\hat{\boldsymbol{\beta}} + \mathbf{u}^{*(b)} + \mathbf{e}^{*(b)}$, where $\mathbf{u}^{*(b)}$ and $\mathbf{e}^{*(b)}$ are generated as in Section 3.2. For each bootstrap replication, the null and the alternative models are then fitted and $\ell_\eta^{*(b)}$ is calculated. The significance of the calculated value of ℓ_η is evaluated by comparing it with the bootstrap distribution of $\ell_\eta^{*(b)}$. A word of caution is appropriate at this point. A significant result from the above bootstrap-based test does not mean that the model (10) with $\mathbf{C} = \eta\mathbf{I}_p$ provides a good representation of the data, i.e. the set of direct estimates $\mathbf{y}$. It only means that this particular spatially non-homogeneous model provides a significant improvement in fit compared with the usual Fay-Herriot approach that ignores spatial heterogeneity.

4. Application

In Section we illustrate an application of NSEBLUP method of SAE to real agriculture survey data collected by the National Sample Survey Office (NSSO), India under the scheme titled 'Improvement of Crop Statistics (ICS)'. In particular, aim is to estimate average yield for paddy (green) crop at small area (or district) levels in the State of Uttar Pradesh in India by linking data generated under ICS scheme by NSSO (data collected with much reduced sample size, however, the quality of data is very high) and the Census information. In this application we adopt an area level small area model (2) as well as nonstationary version of area level model (10) for SAE. We applied the EBLUP and the NSEBLUP estimator for SAE described in Table 1.

Table 1. Definition of various estimators.

Acronym	Description	MSE Estimator
EBLUP	Predictor (6) under model (2)	Prasad & Rao (1990)
NSEBLUP	Predictor (19) under model (10)	Expression (28)
SYN	Predictor (7) under model (2)	Prasad & Rao (1990)
NSSYN	Predictor (20) under model (10)	Expression (29)

Here we are working under aggregated or area level version of small area models. As a consequence, this approach of SAE requires area-specific information on direct survey estimates and covariates. In particular, two types of variables are required for this analysis.

(i) The variable of interest for which small area estimates are required is yield for paddy (green) crop. We use data pertaining to supervised CCE on paddy (green) crop under ICS scheme for kharif season for the State of Uttar Pradesh in India collected during the year 2009-10. We are interested in estimating the average yield for paddy (green) crop at the district level. In the State of Uttar Pradesh CCE is carried out in the plots of form equilateral triangle of side 10 meter each and with total area of 43.30 meter^2. Therefore, yield rate for paddy (green) crop is recorded as gram per 43.12 meter^2.

(ii) The covariates (auxiliary variables) known for the population are drawn from the Population Census 2001. Note that use of covariates from the 2001 Population Census to model yield data of paddy crop from the 2009-10 ICS scheme data may raise issues of comparability. However, the covariates used in this study are not expected to change significantly over a short period of time.

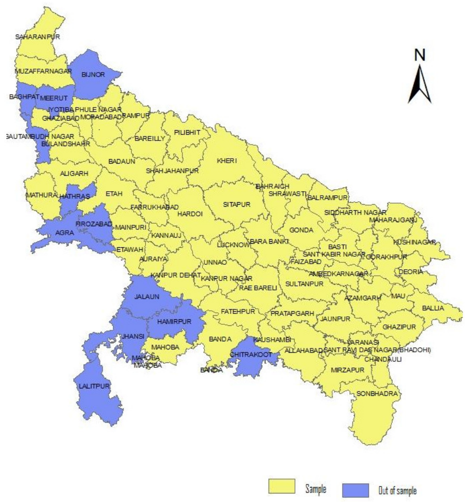


Figure 1. *Map of districts in the State of Uttar Pradesh in India.*

In the State of Uttar Pradesh there are 70 districts however supervision, on a sub-sample, of CCEs work under ICS scheme is carried out in 58 districts only and there is no sample data for the remaining 12 districts. We refer these 12 districts as the out of sample districts. These 70 (58 in sample and 12 out of sample) districts are the small areas for which we are interested in producing the estimates. Figure 1 shows the map of these 70 districts in the State of Uttar Pradesh. In this map the districts in sample are shown in yellow color while out of sample districts are shown in blue color. The area specific sample sizes for 58 sample districts range from minimum of 4 to maximum of 28 CCE with average of 11 (see Figure 2). A total of 655 CCE were supervised for recording yield data in the State of Uttar Pradesh for paddy crop for the year 2009-10. We see that in few districts the sample size is small so the traditional sample survey estimation approaches lead to unstable estimate. In addition, in 12 districts due to non availability of sample under ICS, we cannot estimate paddy yield**.** Indeed, there is no design based solution to provide estimates for these 12 out of sample districts. The SAE is an obvious choice for such cases.

There were 121 covariates available from the Population Census to consider for modeling and choosing appropriate covariates for this analysis. For this purpose, we used data of 58 sampled districts and did some exploratory data analysis, for example, first we segregated group of covariates with significant correlation with target variable and subsequently we implemented step wise regression analysis for identification of such covariates. Finally we identified two significant variables, average household size (HH_SIZE) and female population of marginal household (MARG_HH_F) with 26 per cent R^2 for the SAE. Although, the value of R^2 for this data is very good but this is best possible model we obtained from the available information. Note that for SAE of 12 out of sampled districts we used the same two covariates since we assume that the underlying model for sample areas also holds for out of sample districts.

For fitting the geographically weighted linear mixed model, i.e. spatial nonstationarity version of Fay Herriot model (1) we also require coordinates of different small areas. The developed SAE method is suitable for the data exhibiting the *spatial nonstationarity*. That is, if spatial nonstationarity is present in the data then the developed method of SAE accounts for nonstationarity while generating small area estimates.

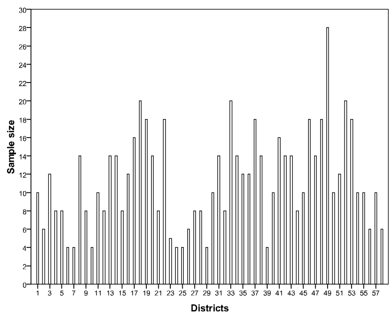


Figure 2. *Distribution of district-specific sample sizes in sample districts.*

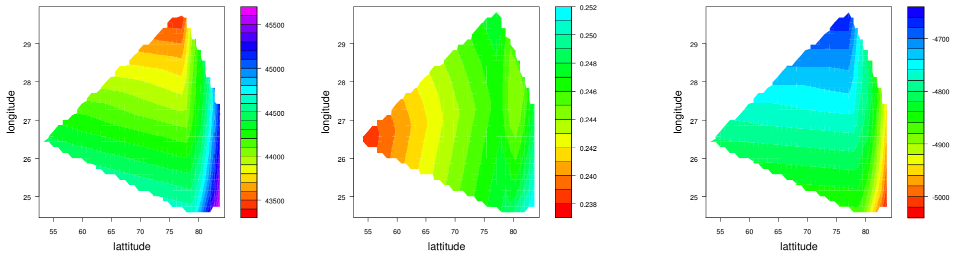
We did some exploratory data analysis to examine whether the ICS data used in this small area analysis (particularly, from sampled districts) have spatial nonstationarity. For this purpose, we computed the district-specific regression coefficients by fitting the spatial nonstationarity version of Fay Herriot model (10). We also obtained the global regression coefficients by fitting the Fay Herriot model (2). In the fitted model we have two covariates, average household size (HH_SIZE) and female population of marginal household (MARG_HH_F), therefore we have three regression coefficients (i.e., intercepts + two slope parameters with respect to HH_SIZE and MARG_HH_F). Table 2 reports the district wise estimates of regression coefficients for ICS data by fitting the spatial nonstationarity version of Fay Herriot model (10). Estimates of regression coefficients for ICS data by fitting the Fay Herriot model (2) are reported in Table 3. Surface plot of regression coefficients for ICS data by fitting the spatial nonstationarity version of Fay Herriot model (10) are shown in Figure 3. The diagnostic procedure to test the spatial nonstationarity described in Section 3.3, that is, the hypothesis $H_{0\eta}:\eta=0$ versus the one-sided alternative $H_{1\eta}:\eta>0$ is applied to NSSO data. Nonstationarity test is significant (p value 0.01), that is, rejected the null hypothesis of spatial stationarity of the model parameters of nonstationarity Fay Herriot model (10). Hence, there is evidence of nonstationarity in the data. In addition, the values of regression coefficients shown in Table 2 and in Figure 3 clearly indicate that the ICS data is not stationary. There is a marginal nonstationarity in the model parameters. Looking at the minimum, maximum, average and median values of model parameters of geographically weighted linear mixed model in Table 2 and the values of model parameters (i.e. global parameters) of linear mixed model in Table 3, we observe that there is evidence spatial nonstationarity in the model parameters. The surface plots of model parameters in Figure 3 and the conclusion from test result also confirm this. It is therefore interesting to apply the developed SAE method with ICS data. As there is evidence of spatial nonstationarity in the data, we expect a slightly better performance of small area estimates with the newly developed method of SAE.

Table 2. District wise estimates of regression coefficients for ICS data by fitting the spatial nonstationarity version of Fay Herriot model (10).

Districts	**Intercept**	**HH_F**	**HH_SIZE**	**Districts**	**Intercept**	**HH_F**	**HH_SIZE**
1	43336.5	0.25	-4653.6	32	44836.4	0.25	-4891.6
2	43620.5	0.25	-4697.1	33	44973.7	0.25	-4914.3
3	44046.5	0.25	-4760.6	34	44542.2	0.25	-4838.9
4	44022.4	0.25	-4757.2	35	44803.7	0.25	-4882.5
5	44076.7	0.25	-4765.2	36	44441.1	0.24	-4803.8
6	43951.9	0.25	-4746.9	37	44856.9	0.25	-4892.7
7	43687.2	0.25	-4707.8	38	44553.1	0.24	-4839
8	43863.3	0.25	-4734.4	39	44658.1	0.25	-4855.7
9	44243.8	0.24	-4790.8	40	44710.7	0.25	-4865.5
10	43934.3	0.25	-4746.7	41	44664.9	0.25	-4857.8
11	44111.6	0.25	-4772	42	44991.5	0.25	-4911.5
12	44192.6	0.25	-4784.4	43	44959.6	0.25	-4908.1
13	44148.4	0.24	-4776.3	44	45062.2	0.25	-4925
14	44165.9	0.24	-4778.3	45	45171.1	0.25	-4941.6
15	44208.8	0.24	-4784.3	46	45164.5	0.25	-4941.6
16	44253.6	0.24	-4791.4	47	45507	0.25	-4995.2
17	44349	0.24	-4805.2	48	45323.3	0.25	-4968.2
18	44811.6	0.25	-4888.8	49	45220.7	0.25	-4952.6
19	44302.4	0.24	-4799.3	50	45364.8	0.25	-4976.1
20	44451	0.24	-4824.3	51	45616.1	0.25	-5016.5
21	44489.4	0.24	-4830.2	52	45127.9	0.25	-4938.4
22	44670.7	0.25	-4862.2	53	45435.6	0.25	-4988.4
23	44244.6	0.24	-4791.2	54	45418.9	0.25	-4986.1
24	44302.1	0.24	-4800.1	55	45305.1	0.25	-4968.3
25	44245.9	0.25	-4793.9	56	45453.1	0.25	-4991.9
26	44680.3	0.25	-4870.5	57	45233.6	0.25	-4957.3
27	44439	0.25	-4823.3	58	45771.4	0.25	-5043.9
28	44085.3	0.25	-4767.8	**Min**	**43336.5**	**0.24**	**-5043.9**
29	44671.9	0.25	-4865.5	**Max**	**45771.4**	**0.25**	**-4653.6**
30	44644.3	0.25	-4858.8	**Mean**	**44627.4**	**0.25**	**-4855.1**
31	44970.8	0.25	-4913.5	**Median**	**44651.2**	**0.25**	**-4856.7**

Table 3. Estimates of regression coefficients for ICS data by fitting the Fay Herriot model (2).

Intercept	44415.191
HH_F	0.24
HH_SIZE	-4800



(a) Intercept (b) HH_SIZE (c) HH_F

Figure 3. *Surface plot of regression coefficients for ICS data by fitting the spatial nonstationarity version of Fay Herriot model (10).*

The coefficient of variation (CV) is used to assess the comparative precision of different small area estimates. The CVs show the sampling variability as a percentage of the estimate. Estimates with large CVs are considered unreliable (i.e. smaller is better). In general, there are no internationally accepted tables available that allow us to judge what is "*too large*". Different organization used different cut off for CV to release their estimate for the public use. For example, Office for National Statistics, United Kingdom has cut off CV value of 20% for acceptable estimates. We computed the percentage CV of direct estimates and two different model based estimates (i.e. EBLUP and NSEBLUP). Besides, comparison of model-based estimates versus direct estimates, we also want to compare the precision of two model-based estimates (i.e. EBLUP and NSEBLUP). Table 4 shows the district-wise distribution of the percentage CVs for the direct estimates and two different model-based estimates defined in Table 1. Figure 4 presents the percentage CV of direct estimates and two different model based estimates for sample districts.

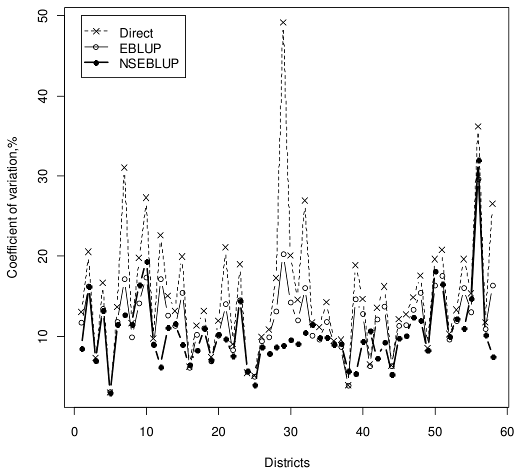


Figure 4. *District-wise plot of percent coefficient of variation for the Direct (dash line,×), EBLUP (thin line, o) and NSEBLUP (solid line, •) estimators.*

Two things stand out from Table 4 and Figure 4. First, the estimated CVs of two model-based estimators (i.e., EBLUP and NSEBLUP) are smaller than the traditional design-based direct estimator. Second, between two model based estimators, the NSEBLUP is better than the EBLUP. That is, the estimated CVs for the model-based estimates have a higher degree of reliability when compared to the direct estimates. In general, relative performance of model based estimates are better as sample size decreases. This result reveals that if spatial nonstationarity is incorporated in SAE it leads to significant gains in efficiency of small area estimates. It is interesting to note that out of 70 districts there are 12 districts with no sample data. For these 12 districts we cannot produce the direct estimates, however, model based estimates generated for these districts have reasonably good CV values and that to within the acceptable limit. In Table 4 If we look at the percent CV it is apparent that the standard errors of the direct estimates are large and therefore the estimates are unreliable. Further, for 12 out of sample districts we observed a significant gain in application of NSEBLUP as compared to the EBLUP method. That is, the NSEBLUP method leads to a drastic gain in precision when estimates were produced for out of sample districts.

Table 4. District wise estimates and percent coefficient of variation for the direct, EBLUP and NSEBLUP estimators from NSSO data.

Districts	**Direct**		**EBLUP**		**NSEBLUP**	
	Yield	**CV,%**	**Yield**	**CV,%**	**Yield**	**CV,%**
Saharanpur	19575	13.04	17737	11.64	17269	8.51
Muzaffarnagar	23483	20.53	17168	16.20	18194	16.26
Bijnor	19442	7.28	18918	6.95	19323	7.00
Moradabad	17700	16.67	16770	13.42	16830	13.18
Rampur	17250	3.01	17173	2.99	17110	2.97
Jyotiba Phule Nagar	10850	13.68	11635	11.78	12009	11.53
Ghaziabad	16800	31.03	16726	17.10	17420	12.70
Bulandshahar	17418	11.64	18126	9.89	17314	11.44
Aligarh	12419	19.77	14302	14.11	12365	16.43
Mathura	10483	27.27	12712	17.35	12146	19.38
Etah	12125	9.73	12514	8.95	12249	9.01
Mainpuri	14019	22.58	13707	17.14	13641	6.20
Budaun	12721	15.05	13315	12.64	13248	11.07
Bareilly	13511	13.18	14150	11.24	14114	11.60
Pilibhit	14938	19.94	14684	15.42	15277	8.96
Shahjahanpur	18863	6.23	18403	6.07	17307	6.47
Kheri	14975	11.37	15081	10.19	15392	8.28
Sitapur	15986	13.11	16428	10.99	16344	10.96
Hardoi	19286	7.39	19315	6.89	19468	7.05
Unnao	12843	11.92	14024	10.09	14144	10.24
Lucknow	17331	21.08	18251	14.00	17573	9.66
Rae Bareli	19506	9.03	19284	8.24	18858	7.61
Farrukhabad	8880	18.95	10470	14.52	10505	14.42
Kannauj *	34050	5.45	30396	5.51	33034	5.64
Etawah	15463	5.07	15431	4.97	15496	3.97
Auraiya	23717	9.96	20987	9.37	19081	8.69
Kanpur Dehat	21200	10.82	19526	9.89	17331	7.88
Kanpur Nagar	15375	17.27	16326	13.06	16434	8.70
Banda	8888	49.15	13406	20.20	15905	8.82
Fatehpur	14612	20.11	15895	14.23	16793	9.59
Pratapgarh	16304	14.52	16439	11.94	16749	9.06
Kaushambi	15450	26.93	16633	16.04	17038	10.50
Allahabad	19465	11.72	20227	10.10	19415	11.50
Barabanki	18668	11.12	18757	9.61	18044	9.87
Faizabad	16379	14.26	16559	11.77	16745	9.86
Ambedkar Nagar	17692	9.44	16650	9.10	16900	9.00
Sultanpur	16609	9.57	16796	8.66	16653	9.07
Bahraich	14714	3.89	14736	3.84	15197	5.63
Shrawasti	15075	18.90	15169	14.60	15947	5.36
Balrampur	11975	14.63	12343	12.76	14200	9.42
Gonda	16981	6.47	16704	6.29	15442	10.67

Siddharthnagar	12829	13.55	12922	12.11	13970	7.26
Basti	14268	16.21	14163	13.65	14327	9.25
Sant Kabir Nagar	13319	6.35	13272	6.21	13169	5.27
Mahrajganj	21690	12.15	18603	11.33	15745	9.78
Gorakhpur	12164	12.73	12441	11.42	12793	10.04
Kushinagar	19343	14.88	16669	13.33	16006	12.39
Deoria	8364	17.58	8873	15.41	9858	12.01
Azamgarh	11957	8.52	12034	8.16	11924	8.26
Mau	9820	19.64	10498	16.29	9578	18.14
Ballia	7029	20.78	7775	17.48	7988	16.53
Jaunpur	16990	10.27	16408	9.60	16745	9.93
Ghazipur	10858	13.29	11286	11.89	10933	12.15
Chandauli	12000	19.63	12231	16.06	12196	10.94
Varanasi	17665	15.38	17055	13.04	17594	14.69
Sant Ravidas Nagar	6693	36.21	7136	29.63	6522	32.04
Mirzapur	15625	11.71	15043	10.83	15162	10.19
Sonbhadra	15283	26.49	16337	16.29	17605	7.41
Meerut			14897	21.60	16167	19.97
Baghpat			11947	27.57	13030	11.03
Gautam Buddha Nr			16677	19.83	17756	6.82
Hatharas			15162	21.27	14326	16.86
Agra			14731	21.84	12789	30.74
Firozabad			14223	22.67	12954	22.99
Jalaun			15028	21.58	15927	10.82
Jhansi			17582	18.54	19186	22.03
Lalitpur			16959	19.43	18698	9.96
Hamirpur			16476	20.01	17280	7.19
Mahoba			16196	20.38	17123	6.01
Chitrakoot			14723	22.14	15202	5.79

5. Concluding Remarks

This paper illustrates that the SAE technique can be satisfactorily applied to produce reliable district level estimates of crop yield using CCE supervised under ICS scheme. Although the ICS supervised CCEs number only 30,000 in the entire country i.e. the sample size is very low, the collected data is of very high quality. The estimates generated using this data are expected to be relatively free from various sources of non-sampling errors. Further SAE provides estimates for those districts where there is no sample information under ICS and so direct estimates cannot be computed. It is, therefore, recommended that wherever it is not possible to conduct adequate number of CCEs due to constraints of cost or infrastructure or both, SAE technique can be gainfully used to generate reliable estimates of crop yield based on a smaller sample. In addition, when there is spatial nonstationarity in the data developed method should be used to improve these disaggregate level estimates. We noticed that the ICS data have evidence of spatial nonstationarity. As a consequence the developed NSEBLUP method when applied to ICS data enhanced the efficiency of small area estimates.

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Assisting total estimation in spatial populations

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Abstract

In the last decade, we witnessed a reappraisal of design-based techniques for inference on synthetic values (i.e., mean or total) for spatially distributed populations. Some authors use splines to incorporate the geographical information in estimation, while others treat the sampling design as a covariate. Our proposal is able to exploit the geographical relationships between the locations in the domain to enrich estimation. Weights are defined as standardized functions of the Euclidean distances. Some statistical properties of the estimator are derived. Results of a Monte Carlo simulation are presented in order to better appreciate the performances of our proposal when compared to other alternatives not able to exploit the spatial information of the data.

keywords: Geographically weighted estimator; Generalized regression estimator.

1 Introduction

In finite population inference, the estimation of population quantities, like the total or the individual mean, enjoys a number of design-based results that do not consider the spatial characteristics of the population. Spatial features, rather, enter in the solution via super-population models; different versions of kriging are a popular tool in this direction. However, model specification is a critical point, and research tends towards estimators that maintain good properties when such superpopulation models are mis-specified. The proposal of introducing the spatial characteristics of the population in a design-based estimator needs to take into account a predefined function of the distance between each element of the population, potentially entering in the sample, and any other element. This was the content of work of Bruno et al. (2013), dealing with design-based spatial individual estimators. These estimators, which accommodate in a statistical framework the non-stochastic proposal of Shepard (1968), are competitive with respect to estimators based on kriging, which however suffer the risk of model misspecification.

Estimation of population quantities like means and totals leads to stronger statistical properties than the estimation of individual values, being based on the properties of the sum of random quantities, exploiting the finite version of the central limit theorem (Hájek and Dupac, 1981). The present paper proposes a design-based model assisted estimator of a spatial population total, say GWGREG, that emphasizes local properties. This is obtained by incorporating the theory of geographically weighted estimation (Fotheringham et al., 2003) into the finite population generalized regression estimation, extensively analyzed since the seminal work of Särndal et al. (1992). The desirable and well known properties of GREG are tailored to our GWGREG estimator, using, when needed, the results of Breidt and Opsomer (2000). They succeed in keeping local relationships into account via a local polynomial regression that adjusts an estimator of global syntheses of the population. Our proposal might be compared with Cicchitelli and Montanari (2012) who propose to estimate synthetic population quantities exploiting a spline-based correction in a spatial framework.

Our synthesis summarizes the ideas contained in Cicchitelli and Montanari (2012) and Breidt and Opsomer (2000) providing an estimator of global population characteristics that exploits local relationships in space, adapting into a finite population proper context the proposal of GWR due to Fotheringham et al. (2003). We are motivated by an innovative way of considering the auxiliary information contained in the geographical coordinates available for the whole population. Such method is exposed in Bruno et al. (2013) and assesses geographical population characteristics in an intersubjective way that may be compared to the variogram estimation needed for kriging. The present solution, in the spirit of the model-assisted design-based paradigm, emphasizes design-based properties which mitigate the risks of a totally model based proposal and lie in the mainstream of the search for robustness.

2 Geographically Weighted Regression

The usual WLS parameter estimator is able to take into account a wide variety of theoretical situations; however, in a spatial context, the geographical relationship between locations ought to be considered in order to provide better results. Geographically Weighted Regression (GWR) has been firstly proposed by Brunsdon et al. (1998) and since then has gained a lot of praise. It is a very flexible tool which aims to capture the spatial nature of the study variable by means of the associated geographical information. In a given spatial domain $\mathcal{D}$, generally continuous, where only a set $L = \{\mathbf{u}_1, \ldots, \mathbf{u}_i, \ldots, \mathbf{u}_n\}$ of n locations is known, GWR is a *local* statistical model able to take into account the spatial varying behavior. For any location in the domain $\mathcal{D}$, identified by some geographical references $\mathbf{u} = (u_x, u_y)$, usually latitude and longitude, an *individual* (i.e. local) linear regression model is specified

$$z(\mathbf{u}) = \mathbf{x}^\top \boldsymbol{\beta}(\mathbf{u}) + \varepsilon(\mathbf{u}), \tag{1}$$

where $\mathbf{x}$ is the p-dimensional vector of auxiliary variables and $\varepsilon(\mathbf{u}) \sim \mathcal{N}(0, \sigma^2(\mathbf{u}))$ (i.e. errors are assumed heteroscedastic). GWR postulates the existence a vector $\boldsymbol{\beta}(\mathbf{u})$ of size $p \times 1$ for each element of the domain. Any unobserved value at the generic location $\mathbf{u}$ can be estimated as

$$\hat{z}(\mathbf{u}) = \mathbf{x}^\top \mathbf{b}(\mathbf{u}),$$

where

$$\mathbf{b}(\mathbf{u}) = (\mathbf{X}^\top \boldsymbol{\Phi}(\mathbf{u})\mathbf{X})^{-1}\mathbf{X}^\top \boldsymbol{\Phi}(\mathbf{u})\mathbf{z}. \tag{2}$$

The individual n-dimensional diagonal matrix $\mathbf{\Phi}(\mathbf{u})$ contains the values of a decreasing function of the Euclidean distances between $\mathbf{u}$ and all the locations belonging to L, rather than the reciprocal of the individual variances as in the classical WLS estimator.

2.1 Proposals on the weighting matrix

For any location in the domain, the n-dimensional diagonal matrix $\mathbf{\Phi}(\mathbf{u})$ assumes a key role, since it contains the information about the population spatial structure. Its values are computed through a decreasing function of the Euclidean distances between the generic location $\mathbf{u}$ and the ones belonging to set L

$$\mathbf{\Phi}(\mathbf{u}) = \mathrm{diag}(\phi_i(\mathbf{u})) = \mathrm{diag}(f(\|\mathbf{u}_i - \mathbf{u}\|)), \quad i = 1, \ldots, n.$$

Each element of matrix $\mathbf{\Phi}(\mathbf{u})$ assigns a decreasing weight to observations at farther distances from $\mathbf{u}$ accordingly to function $f(\cdot)$.

Brunsdon et al. (1998), as a first suggestion, propose the use of the step function

$$\phi_i(\mathbf{u}) = \begin{cases} 1, & \text{if } d_i(\mathbf{u}) \leq h; \\ 0, & \text{otherwise;} \end{cases}$$

where h is the chosen radius of the neighbourhood and $d_i(\mathbf{u})$ is the Euclidean distance between two locations $d_i(\mathbf{u}) = \|\mathbf{u}_i - \mathbf{u}\|$.

Successively, Fotheringham et al. (2003) propose the use of continuous functions to remove the problem of weights' spatial discontinuity. Bell-like kernels are able to replicate more accurately the spatial structure according to the well known Tobler's first law of geography. A straightforward choice is the Gaussian kernel

$$\phi_i(\mathbf{u}) = \exp\left\{-\frac{d_i(\mathbf{u})^2}{2h^2}\right\},$$

where h is the bandwidth which manages the width of the kernel. The bi-square kernel is an alternative bell-like function: it is steeper than the Gaussian up to the bandwidth value and assigns zero values to farther distances

$$\phi_i(\mathbf{u}) = \begin{cases} \left(1 - \dfrac{d_i(\mathbf{u})^2}{h^2}\right)^2, & \text{if } d_i(\mathbf{u}) \leq h; \\ 0, & \text{otherwise.} \end{cases}$$

Figure 1 shows the behavior of the Gaussian and bi-square kernels.

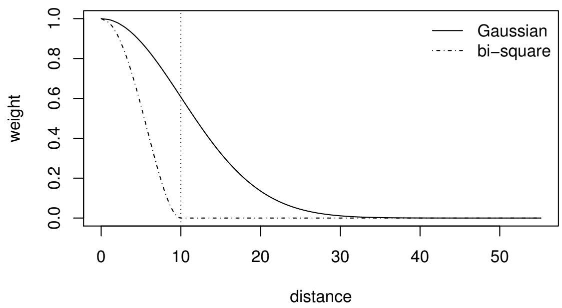

Figure 1: Functions of the Euclidean distances for the Gaussian and bi-square kernels.

3 Introducing GWR in GREG estimation of finite population quantities

When moving from a generic dataset to the estimation of finite population syntheses (i.e. totals or means) via probabilistic sampling, one has to take into account the relevance of the sampling error.

Let us consider a population $\mathcal{P}$ of size N; a fixed size sample s is drawn from $\mathcal{P}$ with probability $p_N(s)$ accordingly to a probabilistic sampling design $p_N(\cdot)$. Let n be the size of s and $f = n/N$ the sample fraction. Inclusion in the sample of the generic population element i is managed by the Bernoulli random variable $\mathcal{I}_{(i\in s)}$ such that $\pi_i = \Pr(i \in s) > 0$ for all $i \in \mathcal{P}$; analogously, inclusion of the generic couple i, j is managed by $\mathcal{I}_{(i,j\in s)}$ such that $\pi_{i,j} = \Pr(i, j \in s) > 0$ for all $i, j \in \mathcal{P}$. Quantities π_i and $\pi_{i,j}$ are the first- and second-order inclusion probabilities, respectively. For sake of simplicity, whenever it will not be explicitly needed, we will write $\mathcal{I}_i$ in place of $\mathcal{I}_{(i\in s)}$.

Usually one needs to estimate the population total $T(z)$ of the study variable, which is observed only for $i \in s$. In such a framework, the well-known and widely adopted Horvitz-Thompson (Horvitz and Thompson, 1952) design-unbiased estimator is

$$\hat{T}_{HT}(z) = \sum_{i \in s} \frac{z_i}{\pi_i} = \sum_{i \in \mathcal{P}} \frac{z_i \mathcal{I}_i}{\pi_i}. \tag{3}$$

Its variance is given by

$$\mathrm{V}[\hat{T}_{HT}(z)] = \sum_{i,j \in s} (\pi_{i,j} - \pi_i \pi_j) \frac{z_i}{\pi_i} \frac{z_j}{\pi_j}.$$

Let us now consider the case where a vector $\mathbf{x}_i$ of p auxiliary variables is known for each population element, or at least its total $T(\mathbf{x})$ over the population is known and the $\mathbf{x}_i$ are available for the sampled elements. The generalized regression (GREG) estimator of the population total $T(z)$ is defined (see e.g. Särndal et al., 1992) as

$$\hat{T}_{GREG}(z) = \hat{T}_{HT}(z) + (T(\mathbf{x}) - \hat{T}_{HT}(\mathbf{x}))^\top \hat{\mathbf{b}}_{GREG}, \tag{4}$$

where $\hat{T}_{HT}(\cdot)$ is the Horwitz-Thompson estimator defined in (3) and

$$\begin{aligned} \hat{\mathbf{b}}_{GREG} &= (\mathbf{X}_s^\top \mathbf{W}_s^{-1} \mathbf{\Pi}_s^{-1} \mathbf{X}_s)^{-1} (\mathbf{X}_s^\top \mathbf{W}_s^{-1} \mathbf{\Pi}_s^{-1} \mathbf{z}_s) \\ &= \left(\sum_{i \in s} \frac{\mathbf{x}_i \mathbf{x}_i^\top}{\pi_i \sigma_i^2} \right)^{-1} \sum_{i \in s} \frac{\mathbf{x}_i z_i}{\pi_i \sigma_i^2}. \end{aligned} \tag{5}$$

Matrix $\mathbf{X}_s$ is the $n \times p$ matrix of the auxiliary variables for the sampled units and $\mathbf{x}_i^\top$ is its ith row vector, $\mathbf{W}_s$ is the usual n-dimensional diagonal matrix of the variances σ_i^2 of the study variable for the sampled units and $\mathbf{\Pi}_s$ is the n-dimensional diagonal matrix of the first-order inclusion probabilities for the sampled elements. Vector $\hat{\mathbf{b}}_{GREG}$ is the estimate of the WLS regression coefficient vector

$$\mathbf{b} = (\mathbf{X}^\top \mathbf{W}^{-1} \mathbf{X})^{-1} (\mathbf{X}^\top \mathbf{W}^{-1} \mathbf{z}).$$

through the first-order inclusion probabilities of the n-dimensional sample collected in matrix $\mathbf{\Pi}_s$. Easy manipulations of (4) give

$$\hat{T}_{GREG}(z) = \sum_{i\in s} \frac{z_i}{\pi_i} + \sum_{i\in \mathcal{P}} \mathbf{x}_i{}^\top \hat{\mathbf{b}}_{GREG} - \sum_{i\in s} \frac{\mathbf{x}_i^\top}{\pi_i} \hat{\mathbf{b}}_{GREG}$$
$$= \sum_{i\in s} \frac{z_i - \mathbf{x}_i^\top \hat{\mathbf{b}}_{GREG}}{\pi_i} + \sum_{i\in \mathcal{P}} \mathbf{x}_i^\top \hat{\mathbf{b}}_{GREG}. \tag{6}$$

In this expression sums explicitly refer to sample s and population $\mathcal{P}$,respectively.

Let us now move to a spatial setting. Suppose that a (regular) finite grid of N cells has been superimposed over the spatial domain $\mathcal{D}$ or that we are interested in N locations in it; in this way stating the coincidence of domain $\mathcal{D}$ and population $\mathcal{P}$. Thus, model (1) can be adopted, where an individual vector of parameters $\boldsymbol{\beta}(\mathbf{u}_i)$, rather than a global one, needs to be specified for each population element. Moreover, the sample is constituted by n locations drawn from $\mathcal{P}$; therefore, the first- and second-order inclusion probabilities now refer explicitly to the selection of population locations in the sample.

The proposal of a local regression model for the relationship between auxiliary variables and the study variable can suitably manage the geographical information. We propose to encompass the geographical relationships between locations in GREG estimation by means of GWR. Thus, analogously to (6), we write the Geographically Weighted Generalized Regression (GW-GREG) estimator as

$$\hat{T}_{GWGREG}(z) = \sum_{i\in s} \frac{z(\mathbf{u}_i) - \hat{z}(\mathbf{u}_i)}{\pi_i} + \sum_{i\in \mathcal{P}} \hat{z}(\mathbf{u}_i). \tag{7}$$

The value of the study variable at the generic location $\mathbf{u}_i$ is estimated by means of

$$\hat{z}(\mathbf{u}_i) = \mathbf{x}_i^\top \hat{\mathbf{b}}_{GWGREG}(\mathbf{u}_i)$$
$$= \mathbf{x}_i^\top (\mathbf{X}_s^\top \mathbf{\Phi}_s(\mathbf{u}_i)\mathbf{\Pi}_s^{-1}\mathbf{X}_s)^{-1}\mathbf{X}_s^\top \mathbf{\Phi}_s(\mathbf{u}_i)\mathbf{\Pi}_s^{-1}\mathbf{z}_s = \hat{\mathbf{w}}_s(\mathbf{u}_i)^\top \mathbf{z}_s$$
$$= \mathbf{x}_i^\top \left(\sum_{j\in s} \frac{\mathbf{x}_i \mathbf{x}_i^\top \phi_{sj}(\mathbf{u}_i)}{\pi_j} \right)^{-1} \sum_{j\in s} \frac{\mathbf{x}_i z(\mathbf{u}_j)\phi_{sj}(\mathbf{u}_i)}{\pi_j}, \tag{8}$$

where the individual $\hat{\mathbf{b}}_{GWGREG}(\mathbf{u}_i)$ is highlighted. The n-dimensional diagonal matrix $\mathbf{\Phi}_s(\mathbf{u}_i)$ collects the values of the decreasing function of the

Euclidean distances between location $\mathbf{u}_i$ and all the sampled ones. In equation (8) the scalar standardized weights

$$\hat{w}_{sj}(\mathbf{u}_i) = \mathbf{x}_i^\top \left(\sum_{j\in s} \frac{\mathbf{x}_i \mathbf{x}_i^\top \phi_{sj}(\mathbf{u}_i)}{\pi_j} \right)^{-1} \frac{\mathbf{x}_i z(\mathbf{u}_j)\phi_{sj}(\mathbf{u}_j)}{\pi_j} = \mathbf{x}_i^\top \hat{\mathbf{H}}_1(\mathbf{u}_i)^{-1} \hat{\mathbf{h}}_2(\mathbf{u}_i) \tag{9}$$

can be isolated, while matrix $\hat{\mathbf{H}}_1(\mathbf{u}_i)$ and vector $\hat{\mathbf{h}}_2(\mathbf{u}_i)$ highlight suitable quantities summarizing the two main factors.

Estimator (7) is linear in the sampled values $z(\mathbf{u}_i)$; it may be rewritten as follows

$$\begin{aligned}
\hat{T}_{GWGREG}(z) &= \sum_{i\in s} \frac{z(\mathbf{u}_i) - \hat{z}(\mathbf{u}_i)}{\pi_i} + \sum_{i\in \mathcal{P}} \hat{z}(\mathbf{u}_i) \\
&= \sum_{i\in s} \frac{z(\mathbf{u}_i)}{\pi_i} + \sum_{j\in \mathcal{P}} \hat{z}(\mathbf{u}_j) - \sum_{j\in s} \frac{\hat{z}(\mathbf{u}_j)}{\pi_j} \\
&= \sum_{i\in s} \frac{z(\mathbf{u}_i)}{\pi_i} + \sum_{j\in \mathcal{P}} \sum_{i\in s} \hat{w}_{sj}(\mathbf{u}_i) z(\mathbf{u}_i) - \sum_{j\in \mathcal{P}} \frac{\mathcal{I}_{j\in S}}{\pi_j} \sum_{i\in s} \hat{w}_{sj}(\mathbf{u}_i) z(\mathbf{u}_i) \\
&= \sum_{i\in s} \frac{z(\mathbf{u}_i)}{\pi_i} + \sum_{i\in s} \sum_{j\in \mathcal{P}} \hat{\mathbf{w}}_s(\mathbf{u}_j)^\top \mathbf{e}_i z(\mathbf{u}_i) - \sum_{i\in s} \sum_{j\in \mathcal{P}} \frac{\mathcal{I}_{j\in S}}{\pi_j} \hat{\mathbf{w}}_s(\mathbf{u}_j)^\top \mathbf{e}_i z(\mathbf{u}_i) \\
&= \sum_{i\in s} \left(\frac{1}{\pi_i} + \sum_{j\in \mathcal{P}} \left(1 - \frac{\mathcal{I}_{j\in S}}{\pi_j} \right) \hat{\mathbf{w}}_s(\mathbf{u}_j)^\top \mathbf{e}_i \right) z(\mathbf{u}_i),
\end{aligned}$$

where $\mathbf{e}_i$ is the ith canonical basis of the n-dimensional space, weighting vector $\hat{\mathbf{w}}_s(\mathbf{u}_j)$ has been defined in equation (8) and $\mathcal{I}_i$ is the Bernoulli random variable managing the inclusion of location $\mathbf{u}_i$ in the sample. The last line of the previous equation identifies the g-weights (Särndal et al., 1992)

$$g(\mathbf{u}_i) = \frac{1}{\pi_i} + \sum_{j\in \mathcal{P}} \left(1 - \frac{\mathcal{I}_{j\in S}}{\pi_j} \right) \hat{\mathbf{w}}_s(\mathbf{u}_j)^\top \mathbf{e}_i, \tag{10}$$

which are useful for estimating the variance of (7).

3.1 The case without auxiliary variables

Let us now consider the GWGREG estimator in the special case where no auxiliary variable is available and the conditions for the applicability of

GREG estimation do not hold. On the contrary the GWGREG estimator can be adopted because the spatial information states relationships between population elements. Thus, the GWRGREG estimator of equations (8) and (9) becomes

$$\hat{z}(\mathbf{u}_i) = (\mathbf{1}_n^\top \mathbf{\Phi}_s(\mathbf{u}_i)\mathbf{\Pi}_s^{-1}\mathbf{1}_n)^{-1}\mathbf{1}_n^\top \mathbf{\Phi}_s(\mathbf{u}_i)\mathbf{\Pi}_s^{-1}\mathbf{z}_s = \hat{\mathbf{w}}_s(\mathbf{u}_i)^\top \mathbf{z}_s$$
$$= \left(\sum_{j\in s}\frac{\phi_{sj}(\mathbf{u}_i)}{\pi_j}\right)^{-1}\sum_{j\in s}\frac{\phi_{sj}(\mathbf{u}_i)z(\mathbf{u}_j)}{\pi_j} = \hat{h}_1(\mathbf{u}_i)^{-1}\hat{h}_2(\mathbf{u}_i). \quad (11)$$

In (11), weights (9) reduce to

$$\hat{w}_{sj}(\mathbf{u}_i) = \frac{\phi_{sj}(\mathbf{u}_i)}{\sum_{i\in s}\phi_{sj}(\mathbf{u}_i)} = \frac{f(\|\mathbf{u}_i - \mathbf{u}\|)}{\sum_{i\in s} f(\|\mathbf{u}_i - \mathbf{u}\|)}$$

and the quantities involved consequently reduces to scalars $\hat{h}_1(\mathbf{u}_i)$ and $\hat{h}_2(\mathbf{u}_i)$.

4 Variance and its estimation

From the GREG theory (Särndal et al., 1992), the approximated variance of the GWGREG estimator $\hat{T}_{GWREG}(z)$ is

$$\mathrm{V}[\hat{t}\hat{t}_{GWREG}(z)] \simeq \sum\sum_{i,j\in\mathcal{D}}(\pi_{ij} - \pi_i\pi_j)\frac{z(\mathbf{u}_i) - \hat{z}(\mathbf{u}_i)}{\pi_i}\frac{z(\mathbf{u}_j) - \hat{z}(\mathbf{u}_j)}{\pi_j}.$$

it is estimated by

$$\hat{\mathrm{V}}[\hat{T}_{GWREG}(z)] = \sum\sum_{i,j\in s}\frac{\pi_{ij} - \pi_i\pi_j}{\pi_{ij}}\frac{z(\mathbf{u}_i) - \hat{z}(\mathbf{u}_i)}{\pi_i}\frac{z(\mathbf{u}_j) - \hat{z}(\mathbf{u}_j)}{\pi_j}.$$

Alternatively, the variance estimator can be obtained by employing the g-weights of formula (10) is

$$\hat{\mathrm{V}}[\hat{T}_{GWREG}(z)] = \sum\sum_{i,j\in s}\frac{\pi_{ij} - \pi_i\pi_j}{\pi_{ij}}\frac{g_i(z(\mathbf{u}_i) - \hat{z}(\mathbf{u}_i))}{\pi_i}\frac{g_j(z(\mathbf{u}_j) - \hat{z}(\mathbf{u}_j))}{\pi_j}.$$

Accordingly to the asymptotic results by Breidt and Opsomer (2000), we make the following assumptions:

A1 the errors of the superpopulation model ε_i have zero mean, finite variance and compact support uniformly for all N;

A2 for all N the locations are fixed;

A3 the spatial mean $m(\mathbf{u}_i)$ is smooth and the variance $v(\mathbf{u}_i) = \sigma_i^2$ continuous and strictly positive;

A4 as $N \to \infty$, $n/N \to f \in (0, 1)$;

A5 for all N: $\min_{i \in \mathcal{D}} \pi_i \geq \lambda > 0$, $\min_{i,j \in \mathcal{D}} \pi_{ij} \geq \lambda^* > 0$ and

$$\limsup_{N \to \infty} n \max_{i,j \in \mathcal{D}; i \neq j} \mid \pi_{ij} - \pi_i \pi_j \mid < \infty;$$

A6 for any t-tuple $G_{t,N}$ of t elements $(i_1, i_2, \ldots, i_t)$ in the domain:

$$\lim_{N \to \infty} n^2 \max_{i_1, \ldots, i_4 \in G_{4,N}} \mid \mathrm{E}[(\mathcal{I}_{i_1} - \pi_{i_1}) \cdots (\mathcal{I}_{i_4} - \pi_{i_4})] \mid < \infty$$

$$\lim_{N \to \infty} \max_{i_1, \ldots, i_4 \in G_{4,N}} \mid \mathrm{E}[(\mathcal{I}_{i_1} \mathcal{I}_{i_2} - \pi_{i_1} \pi_{i_2})(\mathcal{I}_{i_3} \mathcal{I}_{i_4} - \pi_{i_3} \pi_{i_4})] \mid = 0$$

$$\limsup_{N \to \infty} n \max_{i_1, \ldots, i_3 \in G_{3,N}} \mid \mathrm{E}[(\mathcal{I}_{i_1} - \pi_{i_1})^2 (\mathcal{I}_{i_2} - \pi_{i_2})(\mathcal{I}_{i_3} - \pi_{i_3})] \mid < \infty$$

Then assuming A1-A6, it results

$$\frac{N^{-1}(\hat{T}_{GWREG}(z) - t(z))}{\sqrt{N^{-1} \mathrm{V}[\hat{T}_{GWREG}(z)]}} \xrightarrow{\ell} \mathcal{N}(0, 1)$$

and

$$\frac{N^{-1}(\hat{T}_{GWREG}(z) - t(z))}{\sqrt{N^{-1} \hat{\mathrm{V}}[\hat{T}_{GWREG}(z)]}} \xrightarrow{\ell} \mathcal{N}(0, 1).$$

Therefore, we can derive the confidence interval at level $(1 - \alpha)$

$$\left(\hat{T}_{GWREG}(z) - z_{1-\alpha/2} \hat{\mathrm{V}}[\hat{T}_{GWREG}(z)]^{1/2}, \hat{T}_{GWREG}(z) + z_{1-\alpha/2} \hat{\mathrm{V}}[\hat{T}_{GWREG}(z)]^{1/2} \right).$$

5 The simulation study

Three populations were generated over a 60×60 regular grid on the unit square (see Figure 2):

- a realization of a Gaussian random field having Gaussian semivariogram with mean $\mu = 10$ and sill $\sigma^2 = 8$, the effective range is $\phi = 0.7$;
- a realization of a Gaussian random field having exponential semivariogram with mean $\mu = 10$ and sill $\sigma^2 = 8$, the effective range is $\phi = 0.7$;
- a realization of a pure nugget process with mean $\mu = 10$ and variance $\sigma^2 = 8$.

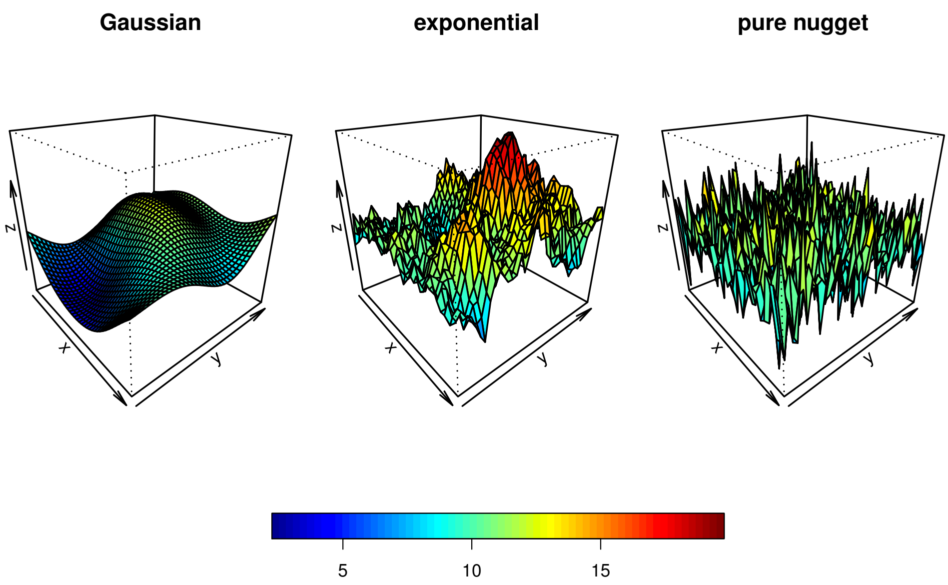

Figure 2: 3-d plot of the three popultions generated for the simulations.

For each population 1000 random samples have been drawn at four different sampling fractions ($f = 0.025, 0.050, 0.075, 0.100$) with SRSWoR.

Four different estimators of the population total have been computed for each sample:

- the GWRGREG estimator adopting the inverse squared Euclidean distances (idw);

- the GWRGREG estimator employing Gaussian kernel with bandwidth 1/8 (k.8) and 1/16 (k.16) of the maximum distance in the domain;
- the expansion estimator (Exp).

The performances of the four estimators are compared by means of:

- the relative bias;
- the relative RMSE;
- the coverage of the 95% confidence interval.

For all the population analysed, the relative bias (Figure 3) is almost null regardless of the sampling fraction and the estimator adopted. The relative bias of the estimators in the exponential and pure nugget population behave slightly better than in the Gaussian.

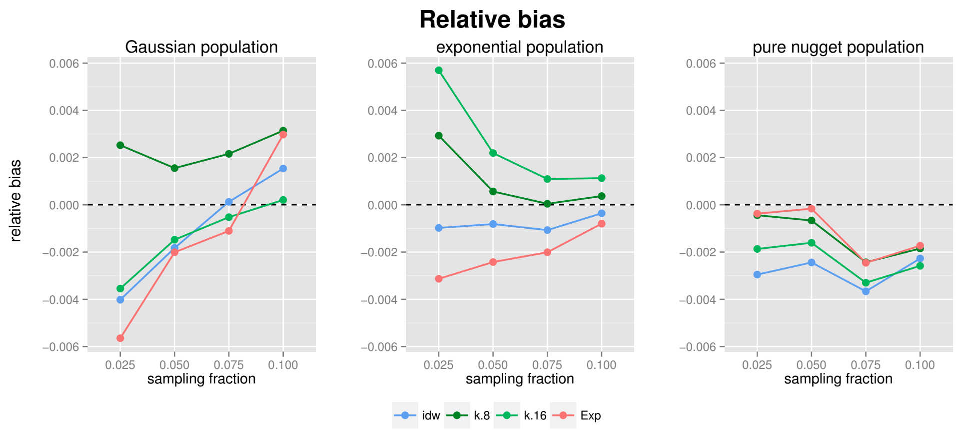

Figure 3: Relative bias of the four estimators analyzed in the simulation study.

The increase of the sampling fraction substantially reduces the relative RMSE (Figure 4) regardless of the population analysed and the sampling fraction. The GWGREG estimator performs better than the expansion estimator for the Gaussian population and less so for the exponential population. Moreover, employing the Gaussian kernel estimator with a bandwidth of 1/16

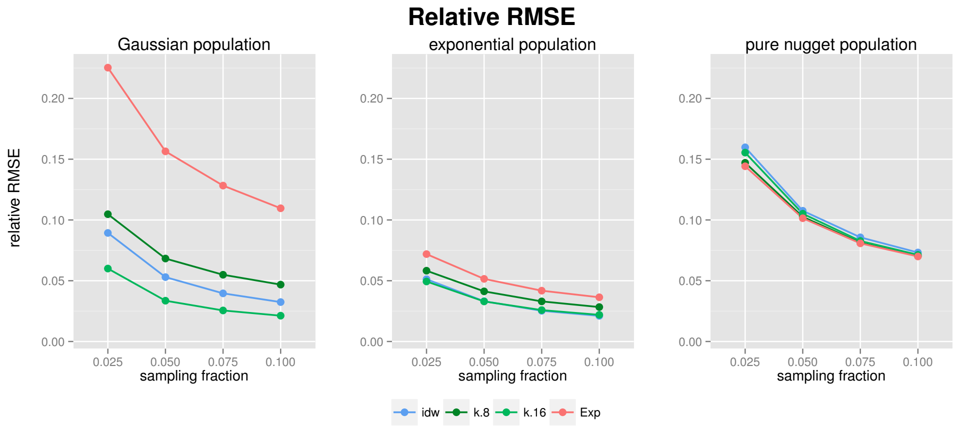

Figure 4: Relative RMSE of the four estimators analyzed in the simulation study.

the maximum distance or the inverse squared distance produces better performances.

The coverages (Figure 5) of the analysed estimators are close to the 95% nominal level, apart for the Gaussian kernel with bandwidth 1/16 of the maximum distance which, however, substantially improves its performances as the sampling fraction increases.

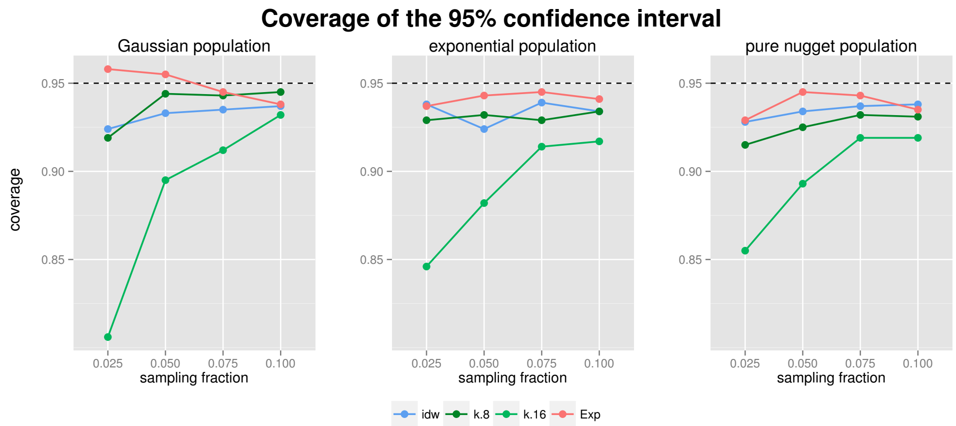

Figure 5: Coverage of the 95% confidence interval of the four estimators analyzed in the simulation study.

6 Discussion and future developments

Employing the GWR in a design-based framework allows to obtain a GREG estimator able to take into account the spatial setting in a simple and intuitive way by means of local models.

The GWGREG estimator is almost unbiased.

When compared to the usual expansion estimator, the GWGREG estimator shows good performances especially in terms of relative RMSE.

The coverage of the GWGREG estimator is close to the nominal level especially as the sample fraction increases.

The simulation study has shown different behaviours for the three functions of the Euclidean distances taken into account; perhaps a preliminary cross-validation study may help in identifying the best function.

It may be of interest to consider different sampling designs, such the stratified or spatially balanced designs.

Effects of the auxiliary variables will be analysed.

Analyses on the estimation of the variance of the GWGREG estimator have been conducted only for the π estimator; a thorough simulation study encompassing the variance estimators based on the g-weights and on resampling techniques will be conducted.

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Estimation strategies with different sources of information

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ABSTRACT

Since 2011, Eurostat began a reorganization of EU social statistics. This project has evolved over time up to the final version presented at the meeting of Directors of Social Statistics, held in September 2014.

The model proposed by Eurostat is based on an approach in modules of target variables which, by construction, can be pooled and, where possible, can exploit the use of information measured at different surveys for the construction of the estimates.

Eurostat also presented a roadmap (Eurostat, 2013j) for the implementation of the project which contemplates short, medium and long term studies. The first study focuses on methods for pooling estimates to be made with the overlap of samples on which were recorded the same variables, regardless of the drawings below; in the medium term the study focuses on redesign of sample surveys aimed to optimize sample size and allocation and exploiting the new modular approach; in the long term a final study for the integrated micro-database for social statistics, powered by both surveys and the information from the statistical registers.

This paper presents a possible scenario for the integration of social surveys which arises from a specific strategy associated with a specific sampling design. The whole purpose is to achieve a complete integration of the system of social surveys and ensure maximum integration with the registries system present in National Statistical Institute.

A Montecarlo simulation study using Census 2011 data has been carried out. In the simulation 200 samples has been drawn for each of 4 very important Istat surveys, referring to two regions Trentino-Altoadige and Marche. In particular the surveys considered are the Labour Force survey, the Multipurpose survey, the Eusilc survey and the Consumer Expenditure survey.

Finally an empirical evaluation is performed on different estimators of the labour force characteristics (employed and unemployed), for different domains, computing the traditional Monte Carlo indicators base on the difference with respect to the census values in order to evaluate the empirical performances of estimator in terms of bias and variability.

Keywords: Integration, pooling, projection

1. Introduction

There are several alternative scenarios studied and proposed by Istat for the System for integration of Social Surveys (SINTESY). These scenarios are in line with the Eurostat project of modernization of social surveys, aimed to obtain a complete integration of the social surveys SINTESY could be exploited for the estimation of hypercube of the next permanent census. The methodologies studied – both at survey design stage and in the estimation phase- is aimed to limit the use of direct survey for the collection of data on socio-economic variables, focusing on a strategy based on the use of administrative sources and on the integration of social surveys. In the paper, paragraph 2 describes the classification of the target variables and auxiliary variables considered in the system. Paragraph 3 presents the integration scenario called *"One survey occasion with pooled sample"* used in the empirical study. Paragraph 4 discusses the estimation strategies with reference to the scenario proposed; paragraph 5 describes the simulation study carried out and the results obtained.

2. Classification of variables

The classification of variables proposed in the paper follows the Eurostat's approach and is aimed to group in homogeneous basic building blocks, called modules, both the variables of interest that the auxiliary variables. These groups of variables are to be kept together for analytical/ data collection reasons.

The modules considered are:

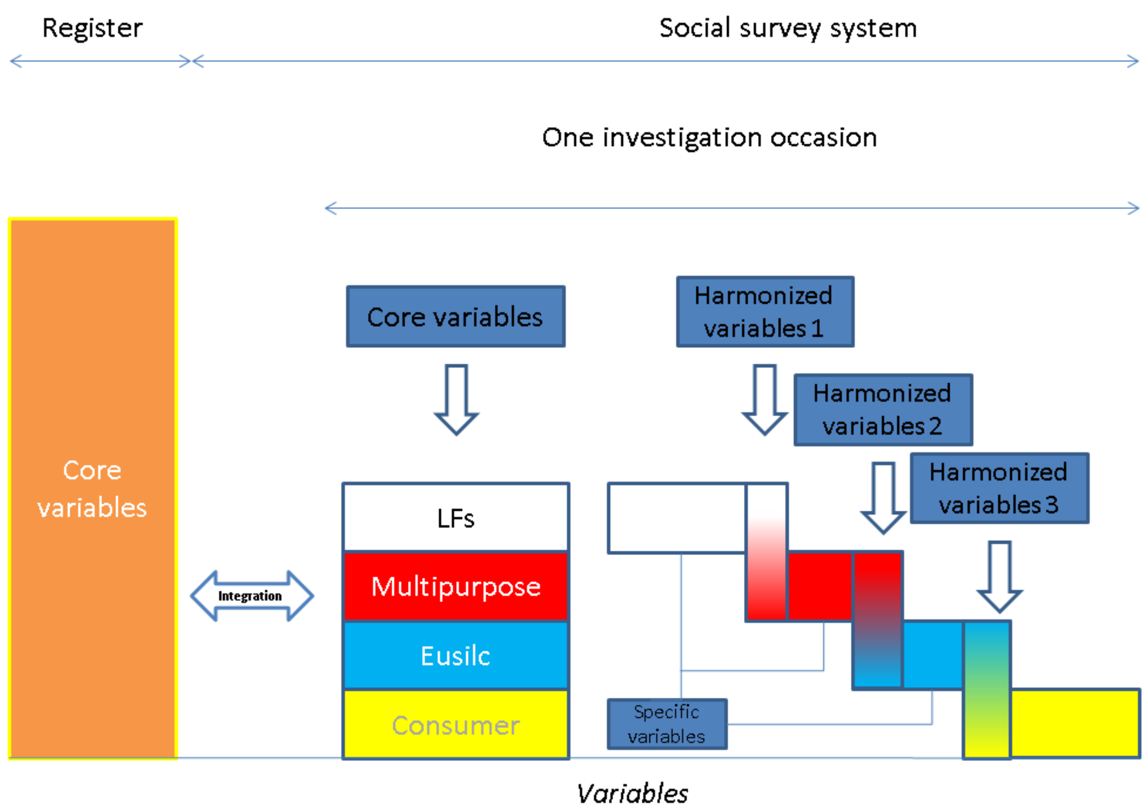
- *Core modules*: in this module are included core variables available in all data collections (samples and register). Furthermore, we consider core variables also those variables available from administrative register whose quality level is not currently considered sufficient for the production of estimates by aggregation of individual administrative register data;
- *Specific modules*: inside this module there are variables observed in only one survey. For example, are specific variables the people looking for job from the Labour Force survey and the income by type collected by the Eusilc survey;
- *Harmonised modules*: this module includes variables observed by more than one survey but often with different statistical domains. For example, fall into this module the income class currently collected by different social surveys.

3. One survey occasion with pooled sample

This scenario is based on a survey instrument design that provides that the households included in a given sub-sample, relative to a specific survey, are interviewed in a single occasion during the year, in which are collected at the same time all the variables of interest, both the structural variables, the harmonized variables and the specialized variables specific to that instrument.

Figure 1 shows the scenario taken into account in the paper. Each sub-sample is composed by different households. In this scenario, all the variables of interest are measured together in a single wave. The pooled sample so constructed allows the use of the same information observed in different surveys/instruments. The ARCHIMEDE register (Integrated archive of economic and demographic micro data) has been integrated with the sample data. This register has the aim of creating bases of useful micro-data for the study of socio-economic phenomena through the integration of variables extracted from 19 different administrative registers. In paragraph 5 will be descripted the ARCHIMEDE's variable considered in the simulation study.

Figure 1: *One survey occasion with pooled sample*



4. Estimation methods

The scenario presented in previous paragraph, thanks to the collection of both specific and auxiliary variables, offers the possibility of pooling information using model based or model assisted estimation techniques methodologies. In particular, the variables can be pooled with model assisted (Kim and Rao, 2012) or model based (Battese et al. 1988) projection estimators.

This approach involves the identification of a working-model linking the dependent variable and the auxiliary variables observed in the different sub-samples and presents in the register. Fitting the model on the data collected in the specific survey it is possible to project the variable of interest, by means the parameters of the estimated model and the auxiliary variables, both on the pooled sample or on the register. This method requires a high level of quality of the auxiliary variables and a high goodness-of-fit of the working-models to provide considerable advantages both in terms of statistical properties of the estimators that in terms of detail of the information that can be produced.

The considered design-based estimators are:

1. Generalized regression (GREG) estimators: built separately for each sub-sample;
2. GREG estimators applied to the pooled sample: obtained by applying direct estimator to the pooled sample;
3. Projection from LFS to Pooled sample: obtained computing the predicted values on the pooled sample based on the working-model fitted on the LF sample data;
4. Projection from LFS to register: determined by defining the predicted values on the population register data based on the model fitted on the LF sample data.
5. Projection from Pooled sample to register: obtained by evaluating the predicted values on the population register data based on the model fitted on the pooled sample data.

Instead, within the case of model-based estimators is considered:

6. EBLUP unit level estimator: obtained computing the predicted values using the population totals of the auxiliary variables included in the working-model fitted on the LF sample data.

5. Simulation study

The simulation study aims to evaluate the quality of the estimators previously presented for different sub-regional domains obtainable either by design-based methods (projection estimators) and model-based estimators (Small Area Estimators, SAE) using the potential of the pooled sample. In particular, we consider three types of sub-regional territorial domains: provinces, aggregation of Local Labour Market Areas (macro-LLMA) and Local Labour Market Areas (LLMA). Only for the variables employed also the municipality estimates have been carried out.

The simulation based on a Monte Carlo experiment is aimed to compare the empirical properties of the estimates in terms of bias and mean square error. 200 samples have been drawn from the 2011 Italian population census, for two Italian regions, Trentino-Alto-Adige and Marche. The target variables are the total of persons employed and unemployed in these two regions. Linear model for the projection estimator have been fitted, with a fixed intercept at macro-LLMA level. The auxiliary variables used in the models are: marital status, educational level, citizenship, not in labour force, cross classification gender-age. The models were also enriched with information from the ARCHIMEDE register, which were linked with the 2011 census and so available for all individuals. Specifically, the variable used is a binary variable that indicates for every individual if he has a signal or not in at least one administrative source related to the employment world.

The working-models studied are summarized in the table below.

Table 1: *Working-models details*

Projection on pooled sample	*Variables*
Full model	*Marital status, educational level, citizenship, not in labor force, cross classification gender-age, ARCHIMEDE variable by regions*
Reduced model	*Marital status, educational level, citizenship, cross classification gender-age, ARCHIMEDE variable by regions*
Projection on register	
Minimal model	*Marital status, citizenship, cross classification gender-age, ARCHIMEDE variable by regions*

Once model selection and fitting has been completed, the prediction properties of the different estimates, obtained on the basis of the selected models, have been evaluated. All the estimators were compared by means of the standard indicators of accuracy of prediction: the Mean Absolute Relative Error (MARE) and Average Relative Root Mean Squared Error (ARRMSE). We further considered the $\boldsymbol{R^2}$ values to compare the goodness of fit of each model and so to evaluate the explanatory power of the different external variables considered in the application.

The indicators are formulated as follows:

$$MARE = \frac{1}{D}\sum_{d=1}^{D}\left|\frac{1}{R}\sum_{r=1}^{200}\hat{y}_{rd} - Y_d\right|$$

$$ARRMSE = \frac{1}{D}\frac{1}{R}\sum_{d=1}^{D}\sum_{r=1}^{R}\frac{\sqrt{(\hat{y}_{rd} - Y_d)^2}}{Y_d}$$

Where $\hat{y}_{rd}$ and Y_d are respectively the predicted value and the correspondent true value of the target variable.

The results for the variable *employed* are shown in Table 2, in which the $\boldsymbol{R^2}$ shows very high values for all the models. The MARE and the ARRMSE indicators are computed for the four type of domains described above. At province level the best results are obtained by the Projection estimator using the register, but also good performances are obtained for direct GREG estimator. At Macro-LLMA level the GREG estimator loose its good properties showed at provinces level, presenting a huge increase of variability (ARRMSE 21.36%). The Pooled estimators presents still good results on this level, very closed to the Projection estimator using the register. At LLMA and at municipality level the estimators both based on the LF data or on the pooled sample show very poor results with respect to those referred to macro-LLM. This is due to the fact that on 54 LLM areas included in the regions only 26 are always present in the 200 simulations, while for the municipalities on 572 areas only 27 are always included in the simulations. For this reason, the synthetic estimators (projection on register and SAE estimator) show similar results in terms of bias and variability as well.

Table 2: *MARE and ARRMSE for the variable employed*

Mean Absolute Relative Error - Employed							
	GREG LFS	Projection LFS-Pooled *Reduced model*	Projection LFS-Pooled *Full model*	Projection LSF-Register *Minimal model*	Projection Pooled-Register *Minimal model*	Pooled	Eblup
R^2	-	**89**	**95**	**89**	**89**	-	-
PROV (7)	0,33	0,55	0,56	0,12	0,08	0,6	-
Macro LLMA (14)	1,97	0,47	0,49	0,14	0,09	0,44	2,42
LLMA (54)	232,44	72,94	74,04	1,15	1,11	71,96	2,74
MUNIC. (527)	1779	550	550	1.97	1.96	551	3.48
Average Relative Root Mean Squared Error - Employed							
	GREG LFS	Projection LFS-Pooled *Reduced model*	Projection LFS-Pooled *Full model*	Projection LSF-Register *Minimal model*	Projection Pooled-Register *Minimal model*	Pooled	Eblup
PROV (7)	4,12	5,5	5,49	1,51	0,95	5,44	-
Macro LLMA (14)	21,36	3,15	2,96	2,07	1,31	2,73	3,74
LLMA (54)	264	109	110	2.6	1.9	108	4
MUNIC. (527)	1791	608	608	3	2.5	610	4.62

The results for the variable un*employed* are shown in Table 3. For this variable the $\boldsymbol{R^2}$ value is similar using the *reduced* and the *minimal* model (14-15%) while goes up to the 33% using the *full* model. As well as for the employed, at provinces level and at Macro-LLMA good results are obtained from the GREG estimator and from the Pooled estimator, especially in terms of bias. At LLMA level only the projection on register estimator show good performance both with the MARE and the ARRMSE indicators below the threshold of the 13% and the 30%. The table 3 shows that considering only the 26 LLMAs always sampled in the 200 simulations, the bias estimates goes down up to the 5%.

Table 3: *MARE and ARRMSE for the variable unemployed*

Mean Absolute Relative Error - Unemployed							
	GREG LFS	Projection LFS-Pooled *Reduced model*	Projection LFS-Pooled *Full model*	Projection LSF-Register *Minimal model*	Projection Pooled-Register *Minimal model*	Pooled	Eblup
R^2	-	**15**	**33**	**15**	**14**	-	-

PROV (7)	0,88	1,04	2,12	0,96	0,46	0,6	-
Macro LLMA (14)	2,53	1,25	1,4	1,36	1,05	0,98	34,39
LLMA (54)	242,8	68,1	44,45	12,46	12,26	82,22	48,77
LLMA in-samples (26)	8,02	7,26	6,02	5,34	5,22	2,78	35,76

Average Relative Root Mean Squared Error - Unemployed

	GREG LFS	Projection LFS-Pooled *Reduced model*	Projection LFS-Pooled *Full model*	Projection LSF-Register *Minimal model*	Projection Pooled-Register *Minimal model*	Pooled	Eblup
PROV (7)	16,13	15,46	15,21	14,25	9,38	11,59	-
Macro LLMA (14)	29,95	22,41	21,71	21,92	14,3	15,17	42,2
LLMA (54)	312	111	99	29	21	136	57
LLMA in-samples (26)	54	34	34	22	15	33	44

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Reconciliation of censuses and survey data during the next round of agricultural census

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ABSTRACT

In many developing countries, Agricultural data are mainly derived from decennial censuses providing structural data on agricultural holdings and benchmark data serving as reference for furthers yearly estimates from sample surveys. When conducted through complete enumeration, agricultural censuses also provide a sampling frame for intercensus sample surveys. Samples for current agricultural surveys are drawn from the sampling frame of the last agricultural census to provide annual updates on some of the agricultural data items and variables such as agricultural area, production etc. These annual estimates are based on the agriculture structure during the last census.

Very often, when a new census is conducted, there are discrepancies between the time series coming from the annual surveys conducted since the last census and the results of the new census. Although discrepancies may be due to legitimate changes in the already dynamic agriculture structure, common sources of these discrepancies are related to changes in the sampling frame, survey methods, concepts and definitions. These especially occur when the intercensal period is too long (more than the ten-year period that is usually recommended by FAO).

Even though this is a very common problem, even in countries with more advanced statisticalsystems, there are very limited studies and methodological guidance to address the issuessystematically after each census.

This paper analyses the possible sources of the discrepancies between time series fromintercensus annual surveys and the results of the new census. It reviews the statistical methodsthat can be used to address them; taking into account country experiences, and results of asimulation conducted on real data form a pilot country. It will present strategies and methodologicaloptions that can be considered on the ways to systematically reconcile inter-censuses surveysdata and results of a new census. The paper builds on the content of a technical report prepared inthe framework of the Research Programme of the Global Strategy to Improve Agricultural andRural Statistics.

Keywords: Reconciliation, Regression, Sampling.

1. Introduction

A census of agriculture (or agricultural census) is a statistical operation aimed at collecting, processing and disseminating data on the structure of agriculture, over the whole or a significant part of a country. Typical structural data collected in an agricultural census are the number and size of holdings (broken down by region, province, district, village, etc.), land tenure, land use, crop area harvested, irrigation, livestock numbers, labour and other agricultural inputs. In an agricultural census, data are collected directly from agricultural holdings, although some community-level data may also be collected. A census of agriculture normally involves collecting key structural data, by means of a complete enumeration of all agricultural holdings, and more detailed structural data, using surveys and sampling methods.

Data from agricultural censuses are useful in a variety of economic and social domains, including agricultural- and rural-sector planning and policymaking, as well as monitoring progress towards the Millennium Development Goals and addressing problems relating to poverty, food security and gender. Agricultural census data are also used in the establishment of agricultural indicator benchmarks and tools, to assess and improve current agricultural statistics during inter-census periods. In several developing countries, agricultural data are derived mainly from decennial censuses, which provide structural data on agricultural holdings and benchmark data that serve as references for yearly estimates subsequently computed on the basis of sample surveys. When conducted by means of complete enumeration, agricultural censuses also provide a sampling frame that can be used in designing inter-census sample surveys. Samples for current agricultural surveys are drawn from the sampling frame established for the most recent agricultural census, aiming to provide annual estimates on certain agricultural data items and variables, such as planted or harvested agricultural area, production and yield. These annual estimates are based on the structure of agriculture identified in the latest census.

When a new census is conducted, discrepancies are often found between its results and the time series derived from the annual sample surveys conducted since the most recent census. Countries tend to encounter difficulties in reconciling crop or livestock data from the most recent agricultural census with the agricultural statistical series obtained from sample survey data. In some cases, there may be valid statistical reasons for these differences. For example, the geographic area covered by one of collections may be incomplete, as urban areas have been excluded. Certain types of holdings, such as small holdings, may have been omitted from one of the collections. Different concepts and definitions may have been applied in the treatment of mixed cropping. There may be inconsistencies in the reference periods or in the definition of crop seasons. Subnational data may be inconsistent because the agricultural census collects data on the basis of the holder‟s place of abode, and not the location of the land or livestock. If sampling is involved, the sample results may suffer from sampling errors. These discrepancies easily arise when the inter-census period is excessively long.

Although this is a common problem, few studies and methodological guidances systematically address the issues arising after each census, even in countries with more advanced statistical systems.

2. Objectives

The main objective of the study is to deeply explore the methodologies displayed in the literature review and to develop an appropriated statistical methodology for reconciling agricultural census and survey data. Simulated data are used to assess the proposed method.

3. Source of Discrepancies

The sampling frame reflects the structure of agriculture at the time of its construction. Agricultural censuses conducted ten years apart may present inconsistencies in their data, especially if these have not been adjusted during the intercensal period. The sources of data discrepancy are the following:

a) Changes in the sampling frame

Measurements may be sought from agricultural holdings during annual surveys, to take into account any changes in the holdings‟ practices and therefore any changes in the performance of the agricultural holdings sampled. However, if survey weights are not revised to capture the changes in the number of agricultural holdings and their distribution by size or strata, this may lead to inconsistency between data.

In the United States of America, the National Agricultural Statistics Service (NASS) conducts several data collection operations. Two of these are the June Agricultural Survey (JAS) and the Census of Agriculture. The JAS is based on an area frame and is conducted annually, whereas the Census of Agriculture is conducted every five years. In 2012, a capture-recapture approach was used to produce estimates for the Census of Agriculture. The capture-recapture methods require two independent surveys to be conducted: the Census of Agriculture and the JAS were chosen for the purpose. Records that have responded to the census questionnaire as farms are assigned weights that adjust forundercoverage, non-response and misclassification. Generally, follow-on surveys to the Census of Agriculture, conducted during the intercensal years, have been based on the assumption that the NASS list frame – which is the foundation for the census mailing list – is complete. Although continual efforts are made to update the list frame, undercoverage persists. Failure of these follow-on surveys to account for such undercoverage has resulted in estimates that are biased downward. In 2016, for its local foods survey, the NASS used a list frame obtained by means of web scraping; capture-recapture methods were used to compute adjusted weights for the list frame records.

In Brazil, during the 2006 agricultural census, it was found that 11 per cent of holdings had ceased to provide information on production, while in previous years (specifically, 1980, 1985 and 1996), this rate was only 2 per cent, approximately. Furthermore, the results of the production of certain products that could be compared with estimates from other sources – or from the supply balance based on information processing, exports, imports and inventory changes – indicated that the census data was affected by significant underestimation at national level. For soybeans, the underestimation is in the order of 13.6 per cent; for cane sugar, 17.2 per cent; and for orange, 42.9 per cent (Guedes& Oliveira, 2013).

When the surveys are conducted with a panel of agricultural holdings selected from the data of the most recent general agricultural census, the discrepancies between census and survey data could be ascribed to the disappearance, division, or merger of holdings over time due to endogenous or exogenous events. Phenomena occurring in the population may also impair sample quality. These changes adversely affect panel quality because they directly influence sample size and the weight of the statistical units (Global Strategy, 2015).

b) Misclassification

Misclassification occurs when an operating arrangement that meets the definition of a farm is incorrectly classified as a non-farm, or when a non-farm arrangement is incorrectly classified as a farm. In the US, the census data consist of responses to a list-based survey, the mailing list for which is created and maintained wholly independently of the JAS area frame. The census data can be used to assess the degree of misclassification occurring in the survey. For this purpose, when analysing the 2012 Census of Agriculture, the NASS matched each 2012 JAS tract to its 2012 census record. Disagreements in the conferral of farm status between the census and the JAS occurred when (1) tracts identified as non-farms in the JAS were subsequently identified as farmsin the census, or (2) tracts identified as farms in the JAS were identified as non-farms in the census. If the tract was identified as a farm in either the JAS or the census, then the tract was considered to be a farm.

For the censuses prior to and including that of 2007, the analysis assumed that there had been no misclassification in the JAS. However, in 2009, the Farm Numbers Research Project (FNRP) was conducted. Twenty per cent of the new JAS records were revisited, as these had been added to the sample and that had been estimated to be or designated as non-agricultural during the pre-screening process. This demonstrated that there had been a substantial degree of misclassification; if the rest of the sample was affected by the same rate of misclassification, then the estimate should have included 580,000 more farms (Abreu et al., 2010). This was the first indication of an underlying cause that could help to explain the discrepancy in the published estimates.

c) Varying concepts and definitions

In an integrated agricultural statistics system, it is recommended that concepts and definitions be harmonized between agricultural censuses, other censuses (such as population censuses) and agricultural statistical surveys. Inconsistencies in data may be due to changes or variations of concepts and definitions. Serious changes in concepts and definitions may affect estimates, as the series of data collected in different years do not measure the same variable,or measure the same variable for different survey populations. Either of these variations introduces inconsistencies.

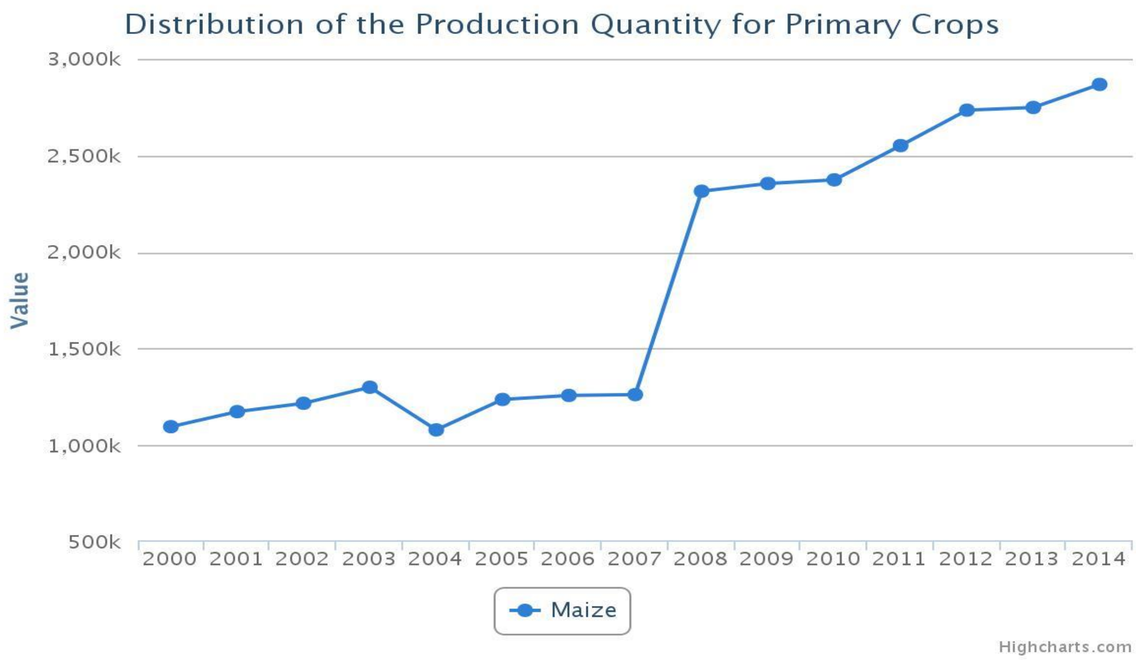

Figure 1. Example of discrepancy in time series data. Source: CountrySTAT-Uganda

d) Greater reliability of data from latest agricultural census and surveys based

on census sampling frame

The most recent agricultural census and surveys based on the census sampling frame may provide more reliable data than those gained in previous collection efforts, and thus lead to discrepancies.

These may be caused by the following:

- The frame has changed because of changes in the structure and number of holdings and their distribution;
- Improvements in methodology;
- Improvements in the supervision and control system;
- Improvements in the relevant technology (new tools, GPS, tablets, etc.).

e) Non-response

Non-response occurs in all censuses and surveys. To address the problem, several countries estimate the missing data, even though this increases the uncertainty associated with the estimates and may lead to bias. In the US, reporting is mandatory for the census, but is voluntary for surveys. However, legal measures are usually not invoked, to avoid the spectacle of prosecuting farmers. Censuses thus suffer a non-response rate similar to that of surveys. To take into account this non-response, the NASS adjusts the weights for responding records. This also increases uncertainty and may result in bias.

f) Other non-sampling errors

Other non-sampling errors may arise due to inadequate questionnaires or defective methods of data collection, tabulation, coding, etc.

g) Sampling errors

The sampling errors noted in the literature can clearly be considered sources of discrepancy between the results of surveys and censuses.

Sampling errors arise solely from the drawing of a probability sample, and not from the conduction of a complete enumeration. The methods to address theseerrors may determine a gap between census and survey data. Sampling errors may be linked to several factors, including a lack of representativeness due to insufficient sample size, errors in the sample selection process or a failure to validate some assumptions made in the sampling theory. For example, in two-stage sampling, the selection probability of an SSU is the product of the selection probability of the corresponding PSU and the conditional selection probability of an SSU for the given PSU. If PPS sampling is applied, this probability is proportional to a measure of size. This measure of size, seen as an auxiliary variable, should at least be positively correlated to the variable of interest, to reflect the correct weights of the sampled units in the population. This means that in repeated PPS sampling, the Horvitz-Thompson estimator usually used to compute estimates during survey operations is an unbiased estimator for the finite population total. However, if the probability of inclusion and the variable of interest are not closely related, this procedure may be rather inefficient due to variation in the selection probabilities. For example, if the measure of size is the number of agricultural households in an Enumeration Area (EA) and the variable of interest is the area harvested, it must be assumed that the number of agricultural households in the EA is at least positively correlated with the area harvested, to ensure that valid sampling weights are obtained. The contrary is also possible, and a sample based on this auxiliary variable should lead to biased estimates of the variable of interest. This generates inconsistency with the data from the new census.

4. Methodological Approach

Changes in sample design or in the interview process and shifts in the sampling frame may lead to unrealistic changes in aggregates over a short period of time. The purpose of survey weights is to ensure that the sample represents the population. Therefore, these weights play an important role in creating consistent aggregates over time. Surveys select different holdings with different inclusion probabilities due to both intentional design and accidental factors. Some farms are therefore overrepresented compared to others; if the sample estimates are to reflect the population accurately, each farm must be weighted according to its „true" inclusion probability.

Each farm is weighted by the inverse of its probability of inclusion in the sample (Deaton, 1997). This is reasonable because a household with a low probability of selection represents a large number of households in the population, while a household with a high probability of selection tends to be a minority-type household in the population. These weights are often referred to as "raising" or "inflation" factors, because they inflate the sample to resemble the total population. Divergences in weights across households arise from differences in selection probabilities, which may be ascribed, in turn, to both planned and accidental factors. Accidental differences may arise due to measurement errors and sampling errors; such as use of an obsolete sampling frame or non-response.

4.1. ChangepointDetection

Several methods have been proposed to estimate the point at which the statistical properties of a sequence of observations change. The most common approach to identify multiple changepoints in the literature is to minimise

$$\sum_{i=1}^{m+1} [C(y_{(t_{i-1}+1):t_i})] + \beta f(m) \qquad (a)$$

where C is a cost function for a segment e.g., negative log-likelihood and $\beta f(m)$ is a penalty to guard against over fitting. The changepointdetection could be implements three multiple changepoint algorithms that minimise (a); Binary Segmentation (Edwardsand Cavalli-Sforza, 1965), Segment Neighbourhoods (Auger and Lawrence, 1989) and therecently proposed Pruned Exact Linear Time

(PELT) (Killick et al., 2012). The R packages*changepoint*and *changepoint.np*could be used at this regard.

The figure 1 shows the plots of the time series for 4 crops. The point is to identified whether the year of the census is a changepoint. The table 1 presents the results for the selected crops. The method used is the PELT method, the empirical distribution is used to compute the statistical test and the Modified Bayes Information Criterion (MBIC) has value 8.124151. For all crops, 2007 is the location of the changepoint. The implementation of the 2008 censuscould explain the break in the time series data. For Rice Paddy, the method identifies 2007 as the changepoint, while on the plot is not clear. For sorghum, 2004 has been identified as a changepoint. Since any census have been done in this year, the break in the time series cannot be the result of the implementation of a new census. The method allows to identify a changepoint, but since we intend to reconcile census and survey data, only changepoint in the year of the census could be taken into consideration.

Crop	Maize	Sorghum	Cassava	Rice Paddy
Changepoint Locations	2007	2004, 2007	2007	2007

Table 1. Identification of the change point (number of quantiles=3)

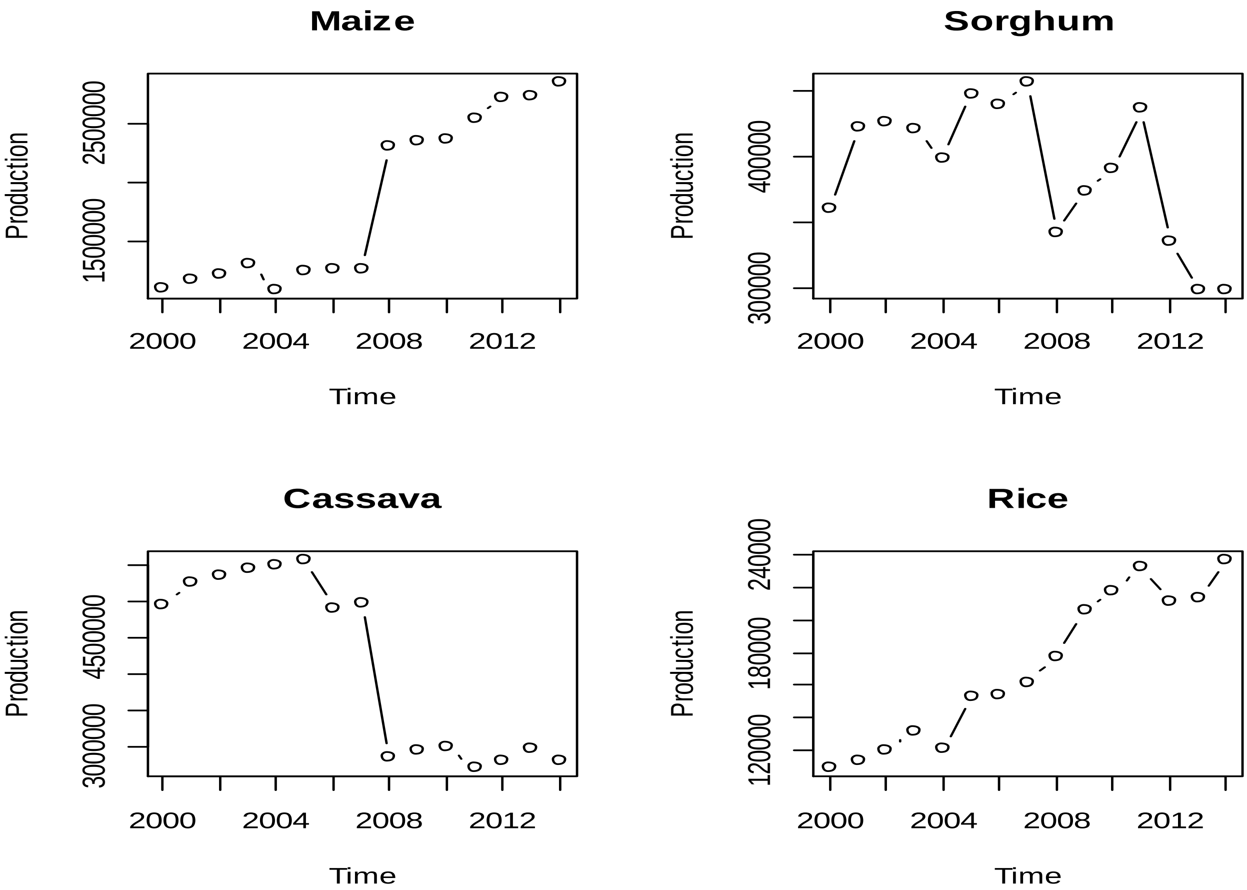

Figure 1. Plot of the time series of different crop. Source: CountrySTAT Uganda.

4.2. Cross Entropy Estimation Method

Calibration estimation can be described as a method to adjust the original design weights so that the known population totals of the auxiliary variables may be incorporated. Generally, the calibration procedure selects the adjusted weights that minimize distance between the original weights and the adjusted weights, while also satisfying a set of constraints relating to the auxiliary variable information.

The estimation approach represents an efficient "information processing rule" using an estimation criterion based on an entropy measure of information. The survey household weights are treated as a prior. *New weights are estimated that are close to the prior using a cross-entropy metric and that are also consistent with the additional information.* These additional information is about the adding-up normalization constraint of the probabilities and a moment consistency constraint. Using this method, information from the census can be capitalized to adjust survey sampling weights.

In particular, the model consists of an objective function which is minimized subject to constraints. An extrapolation method can be used on census data in order to obtain a *prior* data in the year of the survey. This extrapolation can be done by using trend estimation.

$\bar{S}_k$ is the original sampling survey weight for a given statistical unit, S_k is the new sampling survey weight used for the reconciliation, C_k is the prior obtained from an extrapolation based on census data, w_l error weights estimated in the Cross-Entropy procedure, $\bar{w}_{k,l}$ is its prior, $\bar{v}_{k,l}$ is the error support set, f_t represents a general aggregator and p_k a probability or a sample weight.

$$Min_{S,w} \sum_k S_k \ln\left(\frac{S_k}{\bar{S}_k}\right) + \sum_{k,l} w_{k,l} \ln\left(\frac{w_l}{\bar{w}_l}\right) \quad (1)$$

subject to

$$\sum_k p_k\, f_t\,(S_k) = C_t + \sum_l w_{t,l}\bar{v}_{k,l}\,, \quad t \in [1, \dots, T], l \in [1, \dots, L] \quad (2)$$

and additional adding-up constraints on the error weights

$$\sum_k p_k = 1, \ \ and \ \sum_l w_{k,l} = 1 \quad (3)$$

$$Min\{\bar{S}_k, C_k\} \le S_k \le Max\{\bar{S}_k, C_k\} \quad (4)$$

The set l defines the dimension of the support set for the error distribution and the number of weights that must be estimated for each error. The prior variance of these errors is given by:

$$\sigma = \sum_l \bar{w}_{i,l}\bar{v}_{i,j}{}^2$$

$\bar{w}_{i,l}$ is the prior weights on the error support set.

Assuming a prior distribution with zero mean and a standard error equal to σ , we used a support set with five terms equal to (-3 σ , - σ ,0, σ, 3 σ). Assuming normality of the prior distribution, the prior values of the weights can be computed given only knowledge of the prior mean and standard error. The constraint (2) is stochastic, where C_t is assumed to have a measurement error. The minimization is performed by a non-linear optimization algorithm. Constraint (4) makes sure that

S_k lies between the original $\bar{S}_k$ andC_k. The minimization is performed by a non-linear optimization algorithm (Ouedraogo & Nyamsi, 2016).

The challenge lies in identifying the correct moment consistency constraint. For example, with regard to livestock reconciliation data, the intercensal growth rate between two censuses may be used to estimate an aggregate value in the survey year. Therefore, a moment consistency constraint can be determined by means of this aggregate. A household consumption data could be used as auxiliary information.

4.3. Post-stratification Method

Post-stratification can be seen as a form of re-weighting. The post-stratification methodology is to re-consider the size of the strata based on the last census, and re-calculate the probability of inclusion, and therefore the sampling weight using new information based on the new census. Based on the information of the new census, new strata are "re-defined" (post-strata), and new weights are calculated considering the part of sample units included in the new strata. This "re-definition" is necessary, if the previous strata are no longer valid.

Let Y be the variable of interest and H the number of post-strata (After the redefinition of strata).

- N_h is the number of agricultural holdings in the post-stratum h
- S_h is the set of agricultural holdings in the stratum h
- $Y_h = \sum_{k \in S_h} y_k$ is the total of Y in the post-stratum h

- Let U_h be the part of the sample included in the post-stratum h. The number of holdings in U_h is n_h.
- $\bar{y}_h = \frac{1}{n_h} \sum_{k \in U_h} y_k$ is the mean of the variable of interest in the post-stratum h.

The Post-Stratified Estimator of the total Y is given by

$$\hat{Y}_{post} = \sum_{h=1}^{H} N_h \bar{y}_h$$

If the true value of N_h is used this estimator is unbiased.

4.4. Time series Smoothing Techniques

Weighted Moving Average (WMA) could be used to reduce the gap in the time series. WMA assigns a heavier weighting to more current data points since they are more relevant than data points in the distant past. The new value use the WMA method could be compute at a local level and for any strata, and the national total could be obtained.

It could be combined with the cross-entropy method. It could be used to define the relation in (2), in fact C_t could be the total based on WMA method for a given year.

Other technique such as**Exponential Smoothing** could be also used to adjust the trend.

4.5. Handling Misclassification

Abreu*et al.* (2011a) identify misclassification as a direct cause of the undercount of the number of farms produced by the JAS in the US. One approach to correct for this undercount is to use the NASS's sampling list frame, which is independent of the area frame. However, the list frame does not present a farm/non-farm status classification. Abreu *et al.* (2011b) used matched records from the 2009 JAS, the 2009 list frame, and the 2009 Farm Numbers Research Project (Abreu *et al.*, 2010) to explore the characteristics of the inaccuracies in the list frame farm status. They then developed an estimator of the probability that a 2011 list frame record was a farm using logistic regression, and used this estimator as a foundation for providing an adjusted number of farms for the 2011 JAS. The two estimators were based upon two assumptions: (1) the adjustment was independent of the original JAS estimator of the number of farms; and (2) the previous census farm rates provided a good estimate of the probability of farm status for each list frame record. However, both of these assumptions were questionable.

To address the concerns raised by the previous approach, and to obtain a coherent set of methods for the agricultural census and the JAS, Abreu *et al.* (2014) developed a capture-recapture approach to estimate the number of US farms from the JAS. They proposed the following estimator for the number of farms from the JAS, with an adjustment for misclassification:

$$T_2 = \sum_{i \in SARJ} \frac{t_i}{\pi_i} \frac{\hat{p}_i(F \mid SARJ)}{\hat{p}_i(J \mid SARF)\hat{p}_i(R \mid SAF)\hat{p}_i(A \mid SF)},$$

where

i = indexes tract on the JAS

t_i = proportion of a farm represented by tract i

π_i = sample inclusion probability for tract i

S = tract is within the sample

A = tract passes the agricultural screening process

R = tract responds to the survey

F = tract is truly a farm

Logistic regression was used to estimate each of the above probabilities. Based on this estimator, at US level, the estimated misclassification rate for farms was 9.4 per cent.

4.6. Non response

Generally, in case of non-response, the data required are estimated. Therefore, the problem of non-response is related to the estimator error. A vast body of literature exists on how to account for non-response.

To reduce non-response bias in sample surveys, a common method of adjusting for non-response consists in multiplying the respondent‟s sampling weight by the inverse of the estimated response probability. Kim and Kim (2007) demonstrate that this approach is generally more efficient than relying upon an estimator that uses the true response probability, provided that the parameters governing this probability are estimated by reference to maximum likelihood. Based on a limited simulation study, they also compare variance estimation methods that account for the effect of using the estimated response probability, and present the extensions to the regression estimator. The authors found that adjustment using the estimated response probability improves the point estimator‟s efficiency and also reduces bias, because it incorporates additional information from the auxiliary variables used in the response model. In this case, the variance estimators discussed account for the variance reduction related to the estimation of the response probability.

McCarthy et al. (2010) have modelled non-response in NASS surveys using classification trees. They describe the use of classification trees to predict survey refusals and inaccessible respondents.

The methods for solving non-response issues may be applied during the reconciliation of census and survey data, if this has not been done during survey data estimation. Most of these methodologies do not use census data and can thus be applied before the census year. If they have been applied, problems relating to non-response are considered to be estimation problems.

4.7. Model-Based and Model-Assisted Methods

We assume that the variable of interest Y (Production or Area) is related to a number of variables observed within the population throughout the years.

We have:

$$Y=f(X)$$

The idea is to assess f based on the census data and impute data for unobserved units during the survey.

The total production can also be written as

$$T = 1_s^T y_s + 1_r^T y_r = 1_s^T y_s + 1_r^T f(X_r)$$

where 1_s^T and 1_r^T are vectors of n sampled units (sample size) and *N-n* non sampled units respectively. The population matrix of covariates is $X = [X_s, X_r]^T$ where $X_s$is the *n x p* matrix for sampled units and X_r is the *(N-n) x p* matrix for non-sampled units.

The estimated weight is

$$\widehat{w}_s = \frac{1_s^T y_s + 1_r^T \hat{f}(X_r)}{1_s^T y_s} = \frac{\sum_{s=1}^{n} y_s + \sum_{r=1}^{N-n} \hat{f}(X_r}{\sum_{s=1}^{n} y_s}$$

The accuracy of the method lies in determining *f*.

a) Spline Regression Method

We are interested to the estimates, not necessary to the *f* itself, therefore the appropriate method is the semi-parametric regression since the OLS regression are influenced by extreme values.

This method uses the regression model $y_i = m(X_i) + e_i,\ e_i \sim N(0, D_i)$, where m is the spline function using a linear combination of truncated polynomials.

(Henry K. & Valliant, 2012) shows that

$$\hat{T}_{Spline} = \sum_{i \in s} w_i y_i$$

with

$$w_i = \pi_i^{-1} - (\frac{\widehat{m}_i}{\pi_i} - \frac{\sum_i \widehat{m}_i}{n})/y_i$$

With this non-parametrical model, unit with the same characteristics X will have closed estimates of the variable of interested. The effect dues to misspecification in this case are reduced.

b) Generalized Regression Method (GREG)

This method is a calibration approach that involves minimizing a distance function between the base weights and final weights to obtain an optimal set of survey weights. Here optimal means that the final weights produce totals that match external population totals for the auxiliary variables X within a margin of error.

Specifying alternative calibration distance functions produces alternative estimators. A least squares distance function produces the general regression estimator (GREG)

$$\hat{T}_{GREG} = \hat{T}_{HT} + \hat{\boldsymbol{\beta}}^T(T_X - \hat{T}_{XHT})$$

where $\hat{\hat{T}}_{XHT} = \sum_{i \in s} w_i x_i$ is the vector of Horvitz-Thompson totals for the auxiliary variables,$\hat{T}_X = \sum_{i \in s} x_i$ is the corresponding vector of known totals, $\hat{T}_{HT}$ is the Horvitz-Thompson estimator used to estimate the total of the variable of interest during the surveys and $\hat{\boldsymbol{\beta}}$ is the regression coefficient estimated from census data.

The term $\hat{\boldsymbol{\beta}}^T(T_X - \hat{T}_{XHT})$ represents the estimate of the difference between the total value of the variable of interest and the HT estimates. This term could be positive, when the HT calculations underestimates the true total value and negative, when it overestimates.

5. Other Methods to Adjust data

Some methods could be performed to adjust data, as required. However, reconciliation of the survey data with the census data may still be necessary after these techniques are applied. These are to be implemented when the survey is being conducted. In fact, it is important take some actions in order to avoid the gap in the time series. Adjustment in data, could be done throughout the intercensal period.

a) Additional samples

Due to population movements, over a certain period of time, new statistical units may appear in the population of households or farms. Therefore, discrepancies may arise between the estimates based on survey data and the data from the previous census. If the list frame of these units is available (e.g. from administrative files), an additional sample of the new units can be drawn. The population of new units may be considered as a stratum, and the new estimates can be obtained (Global Strategy, 2015).

b) Tracking

Changes in statistical units adversely affect their representativeness and make estimates less precise, thus generating inconsistencies between census data and survey data. These changes must be corrected if the integrity of the units is to be maintained. When a part of a unit does not exist at the time of collection, this part will have to be tracked, especially if its absence is not random. For example, if a portion of a farm changes ownership due to a conflict over land, arrangements should be made with the new owner to collect data on this part (Global Strategy, 2015).

c) Weight-sharing methods

When the surveys are conducted with a panel of agricultural holdings selected from the data of the most recent general agricultural census, changes in statistical units may also be corrected by means of weight-sharing methods, including the General Weight Share Method developed by Lavallée (2007). These methods are explored in further detail in another important publication of the Global Strategy: the Guidelines for the Integrated Survey Framework (Global Strategy, 2015).

If a sample panel is used, these methods of adjustment may be of great assistance to the reconciliation with census data.

d) Oversampling

To cope with the disappearance of statistical units in a region or in a stratum, the size of the sample size may be increased to anticipate the loss of statistical units. This helps to maintain sample accuracy, but does not prevent bias (Global Strategy, 2015). This technique is applied when the sample is selected, before obtaining the survey results necessary for the reconciliation. Therefore, even after its implementation, it may still be necessary to proceed to the reconciliation with census data.

e) Update Sampling Frame

A good system to update the sampling frame should be settled. For instance, a part of the sampling frame could be update each year while implementing the survey. It will allow to minimize discrepancies related to the sampling frame.

6. The Experience of Canada

Not all agricultural survey results should be changed when agricultural census estimates are compared. Indeed, the sampled units of some surveys may not be the farm operator (but millers, for example), or some survey variables may not be measured by the census (such as greenhouse area). Consideration is given to historical events that may have introduced a supply or demand shock between census years, to maintain the characteristics of such events during the revision. However, if a shock occurs during the census year, this information will not be used for trend adjustment. In addition, the source of the information will affect decisions on a possible update. For example, administrative data generated from regulatory sources that are widely used across the industry are likely to remain unchanged, unless a clear explanation can be provided.

A) General considerations

Data from agricultural censuses is used for benchmarking at macro level and for data confrontation and verification. The survey estimates are revised to match the census numbers as closely as possible, adjusted for seasonal variation as appropriate. The revisions made on commodities can be summarized as either a wedge adjustment or a logarithmic adjustment, depending on the characteristics of the data and the commodity. Only the trend is adjusted – not the magnitude of the change from year to year. Variables such as area (and, in some cases, expenses) are first compared between surveys and the agricultural census, to determine the extent of the frame change and the potential intercensal adjustments.

Ratios are also used in various ways for the commodities, to support their analysis: (a) the ratio of published numbers to census numbers; (b) the ratio of census numbers to survey-level estimates; (c) the ratio of average yield (from the survey) and total area (from the census), to adjust production; (d) the census inventory data adjusted for seasonal variation (for e.g. cattle and sheep), etc.

When reconciling, the supply and demand outputs are respected as much as possible. Crop supply and disposition tables can still be revised to maintain balance and validate production, in light of any changes that may have occurred in the relevant area.

The livestock balance sheet follows a similar procedure, examining international and inter-provincial trades, inventory and slaughter. For cattle, adjustments are made to "softer" categories such as calves and heifers. Similarly, in financial terms, the agricultural census may trigger revisions for intercensal years to capital value, farm cash receipts and operating expenses, in light of the new production and inventory values fed from the commodity-adjusted estimates. The intercensal revisions provide an opportunity to include modifications to compilation methods or concepts that have not yet been integrated in published data. Census data is also used to revise the value of a number of commodities for which annual data is not available.

The expense benchmarks established during intercensal revisions are typically within 2 per cent of the census estimates. The trends and levels of tax-based estimates (the source of annual estimates of agricultural expenses) are taken into account when determining the exact level, and indicators, of input price and quantity changes. Information on undercoverage, edit, imputation and validation procedures and the historical relationships between tax and census levels are taken into consideration, as are any changes in the questionnaire (e.g. grouping of expense items). Once the benchmarks have been fixed, a smoothing process is applied which only slightly adjusts the annual changes of the intervening years.

The top contributors are compared, to identify the farms missing from the survey frame. As for the census estimates, this enables any changes in subsectors or emerging agricultural sectors to be better identified. This also provides an opportunity to address these changes in survey questionnaires for future years. For a given commodity or geographic area, in future sample selection, a respondent may be included in a different stratum, in light of its relative importance since the previous census.

B) Census validation using survey data

The main objectives of data validation are to guarantee the quality and consistency of the agricultural census data and to make recommendations for their publication before being released to the Canadian public. Data validation is a complex process in which human judgement is vital. Validators follow a Data Validation Plan and a Data Validation Checklist as guidelines to the data validation tools available on the Central Processing System (CPS). However, validators will ultimately have to solve problems and make decisions based on the analysis of background information, respondent feedback, expert consultation and common sense.

First, the analysis is focused at the macro level. Aggregate census data are analysed at the provincial and subprovincial levels and compared to the expectations outlined in the senior validator‟s Data Validation Plan.

The analysis is then directed to the micro level. Changes to individual records must be made when appropriate, to guarantee the quality of provincial and small-area data and the usefulness of the agricultural census data as a sampling frame. Due to resource and time constraints, micro editing is done using a "top-down" approach, in which those records with the largest contribution to a variable estimate are reviewed first.

Finally, the results of analysis for a province – including the final estimates of the variables under study and recommendations for their publication – are presented to a certification committee.

C) Certification

Revised survey estimates are verified by other members of the team. Provincial experts are also consulted to obtain their views on the possible extent of revision.

D) Communication plan

A communication plan is established to inform all key users that new intercensal revisions have been made available. Typically, users know that estimates are revised every five years.

E) Timelines

Intercensal revisions to agricultural commodities are usually completed one to two years after the census data are released. Corresponding revisions to the financial variables (farm cash receipts, operating expenses and net income) are released two to three years after the census data release. Revisions from a new census benchmark normally cover the five-year period back to the previous census. (Statistics Canada, 2011)

F) Lessons Learnt

Data reconciliation techniques such as ratios and trends may be useful when revising survey data. Furthermore, these revised data should be consolidated as much as possible with other data, such as supply and demand outputs. The new estimates should be validated by a pool of experts prior to publication. It is important for personnel who were involved in data collection and estimation to be part of this pool.

7. Concluding remarks

There is scarce published literature on reconciling census data and survey data in the field of agriculture. However, several techniques applied to produce sampling weight and trend adjustment may be a basis for data reconciliation. This technical paper has reviewed some of these methods. It has also explored the sources of discrepancy between census data and survey data, and the gap to be addressed to provide countries with guidelines on data reconciliation.

An updated sampling frame is one of the keys issue in order to avoid discrepancy in data. It is also necessary to have updated explainable variables. This can be a limitation of that method: The capacity to have accurate and update correlated variable. Some variables as the size of the holding, the number of holding in an area, the variable to the owning of equipment (tractor, etc.) are collected during the census and they can be updated using other data sources (population census, administrative file or other survey).

In some of the examples presented in this paper, explicit formulas for weights could be obtained. Methods that incorporate realistic models will improve the estimates of totals. By incorporating the relationship between the survey variable and some known auxiliary information, the estimates of the totals may have lower mean square errors. When the model is specified correctly, the associated estimators are optimal. However, when the model does not hold, or if the sample contains outliers, several robust alternative estimators could be developed.

The generalized design-based method smooths weights by modeling them as functions of the observations y. The weight of each unit is then replaced by its regression prediction. Non-response and post-stratification methods are designed to reduce biases or variances.

All of these methodologies are being tested to identify the most suitable ones for each type of problem, and to provide countries with effective and workable guidelines.

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INDIRECT SAMPLING, A WAY TO OVERCOME THE WEAKNESS OF THE LISTS IN AGRICULTURAL SURVEY

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ABSTRACT

The growing demand by policy and decision makers for statistics based on information that is interlinked in economic, social, and environmental aspects, requires a large-scale expansion, in terms of organization and budget, of efforts to implement statistical surveys. In developing countries, agriculture (broadly including fisheries and forestry) is the predominant activity that is interconnected with all these sectors.

Required data to support the development of agricultural projects are usually collected by sector, using different sampling frames and methodologies, without any possibility to measure the cross-sector impact of a given action, consequently affecting the quality of the statistics generated by scattered and manifold data collection methodologies.

Developing a sampling frame for a sector as complex as the rural sector is difficult and expensive for many countries and it is often impossible to establish a frame for certain specific statistical units.
For most countries, the General Census of Agriculture and Population Census, which are usually conducted every ten years, are the only statistical operation that builds lists for agricultural surveys. However, these sources alone cannot provide a sampling frame for all statistical units of interest for data collection in the rural sector, therefore possible lists could be incomplete, unavailable or obsolete.

The *Indirect Sampling* with the application of the *Generalized Weighted Sampling Method (GWSM)* could represent a suitable cost-effective method, capable of offsetting the shortcomings of lists, for rural and agriculture data collection. This method produces estimates for the unknown population object of interest, by calculating the weights of each sampled statistical unit for which there is no list, using the weights of the sampled units of a population for which a sampling frame exists. The essential requirement is the existence of a relationship between the units of the available frame and the units of the target population compared to the phenomenon to be surveyed.

Based on the Indirect Sampling and GWSM, a further extension which observes two populations jointly has been analysed to develop an integrated survey framework that can propose an alternative to the current multipurpose surveys, with the aim of reducing implementation costs as well as producing unbiased estimations and improving the quality of data collection.

Works on the application of the indirect sampling method on agricultural surveys have been developed by the lead of the Research Program of Global Strategy to Improve Agricultural and Rural Statistics.

Keywords: Indirect sampling, Agricultural statistics, Rural statistics, Integrated survey Framework**,** Cost-effective methods, Weight Sharing Method, Link between units of different populations

1. Introduction

Agriculture sector is a vital activity of the developing countries for their economy as well as a mean of subsistence of most rural population. The "growth in the agriculture sector is about two to four times more effective in raising incomes among the poorest compared to other sectors. This is important for 78 per cent of the world's poor who live in rural areas and depend largely on farming to make a living. Agriculture is also crucial to economic growth: it accounts for one-third of gross-domestic product (GDP) and three-quarters of employment in Sub-Saharan Africa."[1]

The statistics demanded by policy and decision makers are based on information that is interlinked in economic, social, and environmental aspects, which require a large-scale expansion of national efforts to implement statistical surveys, in terms of organization and budget. An alternative approach for collecting data, by integrating information from different sources using cost-effective methods, is becoming a crucial requirement for the production of reliable statistics. Especially for developing countries, where the purpose or objectives, for which the information is required, depend on available budgetary resources and time constraints, the combination of various methodologies could be the only possible solution to generate rural and agricultural statistics.

Data collection on agricultural statistics varies by the type of data to be gathered[2] and across countries in terms of local items, periodicity and methods and is carried out by sampling methodologies (agricultural census and surveys) conducted on agricultural holdings. Indeed, other sources, such as population censuses, administrative reports and household sample surveys, though not specifically focused on the entire agricultural sector, may still provide relevant information.
Sample surveys conducted on holdings do not only collect economic data, but they can also be sources of relevant information on social dimension as well as on agricultural practices that affect the environment. Thus, the information sought should be the result of a statistical system or of a combination of different sources, which are linked to each other and share a common conceptual and methodological basis, or at least mechanisms to foster complementarities.

Although the surveys integration can improve data collection by using a single consistent sampling frame to gather data on several domains, field experience has revealed that sometimes the lists of target populations can be outdated or incomplete. The production of the related statistics would require alternative strategies to those based on the classic direct sampling methods. The proposed approach is a method that deals with cases of unknown or rare populations such as the *Indirect Sampling* with the application of the *Generalized Weight Share Method (GWSM)* developed by P. Lavallée.[3]

[1] World Bank. March 2016. http://www.worldbank.org/en/topic/agriculture/overview
[2] Global Strategy, 2015. Integrated Survey framework.
- Current data. These are related to agricultural activities that are almost continuous and are repeated every year. Examples are crop area, yield and production of crops and livestock, production inputs, utilization of output, and prices. Usually, these data are collected through sample surveys on a continuous or seasonal basis, possibly several times in an agricultural year.
- Structural data. These reflect the structure of the country's agricultural economy, reporting elements such as the number of holdings, machinery, manpower, land cover and use. Since changes in this context generally do not occur very rapidly, this information need not necessarily to be compiled on a frequent basis; compilation every five or ten years is sufficient. These data are usually collected through agricultural censuses.

[3] Lavallée P. (2007), Indirect Sampling, Springer Series in Statistics, ISBN-10:0-387-70778-6

This method sets up a framework that relies mainly on the concept of relation among groups joined together by common characteristics which are identified by clusters and classified by the observational analysis subject to the study, such as economic activities, recipients of services, frequented places, recreational activities during certain periods of time and so forth.
Therefore, a statistical population can be considered as if it comprised sub-sets, which present common features and may knowingly or unknowingly have a cluster structure. Such groups are identified by the phenomenon being studied and are in relation with other statistical populations.

In practice, when a survey is conducted on a target population that is unknown or rare, the relation with the known population is not evident*,* therefore the path to tackle is to analyse the behavioural observation of statistical units between the target population (which may be rare or hard-to-reach) and another known population where the linkage between the two populations can be identified during the data collection phase. The observation defines the relation that comes out by submitting specific questionnaires. The relation, between the units of the two populations, can be either at individual level or at cluster level and is the essential component of the framework, which determines the number of links needed to calculate the weights of the target population units.

Operationally it means that, if two populations U^A and U^B are related to one another on the specific object of study and only the sampling frame of the population U^A is available, "it is possible to imagine the selection of a sample from U^A and produce an estimate for U^B using the existing links between the two populations. This is what we can refer to as *Indirect Sampling*" (P. Lavallée, 2007).
In due course, the *Generalized Weight Share Method (GWSM)* calculates the weight of each sampled unit of population U^B, using the numbers of its links with the population U^A and the weights of the sampled units of population U^A linked to it.

Furthermore, this method can be extended to develop an integrated survey framework, by observing two populations jointly who are in relation (P. Falorsi, 2014)[4]. The adoption of this framework may be the best solution when dealing with multipurpose surveys such as the following examples:

- sample surveys conducted on households, which do not only collect demographic data, they are also sources of information on the working status and economic well-being. Willing to analyze the contribution of women's work activities to agriculture, it would be interesting to use a households list which includes the entire female population (rural and urban), to extrapolate the second population related to the holdings which could include both female owners and female employers. Otherwise, the latter would have been automatically excluded if the initial list had been that of the holding. An integrated survey should jointly observe and analyze:
  1) the household sector to collect demographic data and,
  2) the holding sector, to collect data on the land tenure from which the female household members generate annual income.

  The relationship between the two sectors is defined by the various roles that women perform within the holding.

- livestock surveys, which provide significant contribution to national income as data is collected to estimate the yields of milk, eggs, meat, feeding as well as the related work-employed, and responding to environment mitigation purposes by gathering information on

[4] Global Strategy, 2014. Technical Report on ISF. Chapter 3. http://gsars.org/wp-content/uploads/2014/07/Technical_report_on-ISF-Final.pdf

management practices. Unfortunately, the surveys are usually conducted to provide data on food supply (milk, eggs, and meat) separately from specific information gathered on off-season and part-time employment for households and raw material for industries (wool, hides, skins, hair, bristles, etc.), thereby making costly and complex multipurpose surveys. Also in this case, a sample survey framework, that integrates the data collection on holdings and households starting from the holding list, should jointly observe and analyze the two statistical populations, to produce the related estimates.

In conclusion, when the traditional direct sampling strategy is not convenient due to cases of "hard-to-reach" [5] populations or budget constraints, the Indirect Sampling method can then be used because it deals with cases which present the following conditions:

1. No adequate sampling frame as it could be incomplete, obsolete or not available.
2. Possible use of a different frame, due to the relation with the units of target population.
3. A clustering tendency of the target population according to the phenomenon to be analysed.

The advantage of adopting the Indirect Sampling with GWSM is to reduce costs and implementation time, using statistical procedures through the existing and updated frames such as censuses or sample surveys, to estimate unbiased statistics of unknown populations intended as either rare populations or populations with obsolete lists. It is also possible to develop integrated surveys by observing jointly two populations that are in relation, thus improving the data quality based on harmonised statistical units, concept and definitions and classification.

This paper proposes the *Indirect Sampling* with the application of the *GWSM* on some cases in agriculture sector, describing the possible uses on unknown or obsolete lists of the target populations.

2. Indirect Sampling and GWSM applied to Agriculture

Developing countries present a strong preponderant agricultural traditional sector, considered also as subsistence agriculture and attributable to the agricultural households, so that most of the rural areas is employed in this sector. "It is for this reason that in most censuses and surveys, holdings in traditional sectors are identified through household using a list of households" [6], so that a correspondence is often assumed between the Households and traditional Agricultural Holdings [7], thus collecting data on traditional agricultural holdings is equivalent to collecting data on households. "*A farm household can be defined as a household in which any member has both an agricultural main activity and a status of "own account worker*"[8].

Although, the Guidelines for Linking Population and Housing Censuses with the Agricultural Censuses recommends and supports the coordination between the two censuses to be consistent with the reference lists, concepts and definitions, in practice many countries do not have appropriate resources in terms of budget, well-skilled technical personnel, good organizational systems to coordinate the activity of linking the two censuses, as well as keeping updated lists.

[5] Marpsat and Razafindratsima. 2010. Survey methods for hard-to-reach populations: introduction to the special issue. http://mio.sagepub.com/content/5/2/3.1.refshttp://mio.sagepub.com/content/5/2/3.1.refs
[6] FAO.1983. Paper series 35/Prov. Use of household surveys for collection of food and agricultural statistics. Rome
[7] FAO. 2005. WCA 2010, paragraphs 3.27 to 3.35. http://www.fao.org/docrep/009/a0135e/A0135E04.htm - ch3.5
8 FAO. 2012. Guidelines Linking Population and Housing Censuses with Agricultural Censuses http://www.fao.org/docrep/015/i2680e/i2680e00.htm

In addition, the social-economic organization of the traditional agricultural systems, which is based on many relations between households and holdings, makes gathering data of small-scale farmers very difficult at this scattered and manifold level. In fact, the holdings or farm households are clustered to manage activities often carried out separately on crops, livestock and fisheries. The management structure is usually geared towards the three types of subsistence farm organizations: i) one household managing one holding, ii) one household managing more than one holding, iii) more than one household managing one holding[8].
In addition, a further organization is made up of many households, which cooperate for a common purpose in joint activities for many holdings.

In this regard, the indirect sampling, does not represent a cost-effective method only, is also a suitable approach to deal with the complex relations of the management structure based on the correspondence between household and traditional holding, worthwhile to conduct integrated socio-economic surveys by using the most updated list frames, either related to households population or holdings population. Furthermore, it is capable of obtaining most of information from heterogeneous groups of individuals at the same time instead of collecting few data from single individuals spread out in different locations, thus saving time and costs.

Figure 1 below shows the possible links that may exist between the households' population (U^A) and the holdings population (U^B), compared to the above-mentioned agricultural traditional system. In fact, the household members belonging to U^A are the individuals who participate in agricultural activities either directly by themselves or indirectly by their own relatives or workers. The holdings (clusters) belonging to U^B represent the households' economic organization.

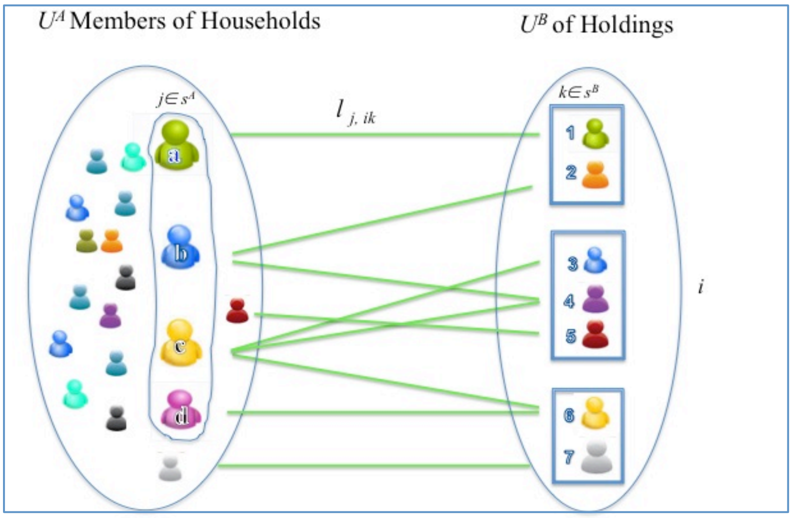

Figure 1: *The relationships between households and holdings*

The observation analysis of the relationships ($l_{j,ik}$) between each member j belonging to the U^A and each individual k of clusters i belonging to U^B, reveals the correspondences between the individuals of the two populations as well as the number of the total links.
This example, also, shows that the links can be one-to-one (case of j = a corresponding to k= 1), one-to-many (case of j = b corresponding to k= 2 and k = 4; or j= c to k= 3, 4 and 6), many-to-one (case of j = c and j=d to k= 6) and many-to-many (case of j = c and j=d to k=3,4,6).

The rectangles represent the holdings (or cluster i) of U^B. Each cluster i comprises the links and all individuals k taking part in agricultural activities, including those not in correspondence with the sampled household members $j\in s^A$ as the cases k=5 and k=7.

The links are identified between all j members of U^A and k individuals of each i cluster belonging to U^B, with $l_{j,ik} = 1$ if a link exists and with $l_{j,ik} = 0$ in other cases. Each cluster i must have at least one link[9] with one sampled individual j of U^A that is:

$$L_i^B = \sum_{k=1}^{M_i^B} \sum_{j=1}^{M^A} l_{j,ik} > 0$$

where M_i^B is the size of cluster $i \in U^B$,
M^A is the size of U^A.

Unearthing the links is an exploratory activity on the field to collect reliable information conformed to the survey's objectives, which require the submission of questionnaires as simply and appropriate as possible. A pilot survey and pre-tests could be very useful for analysing possible issues and eventually to work them out.
All individuals within the same cluster $i \in s^B$ (where s^B is the sample of clusters observed in U^B) must be interviewed in order to provide both the measure of the variable of interest y_{ik} and the number of the links $L_{ik}^B = \sum_{j=1}^{M^A} l_{j,ik}$ between ik individuals of U^B and j household members of U^A.

The final step of the framework building is the weighting procedure of the GWSM to associate the weights to each individual of U^B, by using the weights of the household sampling frame of each members $j\in s^A$.

The sections below are mainly focused on the procedure of computing the weights to produce the estimates of the target population (which may be rare) starting from a known population. It is also shown the process on how to observe two populations jointly.

2.1 Main steps of the method

The following steps describe the process to be carried out, assuming that the list of households' population U^A is available and that the holdings' population U^B is the target population.

1) Selection of the probability sample according to a certain sampling design that could be, for example, a traditional multistage Proportional to Size Stratified design of the household population and calculation of the inclusion probability for each individual to get:
   - Sample s^A that contains m^A individuals selected from U^A of size M^A.
   - Selection probability $\pi_j^A > 0$ of all sampled members $j\in s^A$.

2) Analysis and observation of the existing relationships (links) between populations U^A and U^B, to set up the clusters of the population U^B as follows:
   - Population U^B contains M^B individuals
   - U^B is broken down into N^B clusters, where cluster i contains M_i^B individuals.

[9] Lavallée P. (2007), Indirect Sampling, Springer Series in Statistics, ISBN-10:0-387-70778-6

The information on the correspondences and links between the *j* members of U^A and the *k* individuals of U^B is gathered by specific questionnaires based on the subject to be surveyed.

For instance, the questionnaires could identify the links by investigating the specific working role of the household members performed in the holdings such as holder, sub-holder, manager, worker, co-worker as well as enhancing further information about other individuals of the holding involved in the agricultural and rural activities. The questions should be submitted by a face-to-face method with a semi-fixed structure to make it possible to pose additional questions (probing) that may not be included in the original format. In this way, getting further information can facilitate the comprehension of the relations, and obtain the interviewer's collaboration, build a certain degree of confidence, verify that the response is appropriate, as well as assist the respondent if the question is difficult to understand. [10]

3) Assignment of a weight to each individual belonging to the holdings population U^B by applying the GWSM. This entails:

- computing the initial weight of each *k* individual of clusters $i \in s^B$ by the calculation of the weights of sampled *j* individuals of U^A

$$w'_{ik} = \sum_{j=1}^{M^A} \frac{t_j}{\pi_j^A} l_{j,ik}$$

where $t_j = 1$ if $j \in s^A$, and 0 otherwise,
$\pi_j^A > 0$ is the inclusion probability of individual $j \in s^A$

- calculating the total number of links for each *k* individuals of clusters $i \in s^B$

$$L_{ik}^B = \sum\nolimits_{j=1}^{M^A} l_{j,ik}$$

- computing the final weight w_i of each cluster $i \in U_i^B$

$$w_i = \frac{\sum_{k=1}^{M_i^B} w'_{ik}}{\sum_{k=1}^{M_i^B} L_{ik}^B}$$

where M_i^B is the size of cluster $i \in U^B$

- assigning $w_i = w_{ik}$ for all $k \in U_i^B$:

$$w_{ik} = \sum_{j=1}^{M^A} \frac{t_j}{\pi_j^A} \frac{L_{j,i}}{L_i^B},$$

where $L_{j,i} = \sum_{k=1}^{M_i^B} l_{j,ik}$
$L_i^B = \sum_{k=1}^{M_i^B} L_{ik}^B$ that is the total number of the links of cluster *i*.

[10] Global Strategy. 2015. "Guidelines of Integrated Surveys Framework" Chapter 3 part I, page 58.

4) Estimation of the total of the variable $\hat{Y}_B$ related to the holding population is calculated with the Horvitz-Thompson estimator using the weights computed by GWSM as follows:

$$\hat{Y}_B = \sum_{i=1}^{n^B} \sum_{k=1}^{M_i^B} w_{ik} y_{ik}$$

where n^B is the number of surveyed clusters and w_{ik} is the weight assigned to j individual belonging to i^{th} cluster.

The links may be defined at unit level or at cluster level. This is illustrated in figure 2 below where, in the case of unit level (the left hand side of the figure), the index j refers to a single individual. In this situation, the total number of links of cluster F1 is equal to 4. The case of links defined at cluster level is described on the right hand side of the figure where the index j refers to a household. The total number of links of cluster F1 is equal to 3.

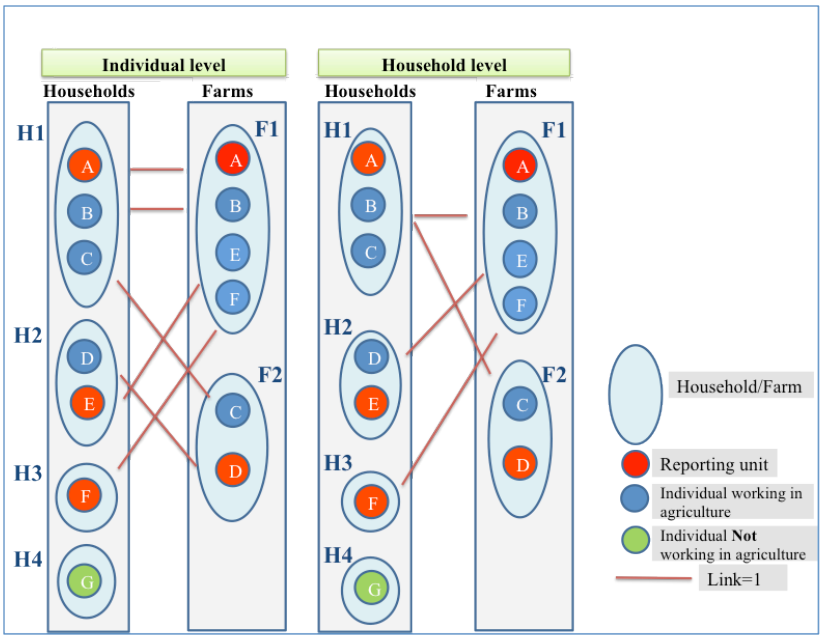

Figure 2: *Example of the links between individuals or between clusters*

2.2 Application to two populations jointly observed

There are cases where it is necessary to undertake surveys that require crossover analyses such as, for example, a study concerning the contribution of women's employment to agriculture in developing countries. In this case, the access to resources control must be gone through, collecting data on the land owned or managed by women in male-headed farms, to evaluate the use of the inputs (improved seeds, machinery, and fertilizers) and the availability of credit and financial services.

The joint observation of households and farmers can provide estimates of all inputs, by associating data at the household level on gender with data at the farm level on parcel/plot land tenure, and defining the links through the activity performed on the land as a female owner, manager or worker.

The scheme consists of a two-step procedure and depends on the available frame, such as:

- if the households list is available
  a. the households are observed in the first step and based on direct sampling,
  b. the farms are observed in the second step and based on indirect sampling.

- if the farms list is available
  a. the farms are observed, in the first step,
  b. the households are observed, in the second step.

The following example shows the case of having the availability of the households' list by selecting the sample with standard stratified multistage sampling design.

The sampling units are stratified according to geographical criteria, where the Enumeration Areas (EAs) of the Census are the Primary Sampling Units (PSU) and all households, belonging to sampled EAs, are observed as Secondary Sampling Units (SSU) with the respective inclusion probability.
In this regard, suppose that the households H1 and H3 were selected from two different EAs and hypothesize that the related inclusion probabilities were respectively equal to $\pi_{\mathrm{H1}} = 0.001$ and $\pi_{\mathrm{H3}} 0.02$ (it would mean that H1 has been selected from a set of 1000 units and H3 has been selected from a set of 50 units).[11]

At a later stage, in which the households are observed in the first step (the left hand side of figure 2), the links are defined with the support of two questionnaires to get the following result:

Step 1 The enumerator starts interviewing the first Household, the head of H1 to collect data on gender and gather information on the farm's links. It is clear that the Household is linked to Farms F1 (with two links) and F2 (with one link).

The second interview is submitted to the head of Household H3 to collect the data on gender and information on the farm's links with the same method adopted for Household H1.

Step 2 The enumerator interviews the agricultural holder of Farm F1 and collects the data on the parcel/plot tenure. Then, he gathers the information on the farm's total links which in this case are equal to 4, where

- the individuals A, B and F represent the links with the members of sampled households H1 and H3,
- the individual E which is linked to a member of H2, therefore it cannot be considered a link because H2 is not sampled.

[11] Global Strategy. 2015. ISF- Chapter 2.

The GWSM weight of farm F1 may then be computed as reported on figure 3:

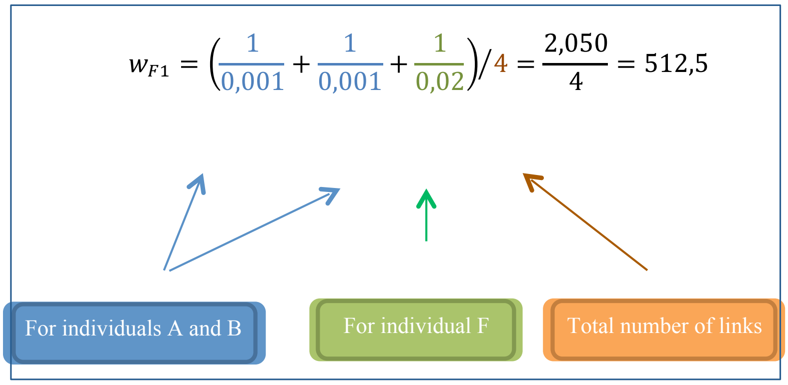

Figure 3: *Calculation of the final weight*

In the due course, the second interview is submitted to the agricultural holder of Farm F2 to collect data on the parcel/plot tenure and information on the farm's links, following the same procedure adopted for Farm F1.

Estimation

Let Y^A be the total of interest (e.g. the total number of women who perform agricultural activities in the country) referring to the population of the households, whose list is available; and let Y^B be the total of interest (e.g. the total land area in the country) referring to the population of the farms, observed indirectly.

Let s^A be the sample of observed households and s^B the sample of observed farms.

The sample estimate $\hat{Y}^A$ of the total Y^A is obtained by:

$$\hat{Y}^A = \sum_{j=1}^{s^A} y_j \, w_j$$

where y_j is the value of the variable of interest of the individual j (e.g. $y_j = 1$ if the women j within the household performs agricultural activities) and w_j is the sample design weight.

Likewise, the sample estimate $\hat{Y}^B$ of the total Y^B is simply obtained by assigning to each farm i observed in s^B a weight w_i obtained with the weight share method (see section 2.1):

$$\hat{Y}^B = \sum_{i=1}^{s^B} y_i \, w_i$$

where y_i is the value of the variable of interest (e.g. the total parcel/plot land tenure in the farm) of the farm i and w_i is the weight calculated by GWSM.

3. Case studies

The cases described below have been taken from the recent research program of the Global Strategy to Improve Agriculture and Rural Statistics (www.gsars.org.) which deals with methodologies to collect data in order to make them comparable cross over the countries, respecting the international quality standards as well as to facilitate the development of cost effective methods.

The reported examples refer to some studies to apply the indirect sampling with GWSM taken from the "Guidelines of Integrated Survey Framework" and the "Guidelines on the Enumeration of Nomadic and Semi-Nomadic Livestock" to simulate the practical use on how to build a logical framework, based on articulated questionnaire[12], as well as the running of weights calculation. They can represent some opportunities to develop integrated surveys and improve initiatives on the field to adapt this method as needed.

The following sections describe three proposals of this approach for the use in agriculture sector in:

- estimating statistics on holdings starting from a household frame,
- updating of the units weights in case of change in the statistical units,
- producing estimates for the Nomadic and Semi-Nomadic Livestock.

Detailed information on these subjects is available on the web site of the Global Strategy.

3.1 Estimating statistics on holdings starting from a household frame

An interesting application is the case carried out by Burkina Faso to conduct a national study to collect information on agriculture sites where several farmers work individually or in groups for the production of rice, corn, vegetables etc. Specifically, this study should produce estimates on the area harvested, crops production, number of farmers and farmers' incomes working in these sites. In particular, irrigated crop production is practiced mainly on a number of sites, developed by the State's funds as well as by Non Governmental Organizations (NGOs) and other private projects.

The economic-social structure is organized to provide each farm's individual with the sites and the parcels, however the limited number of developed sites does not allow several producers to obtain a parcel for irrigated production on a developed site. Thus, for many households, their links to irrigated sites are limited to the work of some of their members as permanent or temporary employees on these sites and members of the same household can work on different farms. At the same time, the head of a site's management unit is aware of the number of farmers on the site, but not of the number of households whose members work there. Therefore, for the objective of this survey it would be necessary to include all these employees in order to cover a larger number of sites.

Moreover, Burkina Faso conducts permanent annual agricultural surveys based on the "Recensement General de l'Agriculture" (RGA) sampling frame and as the purpose of the matter, here described, refers to the farm household, intended as farm household of traditional agricultural systems, the known population is represented by the available household sample frame selected from the RGA frame and used in other surveys. This sample appears to suit to our study also for the following two reasons:

[12] Global Strategy. 2015. ISF- Chapter 3. Modules and operational rules for observing farms starting from households http://gsars.org/wp-content/uploads/2015/05/ISF-Guidelines_12_05_2015-WEB.pdf

- Such a sample will enable the subsequent availability of more information to analyze the data, because the survey will be linked to other ongoing surveys,
- It also has the advantage of working with a more up-to-date sample, reflecting the changes arising in the statistical units since the sampling frame was created.

Hence, this case is featured by the initial requirements of the indirect sampling method, within the following conditions:

- The farm workers at work sites represent the unknown population.
- The farm household members frame is available to create the links framework.
- Each work site is a cluster of the unknown population.

The following steps describe the application of the above-mentioned approach.

1) Selection of the farm household members sample by a certain design sampling.
2) Analysis and observation of the relationships between the farm household members and farm workers at work sites, defining *a household linked to an irrigated production site if at least one of its members works on this site as a farmer or employee.*

   The links between the household members and the farm workers are built with the two steps procedure using respectively two questionnaires and interviewing:

   Step 1 Each household member, for collecting a great deal of possible reliable information to identify the location of the sites, its total number as well as the working status of the household member as farm owner or employee.

Household Code:	Economically Active Member code:……….
Are you a farmer on an irrigated site?	
If yes, list the sites concerned:	
• Name of Site 1..............................	
• Name of Site 2..............................	
Did you work as an employee on an irrigated site last year?	
If yes, list the sites concerned:	
• Name of Site 1..............................	
• Name of Site 2..............................	

Table 1: *Questionnaire to observe households and farm sites links*

Once the questionnaires are filled in, the enumerator should complete the list of sites linked to the household, and summarize which sites are linked to the household member. A unique code (such as geo-referential coordinates) is also assigned to each site that is linked to the respondent household member.

	Site Name	Member Respondent Code	Site Code
1.	....	....	....
2.	....	....	....

Table 2: *Summary table on links information from households*

Step 2 Each worker at work sites, for gathering information on farmers and employees, which should incorporate the same site code of the households' questionnaires submitted for the preliminary identification of the links.

Site Name:		
Site Code:		
Name of the Respondent on the Site:		
Questions to the Respondent	• In total, how many farmers are working on this site?	
	• Can you provide an estimate of the total number of employees working on the site?	

Table 3: *Questionnaire carried out on the sites*

The result of the above mentioned questionnaires is shown in the framework on figure 4, where the links $l_{j,ik}$ are drawn up between all farm household members belonging to M^A and those individuals k working in each i site belonging to M_i^B (size of each cluster). The inclusion probabilities π_j^A, of each household member $j \in s^A$, compute the initial weights of each individual $ik \in M_i^B$.

Moreover, throughout the survey, data collected in each site i have also furthered the list of the individuals to be surveyed, increasing significantly the initial information obtained from the farm household members.

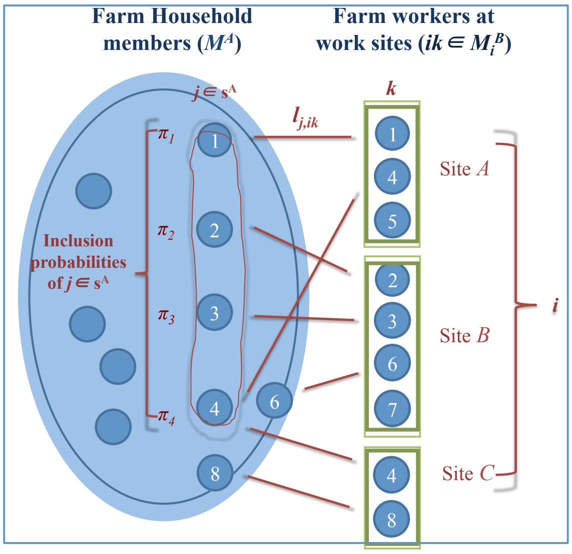

Figure 4: *Correspondences between Farm Household members and Farm workers*

3) Assignment of a weight to each farmer site by applying the GWSM as follows:

- Computing the initial weight w'_{ik} of k individuals in each i site. It is calculated[13] by summing the weights $\frac{1}{\pi_j^A}$ of farm household members $j \in M^A$ linked to each ik, with $t_j = 1$ if $j \in s^A$ (cases 1, 2, 3 and 4) and 0 otherwise (cases 6 and 8). An initial weight zero is assigned to all individuals not having a link (cases 5 and 7).

i	k	$w'_{ik} = \sum_{j=1}^{M^A} \frac{t_j}{\pi_j^A} l_{j,ik}$
A	1	46
	4	58
	5	0
B	2	65
	3	28
	6	0
	7	0
C	4	58
	8	0

Table 4: *Initial weight estimation of farm workers*

- Calculation of the total number of links in each work site cluster i (quantity L_i^B), by summing for each work site i all links between the farm household members of M^A, both sampled and not sampled ones (quantity L_{ik}^B), and the individuals k of work sites i belonging to M_i^B.

i	k	$w'_{ik} = \sum_{j=1}^{M^A} \frac{t_j}{\pi_j^A} l_{j,ik}$	$L_{ik}^B = \sum_{j=1}^{M^A} l_{j,ik}$	$L_i^B = \sum_{k=1}^{M_i^B} L_{ik}^B$
A	1	46	1	2
	4	58	1	
	5	0	0	
B	2	65	1	3
	3	28	1	
	6	0	1	
	7	0	0	
C	4	58	1	2
	8	0	1	

Table 5: *Calculation of total number of the links within the work sites*

- Calculation of the final weight w_i for each work site cluster i belonging to M_i^B, by dividing the initial weight with the total links number of each work site.

i	k	$w'_{ik} = \sum_{j=1}^{M^A} \frac{t_j}{\pi_j^A} l_{j,ik}$	$L_{ik}^B = \sum_{j=1}^{M^A} l_{j,ik}$	$L_i^B = \sum_{k=1}^{M_i^B} L_{ik}^B$	$\sum_{k=1}^{M_i^B} w'_{ik}$	$w_i = \frac{\sum_{k=1}^{M_i^B} w'_{ik}}{\sum_{k=1}^{M_i^B} L_{ik}^B}$
A	1	46	1			
	4	58	1	2	104	104/2 = 52
	5	0	0			
B	2	65	1			
	3	28	1	3	93	93/3 = 31

[13] These figures have been made up to run the simulation.

	6	0	0			
	7	0	0			
C	4	58	1	2	58	58/2 = 29
	8	0				

Table 6: *Final weight of each work site*

- Assignment of the final weight w_{ik} to each farm worker *ik* within the work site cluster *i*. These final weights are used to estimate the variable to be measured $\hat{Y}^B$, calculated by GWSM.

i	*k*	$w_{ik} = \sum_{j=1}^{M^A} \frac{t_j}{\pi_j^A} \frac{L_{j,i}}{L_i^B}$
A	1	52
	4	52
	5	52
B	2	31
	3	31
	6	31
	7	31
C	4	29
	8	29

Table 7: *Final weight estimation of each farm worker at work sites*

3.2 Updating of the units weights in case of change in the statistical units

This case, extracted from a more extensive discussion in the "Guidelines of Integrated Survey Framework"[14] (ISF), deals with the changes of the statistical units of surveys based on a panel agricultural holdings, mainly caused by disappearance, fusion, division and population change. This phenomenon may undergo significant modifications from one year to another, due to endogenous or exogenous events. Some solutions are presented in the ISF Guidelines[15], and among these the indirect sampling with the GWSM has been proposed as an alternative solution to handle the lists updating. The practice here reported refers to the *Changes in households* with the weight calculation**.**

In several countries and in the case of most developing countries, statistical surveys use households as statistical units, and the data are collected at the household level.

Although the current solutions are usually sufficient to solve problems related to changes in the composition of households, for cross-sectional estimates in a given year, the system may be interested in the activities, pursued by individual household members, which are relevant to agricultural statistics. In this case, each member becomes a statistical unit, and the weight of a member corresponds to his household weight; indeed, usually all members of a sampled

[14] Global Strategy. 2015. Guidelines of Integrated Survey Framework. http://gsars.org/wp-content/uploads/2015/05/ISF-Guidelines_12_05_2015-WEB.pdf

[15] Alternative methods of calculating the weights are available in the literature. Basically, there are weight-sharing methods, which use the weight of the households of the first wave of the panel (Brick and Kalton, 1994; Schonlau et al. 2013; Lavallée, 2007), and methods based on a model of household inclusion probabilities (Schonlau et al. 2013).

household are taken into account in the survey, and each year, data on all individual members of the household panel must be collected for cross-sectional estimates.

In each Wave of the panel, all households with at least one of these individuals as a member shall be taken into account. For this type of system, changes in statistical units can lead to situations in which it is difficult or impossible to calculate the weights of certain units by the conventional approach because, for example, several members of different households may combine to form a new household, which includes members of other non-sampled households. The weights of all the members of the new household become difficult to estimate.

Also in case of change in the statistical units, the Indirect Sampling with GWSM concerns all households of which at least one member was a member of a household sampled during the first Wave of the panel. Some target households may have members who were in the original sample panel, and other members who were not. Weight-sharing methods enable estimation of the weights of the individuals who were within the original sample.

In fact, the current new structure presents the following conditions:

i) the unknown weights of the household members of Wave 2,
ii) the availability of Wave 1 list to be linked to Wave 2,
iii) the members of Wave 2 are clustered by the new households structure.

As reported in the methodological observation section, the links between the two Waves are built with the support of questionnaires to collect information, by interviewing:

Step 1 Households of Wave 1, to make sure that all cluster Wave 1 Households are linked to the new structure of Wave 2 Households.

Household Code:		
Full name of head of household:		
How many members left your household between last year and this year?.........		
Among these members, how many have joined other households?		
Can you name these members and households they joined?		
Member Code	The new Household Code	Name of the head of the new household
....	....	....
....	....	....

Table 8: *Questionnaire to observe the links of Wave 1 Households*

Step 2 Households of Wave 2, to identify the total number of links with households Wave 1, that can be performed at Individual or Cluster level. In case of Wave 2 Household A (figure 4), the total number of the links is 1 because only individual A1 belongs to Wave 1, while individual E is a new entry.
An example of the questions to be posed at individual or household (cluster) level approach can be adopted as Table 9 shows below.

Type of links	Questions
Household level	1. Are there members of your household that belonged to other households last year? (Yes/No) ....

	2. In how many households did these members live? ....
Individual level	1. How many members of your household belonged to other households last year? ....

Table 9: *Questionnaire to identify the links of the two Household Waves*

The observation reveled some changes of the population panel structure between Year 1 and Year 2, Wave 1 turned into Wave 2, as figure 5 shows below:

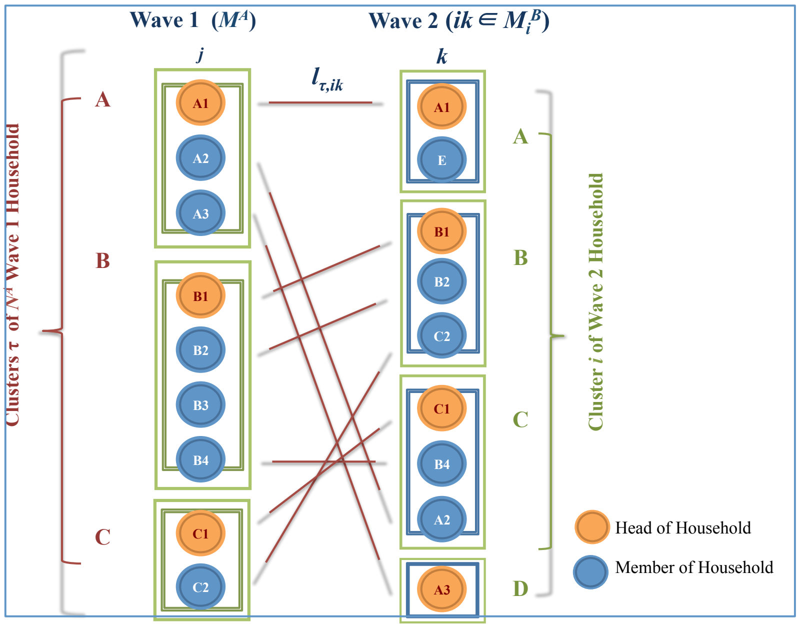

Figure 5: *Framework of changes in the composition of households*

At a later stage, the weighting procedure entails the following steps:

- Estimation of the weights $\frac{1}{\pi_\tau^A}$, for each Wave 1 of N^A cluster τ belonging to M^A, is the inverse of the inclusion probabilities π_τ^A, as Table 10 shows.

Wave 1		
Household (τ *clusters* N^A)	Household Members (*j*)	$\frac{1}{\pi_\tau^A}$
A	A1	57
A	A2	
A	A3	
B	B1	104
B	B2	
B	B3	
B	B4	
C	C1	63
C	C2	

Table 10: *Structure and weights of Wave 1*

- Calculation of the final weight w_{ik} of each member belonging to Wave 2. Table 11 shows the new structure of the three households A, B, C including the additional D, the initial weights w'_{ik} of each Wave 1 member as well as the total links L_i^B between the two Waves.

Wave 2					
Households (*i clusters* M^B)	Household Members (*ik*)	$w'_{ik} = \sum_{j=1}^{M^A} \frac{t_\tau}{\pi_\tau^A} l_{\tau,ik}$	$L_i^B = \sum_{\tau=1}^{N^A} L_{\tau,i}$	$\sum_{k=1}^{M_i^B} w'_{ik}$	$w_{ik} = \frac{\sum_{k=1}^{M_i^B} w'_{ik}}{\sum_{k=1}^{M_i^B} L_{ik}^B}$
A	A1	57	1	57	57/1=57
A	E	0		57	57/1=57
B	B1	104	3	104+104+63	271/3= 90,33
B	B2	104	3	104+104+63	271/3= 90,33
B	C2	63	3	104+104+63	271/3= 90,33
B	B3	-	-	-	-
C	C1	63	3	63+104+57	224/3=74,66
C	B4	104	3	63+104+57	224/3=74,66
C	A2	57	3	63+104+57	224/3=74,66
D	A3	57	1	57	57/1=57

Table 11: *GWSM final weights of Wave 2 Households*

3.3 Application of Indirect sampling and GWSM to produce estimates for the Nomadic and Semi-Nomadic Livestock

The nomadic and transhumant livestock[16] enumeration is an important component of the estimate of the total national number of breeding animals, especially for those countries affected by this phenomenon. However, the difficulty and even sometimes the impossibility to collect data through the agricultural census, because of the herders' seasonal or random movements, intra country and across the countries, make the implementation of this activity considerably burdensome both on operational and budgetary aspects.

Among several approaches to data collection, those that are related to the sample surveys on ground, usually collect the information on herds by a questionnaire. It is submitted to the herders when they bring the herds to the Enumeration Points (EPs) or drinking points during the survey year (Lakes, Rivers, Ponds, Wells, Boreholes, etc.)[17]. Although, the EPs are essential sources to collect data, most of them are difficult to access so that the available lists are not often

[16] Global Strategy. 2016. Guidelines on the Enumeration of Nomadic and Semi-Nomadic Livestock, definitions of:

a. Transhumant livestock/pastoralists as not permanently settled; movements characterised by regular, cyclical, short distance movements; livelihoods depend largely on livestock
b. Nomadic livestock/pastoralists as not permanently settled; movements characterised by irregular, erratic, long distance movements; livelihoods depend almost entirely on livestock.

[17] Global Strategy. 2016. Guidelines on the Enumeration of Nomadic and Semi-Nomadic (Transhumant) Livestock. "The identification and definition of enumeration points must be made in a participatory way with all stakeholders: government, local authorities, herders' organizations, and civil society. It is also important to note that the transhumant livestock and nomadic livestock do not always have the same enumeration points. For example in Niger, the enumeration points identified were stock routes for nomadic livestock and water points for transhumant livestock".

completely exhaustive to cover the enumeration list for the entire geographical zone, thus creating many issues in obtaining the needed information.

Also this case could be dealt with the "hard-to-reach" population methods by applying the Indirect Sampling and GWSM to carry out a sample survey on ground. The purpose is to estimate the total number of herds concerning nomadic and transhumant livestock at sub-national level (province), by increasing the initial list of EPs to develop a wider exploratory inquiry on the field. This case is featured by the following conditions:

- The nomadic and transhumant herds are the unknown or rare population, which is in relation with a known population of EPs, where animals gather and are given water, so that it is possible to create a link between the two populations.
- The initial sampling frame of a known population could be made available by selecting a two-stage sampling design at sub national level:
    - the Primary Sampling Units (PSU) as the Enumeration Areas (EAs) of the census (however, it is also possible to select counties, villages or other relatively small geographical areas). The PSUs can be selected either with probabilities proportional to their sizes (which could be the number of EPs in each EA) or equal probabilities.
    - the Secondary Sampling Units (SSU), that correspond to the EPs, are selected for each PSU with equal probabilities in each stratum.
- The herds (the unknown population) can be considered as clusters which group the EPs selected by herder, who gets used to taking the animals to drink.

The observational approach is described by analysing the links between the initial sampled EPs and the real EPs frequented by the herds through the information received by the herders, defining "*a herd as linked to an enumeration point if it frequents that enumeration point at least one time during a period of time (generally a year or several months in a year)*".[18]

Table 12 below proposes a kind of the questionnaire that could be submitted to three hypothetical herders who are responsible respectively for the herds A, B and C. The interview should take place at one of the sampled EPs and should also be widened as much as possible on eventual insights to better gather all needed information that helps in drawing up the framework of the links.

Questions [19]	**Answers**
Q1: How many EPs will you likely frequent with your herd this year?	*A1.* Three EPs by Herd A. *A1.* Four EPs by Herd B. *A1.* One EP by Herd C.
Q2: What are they? (Checking if the declared EP are present in the sample or are additional)	*A2.*Three sampled EPs (1, 2 and 3) are frequented by Herd A. *A2.*Two sampled EPs (1 and 2) are frequented and two not sampled (6 and 7) by Herd B. *A2.* One sampled EP (2) is frequented by Herd C.
Q3: Do you happen to meet other herds in the EPs that you frequent?	*A3.*No
Q4: If yes, how often? And which ones	n.a.

[18] Global Strategy. 2016. Guidelines on the Enumeration of Nomadic and Semi-Nomadic (Transhumant) Livestock.
[19] In case the enumeration points are stratified, these questions must be asked for each stratum.

Table 12: *Example of a questionnaire to build the links*

Figure 6 shows the framework, resulting from the above-mentioned questionnaire submitted to the three herders in the three different EPs, with the correspondences between the EPs frequented by Herd A, B and C and the sampled EPs during the period of the survey. The inclusion probabilities π_j^A of the sampled EPs (1, 2 and 3) belonging to the population M^A are calculated by the sampling design and are used to estimate the weights $\frac{1}{\pi_j^A}$ of each EPs frequented by the Herds.

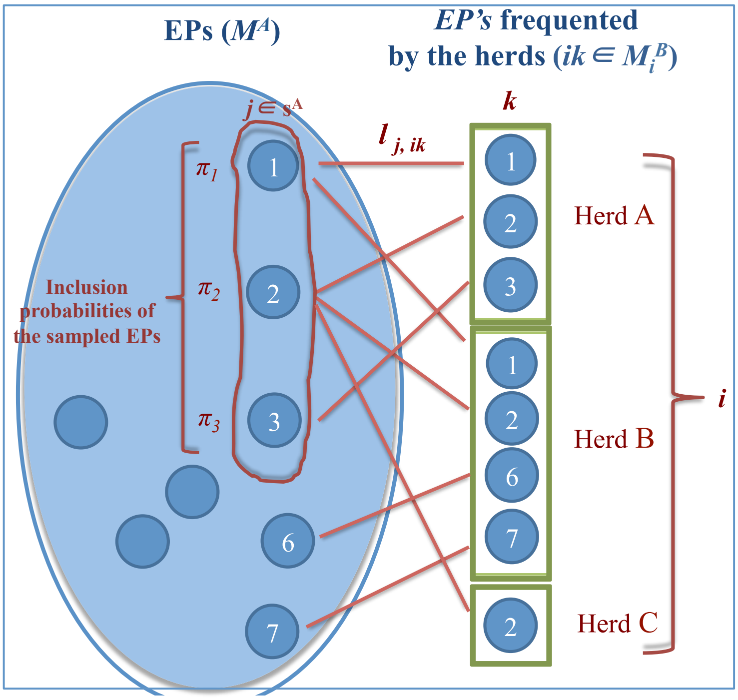

Figure 6: *Correspondences of the EPs and those frequented by Herds*

The following steps describe the application of the weighting procedure with GWSM:

- Computing the initial[20] weight w'_{ik} of the EPs clustered by each Herd. It is the sum of the weights $\frac{1}{\pi_j^A}$ of all the EPs of M^A linked to those frequented by ik Herds, with $t_j = 1$ if $j \in s^A$, and 0 otherwise.

i	k	$w'_{ik} = \sum_{j=1}^{M^A} \frac{t_j}{\pi_j^A} l_{j,ik}$
A	1	45
	2	28
	3	55
B	1	45
	2	28
	6	0
	7	0
C	2	28

[20] These figures have been made up to run the simulation.

Table 13: *Initial weight estimation of EPs frequented by Herds*

- Calculation of the total number of links for each Herd cluster *i* (quantity L_i^B), by summing for each Herd *i* all links between all EPs (M^A), both sampled and not sampled ones (quantity L_{ik}^B), and EPs clustered by the *ik* Herds belonging to M_i^B (size of the each cluster *i*).

i	k	$w'_{ik} = \sum_{j=1}^{M^A} \frac{t_j}{\pi_j^A} l_{j,ik}$	$L_{ik}^B = \sum_{j=1}^{M^A} l_{j,ik}$	$L_i^B = \sum_{k=1}^{M_i^B} L_{ik}^B$
A	1	45	1	3
	2	28	1	
	3	55	1	
B	1	45	1	4
	2	28	1	
	6	0	1	
	7	0	1	
C	2	28	1	1

Table 14: *Calculation of the links*

- Estimation of the final weight w_i of each Herd cluster *i*, that is calculated by dividing the initial weights by total number of the links in each Herd cluster.

i	k	$w'_{ik} = \sum_{j=1}^{M^A} \frac{t_j}{\pi_j^A} l_{j,ik}$	$L_i^B = \sum_{k=1}^{M_i^B} L_{ik}^B$	$\sum_{k=1}^{M_i^B} w'_{ik}$	$w_i = \frac{\sum_{k=1}^{M_i^B} w'_{ik}}{\sum_{k=1}^{M_i^B} L_{ik}^B}$
A	1	45	3	128	128/3 = 42,7
	2	28			
	3	55			
B	1	45	4	73	73/4 = 18,2
	2	28			
	6	0			
	7	0			
C	2	28	1	28	28/1 = 28

Table 15: *Final weight calculation of the clustered EPs frequented by Herds*

- Assignment of the final weight w_{ik} to each *ik* EP for the estimation of the variable subject to the study calculated by GWSM with the estimator $\hat{Y}^B$ above mentioned.

i	k	$w'_{ik} = \sum_{j=1}^{M^A} \frac{t_j}{\pi_j^A} l_{j,ik}$	$w_{ik} = \sum_{j=1}^{M^A} \frac{t_j}{\pi_j^A} \frac{L_{j,i}}{L_i^B}$
A	1	45	42,7
	2	28	42,7
	3	55	42,7
B	1	45	18,2
	2	28	18,2
	6	0	18,2
	7	0	18,2
C	3	28	28,0

Table 16: *Assignment of the final weight to each EP frequented by Herds*

4. Conclusions

Developing countries have a particularly strong need to produce statistical data, develop their planning activities and measure the effectiveness of public interventions, especially in vulnerable areas. However, these countries do not always possess the resources required to build exhaustive surveys that can provide reliable estimates at national level.

Furthermore the rural sector is an especially vast and complex sector, where it is not possible to collect all data on the sector during a general agricultural census. For this reason, usually only information on their links with farms is collected. However, data for each of these structures are not collected, although this information is relevant to national statistical program and policy makers.

This is also true for some information that is indirectly related to agriculture, such as its links with the sectors of education, health and infrastructure.

Indirect sampling and the application of GWSM could help to obtain reliable data on the areas mentioned above. For each of these countries, it is necessary to diagnose information needs and existing data collections, and to analyse the possibility of using indirect sampling for integrated surveys in the rural sector while maintaining costs at a sustainable level.

These methods are very useful tools to enable the collection of information using alternative and cost-effective methods that facilitate the data gathering in case of difficulties to get information about rare and unknown populations using statistical procedures.

This paper has presented some examples applied in the agricultural sector that should be deepened and tested on the field at local level in order to meet national needs and eventually develop experiences to strengthen the statistical capacity building of the countries.

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THEMATIC SET

F36

MASTER SAMPLE FRAME FOR AGRICULTURAL SURVEYS

Session Organizer
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J. Gallego | EC JRC, Econometrics and Applied Statistic | ISPRA | Italy

ABSTRACT

One of the major tools for improving the cost efficiency of agricultural statistics is building a sampling frame that can be used for many types of agricultural and rural surveys, ideally all of them. The traditional fields of agricultural and rural statistics including production estimation, economic analysis and social issues are being more and more enlarged with the growing environmental concerns that pose new challenges to building flexible Master Sampling Frames.
Papers submitted to the session may present:

- Practical cases of master sampling frames that have been built or are being designed for a particular country or region.
- An overview of the topic
- Methodological analysis of specific problems that appear when building a master sampling frame.

A non-exhaustive list of aspects and problems that papers of the session can tackle is:

- Combining several sampling frames
- Use of technological tools to build a (master) sampling frame
- Challenges and solutions on the integration of different concerns of agricultural and rural statistics, including production, environmental and social aspects.

LIST OF PAPERS

Development of multiple sampling frames for agricultural surveys in Kenya
P.M. Mwaniki | Kenya National Bureau of Statistics | Nairobi | Kenya
DOI: 10.1481/icasVII.2016.f36

Master sample frame for agricultural surveys in Georgia
M. Guntsadze | National Statistics Office of Georgia | Tbilisi | Georgia
V. Tsakadze | Geostat Agricultural and Environment Statistics Division | Tbilisi | Georgia
DOI: 10.1481/icasVII.2016.f36b

Using administrative registers for making a sample frame for agricultural statistics - Methodologies, techniques and experiences
A.M. Karlsson | Swedish Board of Agriculture | Jönköping | Sweden
A. Grönvall | Swedish Board of Agriculture | Jönköping | Sweden
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Master sampling frames for agricultural, rural and agro-environmental statistics, methodological and practical issues
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Master sample frames for integrated and linked surveys
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DEVELOPMENT OF MULTIPLE SAMPLING FRAMES FOR AGRICULTURAL SURVEYS IN KENYA

CROSS-THEMATIC SET F: Data sources / Data collection / Use of IT tools / Data quality

THEME TITTLE: Master sample frame for agricultural surveys

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ABSTRACT

Agriculture is the mainstay of the Kenyan economy contributing about a quarter of the Gross Domestic Product. The country covers an area of 591,971 square kilometers. Eighty per cent of the land area is arid or semi arid and largely suitable for pastoralist activities. The balance is used for crop production and livestock keeping by the sedentary population. Despite the central role played by the sector in the economy, the quantity and quality of agricultural statistics in Kenya has worsened over time due to a myriad of factors. To address these challenges, the Kenya National Bureau of Statistics (KNBS) in conjunction with stakeholders in the Agricultural Sector and with support from the World Bank is in the process of developing a multiple sampling frame, a precursor to a comprehensive survey programme to address the identified data gaps. The multiple sampling plans will entail the construction of an area frame for collecting smallholder agricultural data and a list frame for collecting data from commercial farms. This approach is motivated by the fact that the smallholder farmers are very many and with small parcels of land while commercial farms are few and hence can be completely enumerated.

The above sampling strategy envisages a survey plan where agricultural input and output data is collected on a seasonal basis to obtain annual agricultural statistics using the area frame. An annual census of commercial farms and green houses will complement data from the smallholder farmers so as to obtain the overall picture of the performance of the agricultural sector on an annual basis. This approach which is taking place in Kenya for the first time is using a collaborative approach which involves the national statistics office as the lead agency, the Ministry of Agriculture, livestock and fisheries and various Non Governmental organizations pooling their expertise and resources together to generate the required infrastructure. This approach is preferred due to the positive aspects of institutional ownership, cost saving and the high quality of the resultant agriculture statistics that will be produced.   This paper outlines the processes and sampling plans that will be undertaken to ensure that the quality of Agriculture statistics is of high quality. The International Conference on Agricultural Statistics (ICAS VII) forum is very timely as it will provide an excellent forum for validating and/or critiquing the entire process that Kenya is taking to address the quality of its Agriculture Statistics whose quality has been declining over time.

Key words: sampling frame, seasonal surveys,

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INTRODUCTION

Agriculture is the mainstay of the Kenyan economy contributing about a quarter of the Gross Domestic Product (GoK, 2016). The country covers an area of 591,971 square kilometers. Eighty per cent of the land area is arid or semi-arid and largely suitable for pastoralist activities. The balance is used for crop production and livestock keeping by the sedentary population.

Despite the central role played by the sector in the economy, the quantity and quality of agricultural statistics in Kenya has worsened over time due to a myriad of factors. To address these challenges, the Kenya National Bureau of Statistics (KNBS) in conjunction with stakeholders in the Agricultural Sector and with support from the World Bank is in the process of developing a multiple sampling frame, a precursor to a comprehensive survey programme to address the identified data gaps.

The multiple sampling plans will entail the construction of an area frame for collecting smallholder agricultural data, a list frame for collecting data from commercial farms and deployment of aerial surveillance methodology for pastoral areas. This approach is motivated by the fact that the smallholder farmers are very many and with small parcels of land while commercial farms are few and hence can be completely enumerated. A census of commercial farms and greenhouses is currently being undertaken countrywide.

METHODOLOGY

The Kenya Seasonal Agricultural Survey (SAS) is intended to inform policy decision and international reporting requirements. The approach adopted in this survey is based on a similar approach learnt from Rwanda (NISR, 2014). Compared to Rwanda, Kenya occupies a much larger geographical area and has a much higher smallholder farmer population. This therefore makes it even more critical to develop as area frame to facilitate periodic smallholder agricultural data collection. It is expected that data collected will be sufficient to generate county level estimates so as to support the data needs at that level. The survey will be conducted twice a year to cover both the long and short rain seasons. The pilot survey is expected to take off in April 2017 and then the main survey in October 2017 to coincide with the short rains season. This section outlines the methodology that will be used to develop the Area Frame and conduct the first round of the Seasonal Agricultural Survey (GoK 2015).

STRATIFICATION

Base Map Layer

The 2010 Land Use Land Cover (LULC) layer from KFS (Kenya Forest Service) will be used as a base layer and updated to come up with a current stratified layer of 2015. This layer was derived from ALOS (Advanced Land Observation Satellite) images which have a 10 Meters resolution. The said images did not have much cloud cover and where there were clouds DMC (Digital Monitoring

Constellation) 22Meters and LANDSATS 30 Meters images were used as a substitute. Higher resolution images will be used in the updating of the 2010.

Stratification
Definition of Strata

1. Built Up Area (Any artificial hard surface that is manmade)
2. Forest (Areas that have trees or shrub land)
3. Uncultivated Wetland (Areas that have water more than six months in a year but do not have any croplands)
4. Waterbody (Areas having water)
5. Bare Areas (Rock outcrops, Bare soil with no definite pattern)
6. Cropland (Areas where crops are planted and cultivated)
   - Small scale/Intensive agriculture below 20 ha
   - Large scale agriculture 20 ha and above
7. Pasture land (Areas used for animal forage)
   - Leys (Having clear fenced areas, regular shaped, established pastures)
   - Natural Grassland (Continuous fenced grassland areas)
8. Grassland (Areas covered with grass that are neither rangeland nor pasture)
9. Rangeland (Free range grassland and/or shrub land in Parks, reserves, conservancies, ranches)

The 2010 base layer covers the whole country with the classes being; Forestland, Cropland, Settlement, Wetland, Grassland and Other land. Assessment of the same led to the decision on subdividing the LULC to different Strata in a three level step: Primary, Secondary and Tertiary which will cover the whole country. Secondary strata will be a subdivision of the Primary strata while Tertiary strata are a further subdivision of the Secondary strata.

Imagery

Images (High Resolution Images, Aerial photographs and Google Earth) License - High Resolution Satellite Images. The high resolution satellite images will be procured by purchasing a license which would give access to parties involved to the full archive of images from 2002 to date. This purchase of the license will be cheaper than purchase of the images. The DRSRS (Directorate of Resource Surveys and Remote Sensing) is expected to provide Aerial Images of the same resolution as the satellite images in order to compliment the satellite images in the high potential agricultural areas. Google Earth images will not be used since we are having high resolution images already. If used the challenge would be reduced efficiency. The images in Google Earth are a mosaic of images from different years hence a reduction in accuracy. Shifts in the google Earth image products would have errors trickle down to the final Strata if used. Lastly, their use in fieldwork leads to an error of 10 meters due to registration. Based on the comparisons above, commercial software will be used in the stratification process, PSU as well as SSU creation. It should be noted that the organizations represented in this the Technical Working Group already have licenses hence no additional costs will be incurred in the use of the commercial software. However, open source such as QGIS may be utilized in field map production.

Ground Truthing Strata

Ground truthing exercise is guided by the need for clarification. Since the initial interpretation and automatic classification will be based on Satellites imageries, this requires validation using ground sample points. During the stratification process areas that are difficult to interpret or having conflicting categorization by the TWG are noted down. These areas will form a basis for verification. The sample points generated will not only clarify the areas but also act as points of assessing the accuracy of the Stratification process. The ground sample points will be uploaded to the tablets for use in the field. The sample points will be required to be in the same reference datum as satellite imageries for the purpose of compatibility. As indicated in the Table 1 above. During this process clarification will be on the tertiary level of stratification since that is the basis of the entire sampling frame. The task above will be undertaken by RS/GIS specialists from the organizations involved (RCMRD, KFS, DRSRS, NEMA, KALRO among others). Drivers will be sourced from the institutions mentioned above. Security personnel will be hired on a need basis. For the ground truthing exercise to be undertaken, Mobile Mapper Licenses will be purchased and installed in the Tablets. The use of the mobile mapper stems from the fact that GPS would capture data as is while the mobile mapper will enable taking of coordinates and the ability to transfer the data to the server with the aid of good internet connectivity. The use of tablets will do away with cameras, GPS and batteries reducing the cost. The same tablets used in ground truthing the strata will be used during data collection. The full list of items required during ground truthing is indicated in the budget. Field sample points used in ground truthing will be based on first draft strata. Sample points will be randomly generated to verify the accuracy of the stratification. The duration of the ground truthing exercise for the whole country will take approximately 12days comprising of 10 teams.

PRIMARY SAMPLING UNITS

Shapefiles (Administrative Units, Rivers, Roads, Rail)

The primary sampling units will be required in a digital GIS format i.e. a shapefile. These are vector data sets that will be overlaid with the images for the purpose of analysis. The Kenya National Bureau will provide boundary data at National, County, Sub county, Locational and sub- locational levels. Kenya Agricultural and Livestock Research Organization (KALRO) will provide the Agro-Ecological Zones (AEZ). The above shapefiles will assist in locating both the administrative units and the Agro-Ecological Zones of various crop in the sampled holdings

Creation of PSUs

Primary Sampling Unit refers to the sampling units in the first stage of selection in a multistage sampling process. The output stratified layer in the previous process will form the base layer. Once the natural boundaries have been identified and extracted, the later will be used in the subdivision of the strata to form the PSUs. The PSUs will be developed by strata and a sample of the PSUs obtained through Probability Proportional to Size (PPS) sampling method. These PSUs will be subjected to an area rule whereby the PSU segments will be divided into blocks of 200 to 400 hectares. The sample size will be such that the estimates will be representative at the county level.

SECONDARY SAMPLING UNITS (SSUs)

Creation of SSUs

Secondary Sampling Unit refers to the sampling units in the second stage of selection in a multistage sampling process. The PSUs generated in the previous process will be used in the creation of the SSUs. These PSUs will be subjected to an area rule whereby the PSU segments will be divided into blocks of 10 hectares which are herein referred to as SSUs. Sampling of the SSUs will be based on systematic sampling method. The SSUs will have unique identifiers in the attribute table. The ID will be used in the selection of the samples.

ENUMERATION SURVEY

Map Production

To improve on the stratification accuracy, field maps will be produced for use through RS/GIS approaches. The maps will be used in validation of the stratification products. For every sampled segment, a segment image map will be produced to aid the enumerators in collecting data. A suitable size and scale of the map will be determined and cartographic visualization applied. The number of maps produced will be dependent on the coverage of the segment and crop calendar (seasons).

Ground-truthing

Field verification will be carried out for the selected SSU. The selected SSUs will have IDs identifying their boundaries. During field verification, the selected SSUs will be identified using landmark features such as boreholes, hospitals, schools, rivers or roads as indicated in the field maps.

The following steps will be adopted for undertaking ground-truthing:-

Preparation of field questionnaires (check-list)

The TWG will determine which thematic areas before developing the questionnaires. These questionnaires will be in digital format to enable real-time transmission to the server. Hard copy questionnaires will be used as back up.

All land parcels in the SSU will be measured using tablets. This will be done by tracking of all the plots in the segment.

Data Collection

The team will be expected to collect various types of data to enable them enrich the initial available auxiliary data. Standard procedures will be adopted as follows:-

- Mobilization of a team of experts - The TWG will ensure that a team of experts are in place before the exercise takes off
- Formulation of a check-list - The check-list will ensure that data gaps are eliminated. This will minimize errors
- Mobilization of survey tools and equipment - Acquisition of tablets, vehicles, maps and items mentioned in the budget
- Publicity - The survey exercise has to be publicized before commissioning. This will enable smooth operation at the community level
- Fieldwork - The experts will be dispatched to different regions within the country based on the classes which will require validation.

Data cleaning, Analysis and Storage

Data from the field will be downloaded from the servers at the KNBS. Data from the server will be cleaned and weighted. Thereafter statistical tables will be generated for both seasons. SPSS software will be used in processing the statistical tables. After the analysis and production of the indicators, the output will be linked to their exact location using the unique ID on a GIS platform. The unique ID will be used to link the non-spatial and spatial data to complete the attributes in the spatial files. A Geo-data base will be designed to facilitate the linking and storage of the files. In the geo-database, access protocols are to be defined to allow access, editing and dissemination.

Awareness/publicity

To ensure maximum cooperation and participation from the citizens, publicity of the survey will be done using fliers, print, electronic media, barazas and other suitable channels. To enhance awareness creation and survey publicity, a team will be created comprising of KNBS and MOALF knowledgeable of the subject matter to steer the campaign through sensitization to the chiefs, village elders, sub chiefs and opinion leaders.

Training (TOT, Supervisors and RAs)

Two levels of training will be undertaken for the Pilot and the Main survey. These are:
Training of Trainers (ToT)
Training of supervisors and research assistants
The TWG will mount training of the TOTs who will then train the supervisors and the research assistants. The training will focus on:

- Mapping, ground truthing
- Use of tablets, mobile mapper
- SAS Questionnaire administration

Report Writing and Publication

The following reports will be prepared.

- Pilot / Pretest Report
- The Seasonal Agricultural Survey (SAS) and other Publications

The experiences and lessons learnt from the pilot report will be used to fine tune both the various survey instruments in the main survey as well as the mode of operation. The survey results and indicators will be published and disseminated to the stakeholders.

Dissemination

Dissemination of the results of SAS is important because it provides information for decision making to users such as policy makers, researchers and the general population among others. Some modes of dissemination include:

- Hold a workshop to release the results
- Highlight in the electronic and print media
- Upload in websites
- Distribute hard copies

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Master Sample Frame for Agricultural Surveys in Georgia

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ABSTRACT

This paper reviews experience of Georgia in building the master sample frame for agricultural and rural statistics. In November 2014 the National Statistics Office of Georgia (Geostat) conducted Agricultural Census together with General Population Census. In particular, census contained the following questionnaires: Questionnaire on Dwelling, Personal Questionnaire, Questionnaire on Emigrants and Questionnaire on Agriculture. Additionally, census identified the holdings that operate aquaculture and greenhouses. The data derived from the census is used for constructing master sample frame.

Census was conducted using the GIS maps, thus, all the data derived from the census will be linked to the GIS data. Geostat also conducted Agricultural Census for legal entities in order to fulfill the agricultural census data (including common land data). This paper describes design process of the questionnaires used in census as a tool for identifying the frame units of different surveys and the main variables subject to be obtained.

As a result, the Master Sample Frame attained from the census is very comprehensive and can be used for many different surveys as it was derived from the integration of population and agricultural censuses. The paper presents benefits of conducting agricultural and population censuses together in building the master sample frame.

The paper will also describe the core set of variables which will be derived from the census and it will provide examples of new surveys which can be conducted using the master sample frame.

Keywords: Master sample frame, census, agricultural statistics, sample survey

1. Introduction

Statistical system in Georgia is centralized. The Law of Georgia on Official Statistics creates a general framework for statistical system in the country and sets coordination principles for all institutions responsible for producing official statistics in Georgia. According to the law, production and dissemination of statistics shall be based on the 10 basic UN principles of official statistics. Geostat is a coordinating body of Georgia's statistical system and the only producer of official agricultural statistics in the country[1]. Geostat is the agency responsible for conducting censuses on population, housing and agriculture.

Georgia has substantial agricultural potential, The government places great emphasis on the need for investment in increasing output and productivity of Agricultural Sector. Demand for agricultural data is increasing daily and Geostat has to respond to user needs.

Agriculture has always been one of the important sectors of Georgian economy. Despite the fact that share of agriculture, hunting, forestry and fishing in GDP was only 9.2% in 2015, 48.6% of employees in Georgia were employed in this sector. The share of rural population is 42.8% according to the Population Census 2014.

Almost every household living in villages is an agricultural holding and even in small towns 2/3 of households are engaged in agriculture. Overall, 3 out of 5 household are engaged in agriculture and they are scattered through every region of the country. According to the Census of Agriculture 2014, total number of agricultural holdings is around 642 thousand, out of them only 2 thousand is legal entity while other 640 thousand is household. Majority of agricultural holdings are small and they produce agricultural products for their own consumption.

Due to favorable geographical location and climate, Georgia produces more than 25 kinds of permanent and more than 20 kinds of annual crops. Also animal husbandry is quite common in the agriculture of Georgia. One of the specificities of the country is that the agricultural sector is not well-specialized and majority of holdings produce many different kinds of agricultural products.

The main source of current agricultural statistics is the Sample Survey of Agricultural Holdings which dates back to 2007 and its methodology was elaborated with the support of Food and Agriculture Organization (FAO) and the United States Department of Agriculture (USDA). Sample frame of the survey was based on the Agricultural Census 2004 which was the first in the history of independent Georgia. In 2014 Geostat conducted the second Agricultural Census of the country together with the Population Census. Based on the census database, in 2015-2016 Geostat prepared Master Sample Frame for agricultural surveys.

[1] The Georgian statistical system covers the whole area of the country, except the occupied territories.

2. Building Master Sample Frame in Georgia

In November 2014 the National Statistics Office of Georgia conducted Census of Agriculture together with the Population Census. In fact, there were 4 different censuses conducted together: Housing Census, Population Census, Census of Emigrants and Agricultural Census. Additionally, census identified holdings operating aquaculture and greenhouses. The census was conducted using GIS maps.

Geostat started preparatory works for the General Population Census in 2006. One of the principal parts of these works was implementing GIS in order to create digital cartographic material and use them in census data collection and dissemination process. At the first stage, GIS group, which was created at Geostat, developed GIS maps using cartographic material available in the country. A supplementary work was done to cover the territories where cartographic material was missing. In addition to this, a numbering script was prepared in order to give its own code to each parcel and buildings located on it through the country territory. After this, a supplementary work was done for updating existing software and for switching to fully automatized system.

In 2013 Geostat conducted preliminary field works to elaborate list of dwellings and households existing in Georgia. In order to digitalize collected information and integrate with cartographic data, there was developed software which was using coding system created by GIS group. Information received from the preliminary field works was used for correcting and finalizing existing data on buildings and for distributing work among census enumerators effectively. In addition to these, household duplication and missing risks were minimized.

By implementing GIS, Geostat managed to significantly decrease time needed for preparing cartographic materials, use financial means in more effective way and prepare high-quality maps.

Register of legal entities engaged in agriculture was prepared separately, due to the fact that General Population Census has only covered household sector. For completing the list of agricultural enterprises, all existing reliable sources were used: existing sample frame of the regular quarterly survey on agriculture, Statistical Business Register, Public register, Information available at the Ministry of Agriculture, at local governments, at the Ministry of Education and at the Patriarchate of Georgia. After the General Population Census Agricultural Census for Legal Entities was conducted separately.

Preparation process of the census questionnaires was held under the international guidelines and recommendations, taking into the consideration the needs of local users. The census questionnaire consisted of four separate parts, respectively to four different censuses: Questionnaire on Dwelling (Q1), Personal Questionnaire (Q2), Questionnaire on Emigrants (Q3) and Questionnaire on Agriculture (Q4). Each questionnaire had unique ID number that was linking them to each other. In total, census questionnaire had 9 pages: 2 for Q1, 2 for Q2, 1 for Q3 and 4 for Q4.

Q1 contained questions on dwelling conditions, as well as the full list of households and persons living in the dwelling with status of the persons - usual resident, temporary absent, temporary present, emigrant. According to the status of the person, appropriate questionnaire was filled (Q2 or Q3).

Since the population and agricultural censuses were conducted together, it was agreed to use the same reporting unit, thus a household was considered as one agricultural holding. In case of two or more holders in the household one of them was selected as a holder and their operated lands and livestock were summed up and assigned to the holder. In case of one or more households in a holding, each household was considered as a separate holding and land and livestock were assigned proportionally according to the share of households in the holding.

There were main identification questions in the Q1 for agricultural holdings. According to them, if household was identified as a holding, Q4 was filled by the enumerators. Besides, Q1 was identifying the holder. Additionally, Q1 contained identification question on holdings operating aquaculture.

Questionnaire on Agriculture (Q4) did not contain any question about the holder rather than holder's unique number indicated in Q1 and Q2, since all relevant information was covered by Q1 and

Q2. Q4 covered all core indicators recommended by the Food and Agriculture Organization and local user's needs were taking into account. [2]

For the Agricultural Census for Legal Entities an electronic questionnaire was prepared, which was also used for the census of municipalities (common land data). The content of the electronic questionnaire was the same as of Q4. In addition to the questions similar to Q4, there were additional questions regarding personal characteristics of the company director/holder.

As a result the census database contains information on dwelling conditions, personal information of the population, personal information of emigrants, agricultural data on holdings, personal information of holders, data on households operating aquaculture and greenhouses and geographic data. The database is a comprehensive source for analysts and researchers to cross-analyze social-economic and agricultural data.

The coding system included in the census database easily links all obtained data and creates Master Sample Frame for Agriculture. The existed MSF is used and can be used for various surveys: integrated agricultural surveys, specific agricultural surveys, aquaculture surveys, greenhouse surveys, social-economic surveys, etc.

In 2015 Geostat prepared Strategic Plan for Agricultural, Environmental and Rural Statistics in Georgia 2016-2020 (SPAERS). It determines the planned activities for improving agricultural, environmental and rural statistics, including new surveys to be conducted in coming years. MSF will be main tool for the agricultural surveys and it will be used as a frame for making samples.

MSF facilitates identification and monitoring process in the field works, since it contains detailed personal data of the holder and her/his household members, as well as GPS coordinates of the household location. It also gives great possibility to prepare maps indicating sampled units for enumerators to be used during the field works.

Georgian MSF covers various variables regarding Family holdings, Agricultural enterprises, Households, Emigrants, Housing conditions, Aquaculture holdings, Greenhouse holdings, municipal (common) land, etc.

3. Conclusions

By conducting population and housing censuses and agricultural census together, the National Statistics office of Georgia has created the first Master Sample Frame for Agriculture. The identification codes system embedded in the questionnaires easily linked the population and agricultural censuses and hence linked the agricultural holdings data to the households data. Use of GIS maps during the census fulfilled MSF with the detailed geographic data.

The Master Sample Frame is used for regular agricultural surveys and will be used for new regular surveys as well as for one-time surveys which are planned to be conducted in the coming years. Merging different surveys using MSF decreases survey costs and respondent burden which is crucial for statistical system. MSF facilitates to meet planned activities determined by SPAERS in more efficient way. It is also good tool for the surveys studying agricultural activities for specific social groups. MSF can be widely used for identification and monitoring process during the field works that will decrease the time needed for data collection and improve data quality.

It is important that MSF will be updated regularly by the data obtained from all agricultural and social-economic surveys based on Master Sample Frame as well as by the reliable administrative sources available in the country in order to keep MSF up-to-date.

[2] http://census.ge/en/methodology/kitkhvarebi

USING ADMINISTRATIVE REGISTERS FOR MAKING A SAMPLE FRAME FOR AGRICULTURAL STATISTICS - METHODOLOGIES, TECHNIQUES AND EXPERIENCES

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ABSTRACT

Swedish official statistics in the agricultural area has since 1995 been based upon the extensive use of administrative data. However, in most cases it is not advisable to produce statistics direct from administrative registers. This paper reviews the methodologies and techniques used in order to ensure sufficient statistical quality when using administrative sources together with the Farm Structure Survey for the creation of the statistical farm register. The Farm register (FR) is used as a sampling frame for all agricultural statistics based on holdings.

In the paper we will show how the frame can be updated regarding the holdings constituting the frame as well as regarding the characteristics for example area of different crops, rented land and number of animals needed to stratify samples. The results show that integrating administrative registers with surveys is a cost-effective way of updating the frame while reducing the burden on respondents. Various aspects of the quality dimensions "accuracy", "comparability" and "coherence" are the key issues for development in order to improve the quality when integrating registers and surveys.However if extensive, systematic work is integrating registers and surveys, the quality in these dimensions can be high. It is shown that there is at least as much need for work with improving quality, methodological studies and quality assurance for statistics based on administrative registers as for statistics based on sample surveys. When using administrative registers, the integration phase where data from several sources are integrated into a new statistical register is central for improving quality.

Keywords: register-based statistics, administrative registers,

1. Background and aim

At least from 1965 and onwards agricultural statistics in Sweden has been dependent on an updated Farm register (FR). The FR consists of all agricultural holdings in Sweden as well as variables needed for creating a typology consisting of type of farm, size of farmand region. The variables includedifferent kinds of animals and crops, rented land and some general information about type of holding and the holder. The typology is used to stratify effectively and thus minimise the sample in almost all agricultural sample surveys. Up until 1996the FR was updated by a yearly census where farmers were asked about all crops and animals.

When Sweden joined the EU in 1995 administrative registers of all farms applying for EU-subsidies where made available for statistical purposes. Subsequently several studies were made to see how the registers best could be used for agricultural statistics.Selander et al. (1998) and Wallgren& Wallgren (1999) for example compared IACS (the register for area-based subsidies) from 1996 with the objects in the FR from 1995. The results showed that 88 per cent of the objects matched, 4.9 per cent of the objects had multiple links between the registers and 6.9 per cent could not be found in IACS. Of the objects in the IACS register on the other hand, 2.9 per cent could not be found in the FR.As a result of the studies work the following years were focused on integrating the registers and FR. Several questionnaires were sent to subgroups of farmers asking them about keys in IACS.

In recent years Dias et al.(2016) has shown,with the example of Portugal, how alternative methodologies to a traditional population-census could be evaluated. They conclude that since there are advantages and disadvantages to all methods, it is important to make a systematic evaluation so that the trade-offs between options could be taken into account in the decision making process. It is stressed that registers might not have all the content needed; instead the registers may need to be combined with traditional surveys. The findings in the studies of Wallgren & Wallgren (1999) also showed that it is not possible to produce the FR directly from administrative registers. However they showed that administrative registers could be used for updating the objects in the FR as well as give information on some variables, for example crops.

As a result,starting in the year 2000 the FR was no longer updated with an annual full census, instead itwasupdated with an integrated use of registers and surveys in the years for which EU require the member states to conduct a Farm structure survey (FSS) according to regulation (EC) 1166/2008.In the years in-between, the FR is updated mainly from registers, together with information from a sample survey on animals. In recent years additional registers have been used,for example administrative registers on cattle, sheep, poultry and pigs.

When using an administrative register there is at least as much need for methodological studies and quality assurance as for statistics based on statistical surveys. However, the quality deficiencies and the approaches to investigate and resolve them differ.Several studies, for example Wahlgren & Wahlgren (2014),Laitila et al. (2011), Daas et al. (2009, 2010) and Agafitei et al.(2015) have discussed quality frameworks for using administrative registers for statistical purposes. This includes the quality of the register itself, the possibilities of integrating administrative registers into statistical registers and how to document the quality of the statistics produced. There is also a discussion about which part of the process to focus on. Holmberg (2015) summarises that there is an ongoing theoretical development on how to assess the quality of administrative data, but that more work is needed for example regarding linkage errors and cowerage errors.

The framework by Daas et al. (2010) is recommended by EU (2016) for assessing the quality of administrative registers. In 2016 the framework was used for evaluating registers for FSS 2016 (SJV, 2016)

1.1 Aim of the paper

This paper will describe how the FR in Sweden is updated using administrative registers in combination with some census data. The quality achieved by using theadministrative registers in combination with a statistical survey will be compared towhat quality could be achieved by updating FR using only a census and using only administrative registers.The framework recommended by Eurostat (2016) presented by Daas et al. (2010) will be used to highlight the quality in the administrative registers.

The quality will be described according to the quality criterias stipulated in regulation (EC) No 223/2009 on European statistics. Furthermore aspects of cost-effectiveness, privacy and response burden will be addressed.

2. Updating the Farm register (FR)

Figure 1 showsthat the overall method for creating the FR is to make a maximal sampling frame (2) withcombining the objects in the FR from the latest FSS year (1a)by all new possible objects that can be found in registers (1b). Next a questionnaireis sent out to the maximal sampling frame(3), and a current FR is made (5)by combining the information in the maximal sampling frame with information from the questionnaire(4). In the end the variables needed for thetypologyare added.

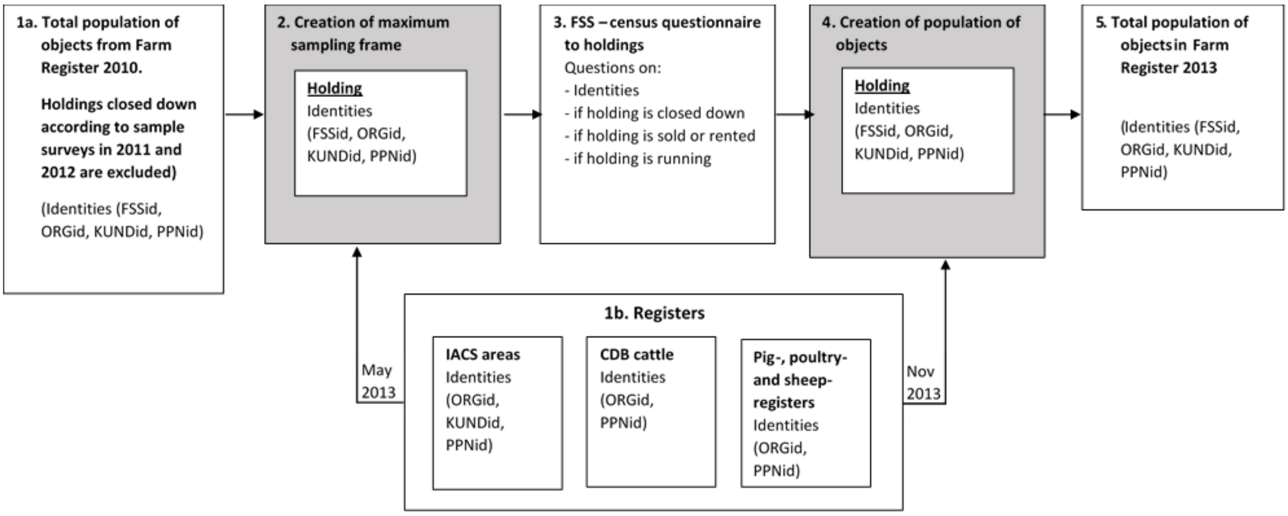

Figure 1:*Creation of the Farm register 2013.*

The target population of the farm register is the same as the target population of FSS. The variables of animals and crops in FR are also defined in the same way as the variables for animals and crops in FSS. I.e. producing the FR means doing a large part of the work needed for FSS.

2.1 Creating the maximal sampling frame

In the beginning of 2013 the total population was taken from the 2010 Farm Register.The indicators related to the source as described in the hyper-dimensions of (Daas et al., 2010) are used to describe the quality of the registers. The Swedish Board of Agriculture is the supplier of the data sources for all registers except the Business register (BR), where the supplier is Statistics Sweden. The Board is also the responsible NSO for agricultural statistics, so privacy and security rules are in place. Historically the registers have always been delivered in time. All persons and organisations in the registers as well as in the FR have a unique organisational number (ORGid). The ORGid is therefore always a linkable auxiliary key between registers.

The IACS register is highly relevant. It consists of all holdings applying for area based subsidies in May each year. In IACS about 60 codes for crops are included. It has unique keys (KUNDid) and the linkability is high. It has clear definitions and the information is well checked. However there is an under-coverage since about 10 per cent of the holdings do not apply for or are eligible for area based subsidies. Following the definition in FR a holding might contain several KUNDid. IACS could be used both for updating the register and for a large proportion of the variables.

The registers for poultry, pigs and sheepas well as the cattle database are aimed at tracing animals in case of an outbreak of a contagious animal's disease. Each production-place with these animals have a unique key (PPNid). The production-place is related to a person or legal entity with an organisational number (ORGid). One holding can relate to several production-places. The information in the registers differs. The poultry-and pig- registers mainly holds information on the number of animals that could be held at the production-place.

In the sheep-register additional information on the number of sheep in December are added by a questionnaire. There is a unit non-response of about 24 per cent. This register also has an over-coverage of about 20 per cent. It can be assumed that the over-coverage of the poultry- and pig-registersis the same. The under-coverage is small since the PPNid needs to be reported when animals are slaughtered. These registers could be used to update the objects in the maximal sampling frame but the quality is not sufficient for the variable values.

In the cattle-databaseeach head of cattle has an identifier thatis related to a production place (PPNid). There is, however, no distinction in the register between dairy-cows and cows for meat-production. Information from a second auxiliary register of milk deliveries is used to obtain the required information. It is assumed that if the holding delivers milk in the month of the reference day, the cows on the holding are all dairy cows. This approach will resultin a small over-estimation of dairy cows and subsequently an underestimation of cows for meat-production. However a sample survey conducted in 2002 showed that the error was less than 1per cent. The cattle database is therefore used both for updating the objects and for the variables needed for cattle.

The use of registers means that thepostal questionnaire sent to the farmers did nothave to include questions on crops and cattle since this information is available from registers. Only questions on the number of horses, poultry, pigs-, and sheep were included.Since there could be multiple to multiple objects in the different registers, the order of merging is decided by specific rules. Each holding in FSS has a set of related keys (for example Orgid and KUNDid). The keys are ordered by their quality. If there are multiple possibilities of linking, the key ordered the highest i.e. with the best quality is used first.

The linkages made in the spring 2013 showed that 64 036 objects could be linked to the registers while11 689 holdings in the FR 2010 could not be found in registers. 3 004 of them had not been found in registers 2010 either and 8 685 are holdings that existed in registers 2010 but not 2013. Information from sample surveys done in 2011 and 2012 indicate that 800 holdings had closed down during the period. 868 additional holdings were found in the cattle register, IACS or the pig-, poultry-, and sheep registers. 934horticultural enterprises in the business register were added to find horticultural holdings that might fit into the frame. In the end the maximal sampling frame amounted to 77 527 holdings. By creating the sampling frame this way there will be an over-coverage in the frame. The under-coverage is assumed to be small as long as the holdings were present in 2010.

When the questionnaire was created it included questions regarding whatkeys (ORGid, KUNDid, PPNid) that were related to the holding and whether it was sold, rented out, closed down or still running. If the holding was sold or rented out it was askedwho was now running the farm. It is assumed that most of the 8 685 holdings that could no longer be found in the registers are no longer farmers, but some of them are likely to be the same as the 868 holdings that were found in registers but not in the register from 2010. This together with the linkage process could mean that the same holding might get more than one questionnaire. Whether this has occurred is therefore a question in the questionnaire. The questionnaire also includes questions on animals and rented land, variables that could not be found in the registers. The variables grazing land and arable land are included as a reference to the area of rented land.

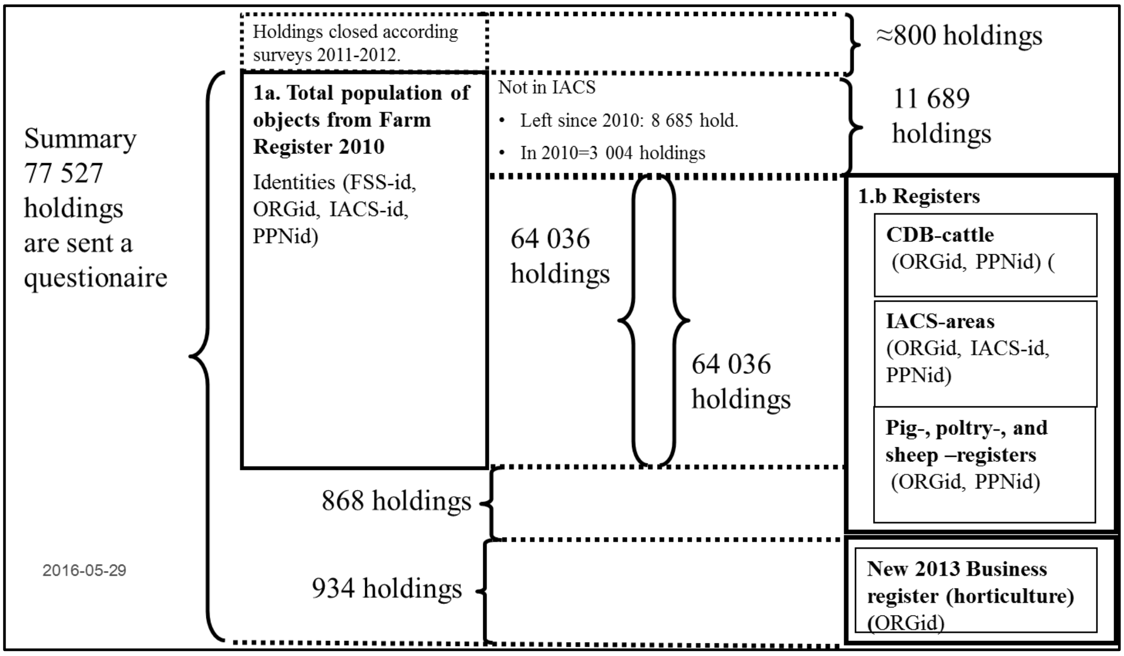

Figure 2.*Creation of the maximal sampling frame.*

2.2 Results from 2013

In November when the answers from the questionnaire were processed, updated data was gathered from the registers and related to the reference time. The information from the questionnaire and the registers wasmatched and the population of objects for 2013was created. In the questionnaire the set of keys and the quality of the keys related to the holding were updated. The linkage was then made using the same principles as when creating the sampling frame. The linkage resulted in 67 126 holdings in the FR for 2013.

613 duplicates were found. The duplicates were mostly holdings in FR 2010 that were not found in registers included in the group “left since 2010”. The duplicates were due to linkage errors.

The holdings in the group “left since 2010” were mainly growing crops. Out of the 8 684 holdings 3 125 had been closed down and 3 626 had been taken over by another holder. I.e. only 16 per cent were still farmers so there is a large over-coverage in this group. Out of the 3 004 holdings in the group “In 2010” 989 holdings had closed down and 541 had sold the farm to someone else. I.e. 58 per cent were still running the holding. It could be concluded that those holdings that for several years are running their business without applying for subsidies continue to do so.

The results regarding the horticultural register showed that 30 per centwere still running their holdings.574 holdings had closed down and 77 had sold it to someone else. For the holdings in this group it is more common to close down the business than letting someone else continue it. Out of the holdings in the pig-, poultry-, and sheep groups about half were still running their holdings and out of the large group that matched with IACS 98 per centwere still running their holding.

When the population was created, the variables were connected to the objects using the established links of keys. The information on areas and crops given in IACS as well as information about cattle given in the cattle register are considered to have high quality since the information is subject to extensive controls. For example, the holding is requested to give information about the total area of arable land in hectares as well as the total area of rented arable land in hectares. If the total area of arable land differs from the summarised areas of arable land used for different crops in IACS, the IACS figure will be used. As a result, the answers in the questionnaire wereonly used to calculate the share of rented arable land at the holding. The divergent answers could also be a sign that the creation of objects had not been fully successful. Consequently the information was used to improve the creation of objects.

3. Comparing quality between registers, census and multiple source

Every 10:th year a full census needs to be made meeting the target-population of FSS according to regulation (EC) 1166/2008. The census includes the variables in the FR. The alternatives which are interesting to compare are different methods for updating the FR in the two times during the 10 year period when the FSS is stipulated to be made as a sample survey. The three alternatives compared are a:

1. combination of census and registers i.e. the current method described in section 2,
2. register based approach, using registers in combination with the FSS-sample survey,
3. full census based method using a census and not any of the registers available.

3.1 Cost-effectiveness, privacy and response burden

Privacy and the principle that information given for statistical purposes should not be used for administrative purposes are fundamental when producing statistics (Eurostat 2016). On the other hand, administrative registers may be used for producing statistics. In Sweden, the Official Statistics Act (2001:99) addresses data disclosure and the Secrecy Act (1980:100) addresses the confidentiality of individual information. In the case of the FR, individual data from administrative registers are protected by the Secrecy Act (1980:100) when used for statistical purposes, regardless of whether the data would be public or not from the body responsible for the administrative register.

Using administrative registers is also a way of reducing the burden on respondents. At our user-meetings the Union of Swedish Farmers states that it is favourable to share information between governmental bodies in order to make it possible for farmers to only provide the same information once. The hours spent filling out the present set of questionnaires are calculated to 5 800 hours. If no administrative registers where used the questionnaire would also need to have information on all animals and all crops and the total number of hours spent could be calculated to 9 600 hours. If only administrative registers were used the time would be 0. However compared both to the current method used and the full census the quality of the register would be lower. The samples for surveys in the years 2014-2020 would need to be larger. We have calculated those extra hours to 9 500 hours. This includes larger samples for the sample surveys of crops, rented land, fertilisers and the census 2020.Over the 10 year period the difference between register-based statistics and the current method regarding response-burden is low.

The total cost for the current method used in 2013 was 750 000 euro. The cost for a full census through postal questionnaires could be estimated to 1 100 000euro and for producing the statistics solely from registers to 450 000 euro. However there would be an additional cost for the larger samples in the years 2014-2020. Producing statistics from administrative registers is cost-effective in relation to postal questionnaires. From a cost-effectiveness point of view it can be seen that a large proportion of the cost is due to handling paper questionnaires. In 2013 only 20per cent answered using the web service. I.e. the most obvious way of saving money would be to persuade farmers to answer through the web.

3.2. Quality criteria

Relevance refers to the degree to which statistics meetcurrent and potential needs of the users. The updated FR is harmonised with the target population and some of the variables in FSS. I.e. the needs from EU-legislations are met. The FR also can be used to disseminate statistics for small regions or groups as well as combining data in new ways without restrictions. It could be assumed that a full census would meet the same quality criteria. If the FR were updated only by registers itwould still fulfil the needs from EU-legislation regarding FSS. However since animals would be sampled it could only be used for producing statistics on NUTS3 sometimes NUTS2 level.

Accuracy refers to the closeness of estimates to theunknown true values.For register-based surveys, key issues are integration errors as well as how well the definition of objects and variables in the registers correspond with the required definitions in the statistics. The problems of matching different sources should not be underestimated. There is a risk for over-coverage in the FR. Parts of the same holding or the same areas could be counted several times. It is possible that a landowner, who is no longer cultivating his land and who belongs to the 8 685 holdings that could not be found in the register, answers the questionnaire on the basis of the land that he owns without cultivation. At the same time, the tenant of the same land who has applied for subsidies also states that he uses the land. Using only a census would lead to an under-coverage of the FR since the holdings not applying for subsides might be lost and new holdings more difficult to find. Using only registers for creating objects might also lead to an under-coverage since holdings not in the subsidy systems would be excluded.

For *timeliness* i.e. the period between the availability ofthe information and the event or phenomenon it describes there are no differences between approaches.Wallgren & Wallgren (2014) stress that timeliness is often a problem when using administrative registers. However in the case of IACS and the cattle-database this is not a problem. IACS data are available in May the reference year and the cattle-database is updated constantly.

Punctuality which means if release dates are kept,*accessibility and clarity* that has to do with the user's possibilities to access and compare data and *coherence* i.e. if the information is put together and presented in a logical way present no differences between alternatives.

Concerning *comparability*, or the possibility to compare results over time, problems might occur. Statistics based on administrative registers are dependent on changes that the statistical bodies may not be able to predict. For example, the change in the CAP in 2005 meant that the holders applying for subsidies in 2005 would be eligible for subsidies in subsequent years. The changes in the CAP affected the statistics in several ways, for example the number of holdings increased. Two explanations to this increase could be found. Firstly it was thought that small farms that had not been eligible for subsidies now applied for subsidies and were consequently incorporated into the population of holdings. The change in administrative rules thus improved the quality of the FR, correcting a previous under-coverage. Secondly, it could be assumed that some landowners applied for subsidies although the land in practice was cultivated by a neighbouringholder, leading therefore to over-coverage in comparison with the definitions in the FR.This problem would be the same for the register based approach but would not occur for the alternative based on full census.

The quality in terms of comparing results from registers and surveys are high because of the wide-ranging work done to merge different registers. In this sense the quality would be lower in the two other alternatives.

1. Conclusion

To conclude the use of registers is cost-effective and reduces the response burden for the holdings. Regarding the quality criteria of relevance, there are advantages to integrating registers with surveys and censuses when collecting data for the FSS. On one hand, in solely register-based surveys, the register may not cover the requested variables. On the other hand, in solely statistical surveys, the questionnaire would be expensive and cause a high response burden.Regarding the dimension of timeliness, the registers used for the FSS are updated and available earlier than results from a survey or census would be. When comparing the accuracy of the results, there are several aspects to consider.However, integrating registers and surveys as well as only using a statistical survey is considered to give accurate results. The coherence and comparability is assumed to be the highest when registers and surveys are integrated because of the wide-ranging work done to merge different registers. The availability is good in all three alternatives.

The paper shows that different aspects of accuracy are the key issues to consider in order to improve the quality when integrating registers and surveys in the FSS.

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Master sampling frames for agricultural, rural and agro-environmental statistics, methodological and practical issues

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ABSTRACT

Methodological and practical problems have to be faced when building a master sampling frame for agricultural, rural and agri-environmental statistics. This paper addresses some of them, focusing on quality and coverage issues and on the impact of increasing computational ability to handle massive data sets on the generation and updating of master sampling frames. Advantages, disadvantages and requirements of the combination of different kinds of frames and the main methods for linking frames at the design stage and at the estimation stage are analysed. A proposal for increasing the efficiency of the allocation of the sample units to the different combined frames is also discussed.

Keywords: Master sampling frame, Multiple frames, Single and two-stage estimators

1. Introduction

In this paper, we present an analysis of methodological and practical problems to be faced when building a master sampling frame for agricultural, rural and agri-environmental statistics. We start from the traditional approach for generating a master sampling frame for agricultural statistics and analyse the effect of incomplete or out of date sampling frames. In section 3, the impact of increasing computational ability to handle massive data sets on the generation and updating of master sampling frames is discussed. Then, other kinds of master sampling frames are taken into consideration (section 4). Section 5, presents a review of the main methods for linking frames at the design stage and at the estimation stage, focusing both on single-stage and two-stage estimators. In section 6, we talk about the use of area sampling frames for collecting crop and agri-environmental data, the advantages, disadvantages and requirements when list frames are combined with area frames, with single-stage, as well as with two-stage estimators, and the difficulties in the identification of the farms selected through the area frame, according to the kind of area frame and adopted technological tools. Section 7 focuses on a method for improving the efficiency of the allocation of the sample units to the different combined frames. Finally, some conclusions are drawn.

2. The traditional approach for generating a master sampling frame

A master sampling frame is a sampling frame that provides the basis for all data collections through sample surveys and censuses in a certain sector, allowing to select samples for several different surveys or different rounds of the same survey, as opposed to building an ad-hoc sampling frame for each survey. The aims of the development of a master sampling frame are: avoiding duplication of efforts, reducing statistics discrepancies, connecting various aspects of the sector, allowing the analysis of the sampling units from the different viewpoints, and having a better understanding of the sector. The traditional approach for producing agricultural statistics adopted in most developed countries is the following (see Benedetti et al. eds. 2010): a complete enumeration census is carried out every 5-10 years. Data are collected through mail, email, personal interviews, computer assisted personal interviews, computer assisted telephone interviews, or the web. The census allows generating the list frame that is updated on the basis of administrative data, in the period between two successive censuses and is used for all kinds of sample surveys of farms; thus, it could be considered as a master sampling frame for agricultural statistics. An assessment of the quality of the data collected allows deciding if and how to use this list as a master sampling frame. For example, at the end of the data collection of the Italian agricultural census, a sample survey for assessing the quality of collected data was designed (Mazziotta, 2013). A stratified random sample of about 50,000 farms was selected and the farmers were interviewed through computer assisted telephone interviews in the period from 20 May 2011 to January 2013. This assessment showed that the complete enumeration census systematically underestimates the main structural variables that are generally used for stratification, when annual sample surveys are designed. In addition, the level of the bias varies in the different regions of the country, reducing the efficiency of the stratification.

3. Impact of increasing computational ability on the generation and updating of master sampling frames

The unbiasedness of this kind of list frame depends on the level of under-coverage and over-coverage of the list at the census date and on the quality of data and the process used for updating the list after the census date. This updating process has become easier, due to great improvements in data base management, including geographic databases (GIS). Moreover, methodological developments for deterministic as well as for probabilistic record linkage have considerably increased the capacity to identify the same record in different lists. For the Italian agricultural census, a very accurate assessment of the coverage was carried out (Mazziotta, 2013) on the basis of an area sample. Around 1,500 sheets of cadastral maps (areal units in which each municipality is subdivided – secondary sampling units) were selected from a sample of municipalities (primary sampling units). The owners of the parcels in the selected sheets of cadastral maps were identified, on the basis of the cadastral archive, and interviewed. 21,588 farmers were interviewed (1.620.884 active farms and 34.070 temporary inactive farms were identified by the agricultural census). The estimates were computed in the framework of the indirect sampling (Lavallée, 2007), and the weights (Lavallée and Rivest, 2012) were assigned based on the selection probability of each sheet of cadastral map and the number of sheets in which a farm has parcels (derived from the interview). A sophisticated record linkage procedure was implemented in three successive steps: deterministic, probabilistic and manual, involving various kinds of administrative registers. 81.4 % of farms in the area frame were included in the census list; 5.2 % of farms in the area frame were present in the census list with different characteristics, 1.7 % of the farms in the area frame had multiple links with census list, and 11.7 % of the farms in the area frame had no link with the census list. Of course, the percentage of farms in the area and in the census list decreased for small farms: 71% and 78.2 % for farms with utilized agricultural area in the range (0.01 - 0.99 hectares) and in the range (1 -1.99 hectares) respectively. This level of coverage is in line with most developed countries. These results of the quality assessment of the census data stimulates a reflection, if the main aims of the agricultural census are creating the list of all farms (including small ones) to be used as master sampling frame, with accurate structural information for stratification and producing estimates for very small administrative domains, at least once every 5-10 years.

Various kinds of administrative registers are generally used for updating the census list. The quality of the result depends on the administrative data that can be used and on the consistency of the identifiers of the units in the different registers. The over and under coverage can be high even if good administrative data, very sophisticated record linkage procedures and geo-location of administrative information are used, as showed by the following experiment. Several kinds of administrative data were taken into consideration for updating the Italian census list in 2008 (8 years after the census). Main registers used were the lists related to farms that apply for subsidies, livestock farms, agrarian income, cadastre, taxes, social security and specific lists created by regional authorities. A sample of 15,682 units was selected out of a subset of 80 municipalities. Enumerators used a web-based data collection system developed on purpose, in order to ensure accurate data collection. The result was that only 39.15% of the farms included in the integrated list were considered existing and active by the test. 44.74% of the farms in the integrated list were not active and 16.11% of them were not identified through the test (Berntsen and Viviano, 2011). This level of over-coverage implies that, if such a list is used for a sample survey, the enumerators waste much time trying to identify farmers, which then prove to be inactive. Moreover, distinguishing inactive farmers from total non-responses is difficult. Finally, the risk of producing biased estimates is high, unless an accurate estimate of the over-coverage is available. These considerations suggest adopting this approach only where the reliability of administrative data used for updating the census list is very high and the definitions adopted by administrative registers are compatible with the ones of the census.

4. Other kinds of master sampling frame

Other approaches have been developed for creating master sampling frames. In several countries, the population census is conducted using an administrative structure in which cartographic or other mapping materials are used to divide the country into enumeration areas. The sampling frame is the list of enumeration areas. In agricultural sample censuses and surveys, a sample of enumeration areas is selected, the list of households in selected enumeration areas is created and a sample is extracted from each of these lists, following a two stages sample design. In many countries, a sample agricultural census is conducted: some enumeration areas are randomly selected and screened for farms. The resulting sampling frame consists of the agricultural census enumeration areas. These approaches present coverage problems at least of the entity of the complete enumeration agricultural census described before. A proposal by FAO and UNFPA aims at avoiding to face the cost of the agricultural census: the list of farms or agricultural households is identified on the basis of specific agricultural questions included in the population census questionnaire. This approach is promising for countries where agriculture is not an important economic sector, like small islands. More work is needed for testing the quality of data collected using long questionnaires and the coverage of the list of farms generated from the population census; particularly, the entity of under and over coverage in different categories of countries should be assessed. Finally, the list frame of farms generated through the module on agriculture submitted to the households presents very few auxiliary variables; thus, the efficiency of the sample designs for annual sample surveys is very low, and this may have a strong impact on annual survey costs. For more details and an analysis of advantages, disadvantages and requirements see Keita and Gennari (2013) and Carfagna *et at.* (2013). In some countries, the list of the farms is based on administrative sources, such as business registrations or tax collections. A big disadvantage of the administrative sources is that they may not include the total population, especially units below a threshold required to be registered or pay taxes. In other words, while they will be inclusive of commercial farms, are not likely to include small-scale farms and subsistence farming units (see Carfagna and Carfagna, 2010).

5. Linking frames at the design stage and at the estimation stage

When the coverage and the accuracy of the structural characteristics are not high, alternative approaches can be followed: creating a sampling frame integrating different lists (design level), combining estimates from different lists (estimator level), using an area frame, combining an area frame with one or more list frames. The first option foresees that different lists concerning the same population are used for creating the sampling frame. In such a case, one single frame is created on the basis of two or more lists. In order to get one list combining more than one, records have to be matched. This is not an easy task because farms can appear with different pieces of information in the different lists, and sometimes only partial or wrong information is available. A wide literature has been developed on record linkage, focusing on deterministic and probabilistic rules for matching; moreover, the capacity of storing and managing databases is increased impressively. However, the coverage of the sampling frame is strongly influenced by the quality of the combined lists. Lists with limited coverage or out of date information can create difficulties in the record linkage process, increase the over-coverage and give little contribution to reduce the under-coverage of the sampling frame. Unless the different lists contribute with essential information to complete the frame and the record matching gives extremely reliable results, the frame will be still incomplete and with many duplications (see Carfagna and Ferraz, 2015).

Another option is treating the different lists separately and selecting samples from each list. All observations can be treated as though they had been sampled from a single frame, with modified weights for observations in the intersection of the lists (single-stage estimation). The basic idea is that a multiple frame sample can be viewed as a special case of selecting two or more samples independently from the same frame. As stated by Kalton and Anderson (1986), when a sample is drawn from two or more overlapping frames, the chance of an element being selected depends on the number of frames on which it appears. Compensation for the varying inclusion probabilities of different population elements may be made, by means of a weighting adjustment in the analysis, such as assigning sample element weights made inversely proportional to their inclusion probabilities. Kalton and Anderson (1986) and Skinner (1991) proposed an unbiased estimator that does not require determining the common units of samples from the different frames. Mecatti (2007) and Mecatti and Singh (2014) also gave a contribution to the development of single-stage estimators proposing their multiplicity estimator. Like the other single-stage estimators developed previously, the Mecatti and Singh estimator has two crucial requirements: the multiplicity of each sample unit is known and the union of the collection of frames covers the target population. Mecatti and Singh (2014) assume that the information on the multiplicity can be given by the interviewed sample units. For agricultural statistics, this assumption implies that each of the selected farmers knows which frames include his farm. The assumption that the union of the collection of frames covers the target population is seldom realistic, even in developed countries. Indeed, if the aim is providing a rough estimate of main agricultural items, the bias introduced by a limited under-coverage tends to be not particularly high, since generally it concerns mainly small farms, whose contribution to the total of main items is limited. However, the bias can be higher and difficult to remove for minor and special agricultural items. Moreover, small farms are important if we want to have an overview of the trends in rural areas. Another way of taking advantage of various frames at the estimator level is adopting an estimator that combines estimates calculated on non-overlapping sample units belonging to the different frames with estimates calculated on overlapping sample units (two-stage estimation). Two-stage estimators do not require the knowledge of the multiplicity for selected units, but assume that the union of the collection of frames covers the target population. Some two-stage estimators need the identification of identical units only in the overlap samples and some others have been developed for cases in which these units cannot be identified (see Fuller and Burmeister 1972). Both single-stage and two-stage estimators do not require record matching of listing units of the different frames (a process that is notoriously error prone when large lists are used). Generally, complex designs are adopted in the different frames to improve the efficiency and this affects the estimators. Lohr and Rao (2006) proposed optimal estimators and pseudo maximum likelihood estimators when two or more frames are used. Ferraz and Coelho (2007) investigated the estimation of population totals incorporating available auxiliary information from one of the frames at the estimation stage, for the case of a stratified dual frame survey; for a review of multiple frame estimators see Carfagna (2001) and Carfagna and Carfagna (2010).

6. Combining lists and area frames, advantages, disadvantages and requirements

Combining a list and an area frame is a special case of multiple frame sample surveys in which sample units belonging to the lists and not to the area frame do not exist. This approach is very convenient when the list contains units with large (thus probably more variable) values of some variables of interest and the survey cost of units in the list is much lower than in the area frame.

Ground data collection through an area frames is the most reliable way for collecting crop data and some agri-environmental data linked to the land, like the ones included in the field data collection form 2015 of the European land use and cover area frame survey (LUCAS). These data allow computing the following indicators: land cover/land use/change, parcel size, cropping system/land management, irrigation, landscape elements, associated trees and shrubs, soil erosion/soil quality. Ground positioning systems (GPS), aerial images, aerial photos (also photo-interpreted and stored on a PDA, Google Earth, Geographic information Systems (GIS) have considerably modified the data collection process and increased the quality of data.

If economic and rural characteristics and/or agri-environmental indicators related to the farm management are relevant for a country, the ground observation through an area frame is not sufficient and the farmers have to be selected and interviewed. Moreover, when the area frame is combined with one or more list frames, the presence on the lists of the farms selected through the area frame has to be assessed for most estimators.

The main typologies of area frames are segments, with or without physical boundaries, and clustered and un-clustered points. When segments are adopted, the fields totally or partially included in the segments can be used for identifying the corresponding farms; then, from the estimation viewpoint, the traditional open, closed and weighted estimators can be taken into consideration. The number of farms indirectly selected through a segment depends on the number of parts of farms included in the segment; thus, it changes from segment to segment and only an expected number of farms can be prefixed by selecting the segment size. If clustered or un-clustered points are selected, the field corresponding to the point identifies the farm.

The challenging part is collecting the data of the farm corresponding to the field. This task is difficult when the farmers live in villages far from the land. When un-clustered point sampling is adopted, the identification of the farmer is more cumbersome because the next farmer to be identified is far away. Close farmers are easier to identify, since one of them can give some information on the others. Sometimes, point sampling of farms in a segment is carried out, in order to select only a subset of the farms totally or partially included in the segment. This approach is appropriate where the optimum segment size for collecting area and yield information in the fields is larger than the optimum segment size for farmers' interviews. This happens where the farm size is small. Point sampling in the segments also allows prefixing the number of farms selected in each segment, in case point sampling with replacement is adopted (the same farm can be selected by more than one point). This is a big advantage for the sample allocation to the frames.

7. Sample allocation

Under a linear cost function, the optimum share of the total sample to be allocated to each frame can be determined, in order to optimize the precision of the total estimate. However, the optimum sample allocation depends on the variances of domains, which are generally unknown before the survey. An adaptive sequential approach could be adopted for determining the allocation during the survey. Consider that adaptive sequential sample designs are very efficient because the sample selection depends on previously selected units and the stopping rule is based on the estimate. Unfortunately, sequential sample designs are biased, for the same reasons. Thompson and Seber (1996, pages 189-191) faced the problem of sample allocation without previous information on the variability inside strata suggesting a stratified random survey in two phases or, more generally, in k phases. In our case, the strata represent the strata in the different sampling frames. At the k-th phase, a complete stratified random sample is selected, with sample sizes depending on data from previous phases. Then the conventional stratified estimator, based on the data from the k-th phase, is unbiased for the population total Y. The key to design unbiasedness of such an estimator is that each of the estimators is design unbiased and that the weights are fixed in advance and do not depend on observations made during the survey, which implies that, at whatever k-th phase, each of the strata needs to be sampled. These elements guarantee unbiased but not very efficient estimates. Carfagna and Marzialetti (2009), proposed the adoption of an adaptive sequential sample selection with permanent random numbers, which allows optimizing the sample allocation to the different strata and the use of optimum weights for estimating the population total. This procedure foresees that one sample unit is selected at each step, the standard deviations of the domains are computed and the next sample unit is assigned to the stratum where the sample size is farthest below the size assigned by Neyman's allocation. In the case of the sample allocation to two or more sampling frames, a less cumbersome k-step procedure with permanent random numbers, where k is equal to a small (2 or 3) number of steps is more appropriate. A permanent random number is assigned to all sampling unit in each domain (each stratum of each sampling frame). Then, a first random sample of sampling units is selected. The main aim of this first sample is generating a first estimate of the standard deviations in the domains, which are used for determining the optimum allocation of the second step sample and the optimum weights for combining the estimates from the various lists, then the process can be repeated.

8. Concluding remarks

The quality of the data collected by a complete enumeration census of agriculture should be checked before using the list of farms generated by the census as a master sampling frame, since the under-coverage is about 20% in developed countries. The impressive progress in managing big amount of data and the use of georeferenced data have considerably improved the quality of the updated list; however, this kind of update does not eliminate the under-coverage and can increase the over-coverage, creating several data collection problems. Creating a muster sampling frame integrating different kinds of lists, taking advantage of the improvements in record linkage can be an alternative. However, unless the different lists contribute with essential information to complete the frame and the record matching gives extremely reliable results, the frame will be still incomplete and with many duplications. Another option is treating the different lists separately and selecting samples from each list, using a single-stage or a two-stage estimator. The single-stage estimators have crucial requirements which are seldom satisfied, whiles two-stage estimators facilitate the use of different and complex sample designs in the different lists, increasing the efficiency of the estimators. Ground data collection through an area frame is the most reliable way for collecting crop data and some agri-environmental data linked to the land; however, if all economic characteristics and/or agri-environmental indicators related to the farm management have to be estimated, the ground observation through an area frame is not sufficient and the farmers have to be selected and interviewed. When un-clustered point sampling is adopted, the identification of the farmer is cumbersome because the next farmer to be identified is far away. The optimum sample allocation to different strata of the sampling frames depends on their variances, which are generally unknown before the survey. An adaptive sequential approach for determining the allocation during the survey increases the efficiency of the estimates.

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Master frames for integrated and linked surveys

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ABSTRACT

To improve agricultural and rural official statistics, FAO designs and carries out action plans. The World Plans with specific focus have a long history: they began in 1930 and the last focuses on integrating agricultural censuses and agricultural surveys within the National Statistical System (NSS). The most recent Global Strategy [FAO (2011, 2012)] focuses on developing master sampling frames that are integrated with the NSS and allow the linkage of the farm as an economic unit to the household as a social unit and both to the land as an environmental unit [FAO (2015)]. Two keywords in this last plan are 'integration' and 'linkage'. 'Integration' refers to the use of the same sampling frame and related materials in multiple surveys, as well as the same concepts, survey personnel, and facilities. 'Linkage' is the basis for analysing the relationships among the economic, the social and the environmental dimensions of sustainable development.

FAO (1996, 1998, 2015) and the United Nations Statistical Division (UNSD,1986, 2008) have elaborated guidelines to assist countries in planning and implementing agricultural and household surveys, respectively. The central topic of these guidelines is the development and maintenance of master sampling frames. In this paper we focus on the integration of a dual sampling frame for agriculture with a sampling frame for households to build a multiple sampling frame that allows the required linkage among reporting units. We apply this strategy in three Latin America countries. We consider multiple frame regression estimators, highlighting its usefulness to integrate register and survey data and for combining data from independent surveys.

Keywords: Multiple overlapping frames, regression estimators, integrating register and survey data, combining data from independent surveys.

1. Introduction

There is consensus in the scientific community about the multidimensional (economical, social, and environmental) nature of sustainable development, and the Global Strategy to improve agricultural and rural official statistics [FAO (2011, 2012)] lays great stress on using a sampling frame that allows for the linkage of the farm as an economic unit, to the household as a social unit, and both to the land as an environmental unit. Multiple sampling frames meet this requirement and are cost-efficient.

Sampling strategies based on multiple overlapping frames have deserved a notable attention in last years, as a tool to deal with nonsampling errors: undercoverage, nonresponse, and measurement errors [Lohr (2011)]. In this paper we follow this sampling strategy for integrating agricultural and household surveys. Focus is on the linkage among farms, households and parcels. We structure the paper as follow. In section 2 we present the sampling strategy and its application in three Latin America countries. In section 3 we consider the multiple overlapping frame estimators proposed in the literature. In section 4 we consider multiple frame regression estimators, highlighting its usefulness to integrate survey and register data. Section 5 is about concluding remarks.

2. Integration of agricultural and household sampling frames

The sampling frames recommended by FAO and UNSD guidelines are dual frames, with an area component and a list component. The area frame ensures completeness, accuracy and up-to-datedness of the master frame: it is well established in the literature [Fecso et al. (1986), Faulkenberry and Garoui (1991), Vogel (1995), Ambrosio and Iglesias (2014)]. In agricultural surveys, the list contains the largest farms and contributes to improve the area sample accuracy. Census enumeration areas are used in household surveys as Primary Sampling Units (PSUs) and a list is elaborated within selected PSUs and is used to select the household sample.

We integrate the agricultural sampling frame and the household sampling frame in a unique multiple sampling frame. This multiple frame provides farms to observe economic variables: acreage and crop yields, livestock production, aquaculture and forestry. It provides also households to observe social variables: household composition, living conditions, employment, income, food and hunger, poverty, or inequality. And it provides parcels to observe environmental variables: soil degradation, water consumption for irrigation, or the quantity used of chemical fertilizers, herbicides, pesticides and fungicides.

Sampling a population with multiple overlapping frames

We use P to refer either the farms population, $F=\{f \mid f=1,2,\cdots,F\}$, the parcels population, $L=\{l \mid l=1,2,\cdots,L\}$, or the households population, $H=\{h \mid h=1,2,\cdots,H\}$. We assume that each population unit, $jj \in \mathrm{P}$ $(jj \equiv f,h,l)$, is associated to at least one sampling unit in the multiple frame

$\mathrm{I} = \{i = 1, 2, \cdots, A^q; q = 1, 2, \cdots, Q\}$, where A^q denotes both, the generic single frame q and the number of sampling units, and Q is the number of single frames. We define the indicator variable $I_{ij}^q = 1$ if the population unit $jj \in \mathrm{P}$ is associated to the sampling unit $i \in A^q$, and $I_{ij}^q = 0$ otherwise $(jj \equiv f, h, l)$.

The sample

We select a set of samples $\{\mathsf{S}^q; q = 1, 2, \cdots, Q\}$ independently from each frame A^q, using a sampling scheme that associates to sampling unit $i = 1, 2, \cdots, A^q$ an inclusion probability π_i^q. From the standard dual frame for agricultural surveys, where A^1 is an area frame with $i = 1, 2, \cdots, A^1$ segments and A^2 is a list frame with $i = 1, 2, \cdots, A^2$ names of farms, we select independently a sample S^1 of segments and a sample S^2 of names. From the standard frame for household surveys, A^3, we select a sample S^3 of names, independent of S^1 and S^2.

As a result, we have: (i) a sample of parcels, $\mathrm{S}_L^1 = \{l \in L | i \in \mathrm{S}^1 \wedge I_{il}^1 = 1\}$, where $I_{il}^1 = 1$ when the area, a_{il}, of parcel l within the segment $i \in \mathrm{S}^1$ is $a_{il} > 0$, (ii) and a set of two partially overlapping samples of farms, $\{\mathrm{S}_F^q; q = 1, 2\}$, where $\mathrm{S}_F^q = \{f \in F | i \in \mathrm{S}^q \wedge I_{if}^q = 1\}$, where $I_{if}^1 = 1$ when the area, a_{if}, of the farm f within the segment $i \in \mathrm{S}^1$ is $a_{fi} > 0$, and $I_{if}^2 = 1$ when the name $i \in \mathrm{S}^2$ is associated to the farm f, (iii) and a sample of households $S_H^3 = \{h \in H | i \in \mathrm{S}^3 \wedge I_{ih}^3 = 1\}$, where $I_{ih}^3 = 1$ when the name $i \in \mathrm{S}^3$ is associated to the household h.

Country examples

We study the case of three Latin American countries: Guatemala, Costa Rica and Ecuador. In these countries, there is a dual sampling frame for agricultural surveys. The kind of limits used to define sampling units differs among countries: limits are geometrics in Guatemala and Ecuador, while identifiable physical boundaries are used in Costa Rica. The area frame, A^1, has 190100 segments in Guatemala [Ambrosio (2013), FAO (2015)], 352254 segments in Ecuador (Ambrosio, 2014) and 120326 segments in Costa Rica (Ambrosio, 2015).

The area frame is stratified into four strata, using the percentage of cultivated surface as stratification variable. The data source for stratification is a land use map in Guatemala and Ecuador and a geo-referenced agricultural census in Costa Rica. A target segment size is defined that varies among strata: in Guatemala it ranges from 6.25 hectares (cultivated surface bigger than 60% and small fields) to 100 hectares (cultivated surface lower than 20%), in Ecuador the range is from 9 to 576 hectares, and in Costa Rica the range is from 10 to 100 hectares. In Guatemala and Costa Rica S^1 has 1500 segments, and in Ecuador 5520 segments. The sample is allocated to strata according to Neyman's criterion, and five replicated samples are selected in each stratum.

The list frame, A^2, differs among countries according to available resources. In Costa Rica, there is a recent agricultural census and a list frame for each one of the main crops and animal' species is available (the bovine list frame has 31171 farms, and the porcine list frame has 14355 farms). In

Guatemala and Ecuador, the agricultural censuses are obsoletes and the number of list frames is reduced to the biggest farms in Ecuador and to the main animals' species in Guatemala.

An area sampling frame of enumeration areas (EA) with mapped, well-delineated boundaries is available for household surveys. In Guatemala the frame has 15511 EA with an average of 140 households by EA. The EA are stratified using available population figures, and a two-stage

sampling scheme is used to select the household sample, S^3. In the first stage, a sample of EA is selected with probabilities proportional to size (in Ecuador the sample size is 2586 EA for labour surveys, 1128 EA for surveys on living standard and 3411 EA for income surveys). In the second-stage, a list of household is updated within each EA in the first-stage sample and a sample of households (12 by EA) is selected with equal probabilities.

3. Multiple frame estimators

Typically, a population unit (e.g. a farm) is covered by two or more single frames (e.g., area and list frames) and, as a result, the weight estimator, $\hat{Y}_{\mathrm{P}} = \sum_{q=1}^{Q}\sum_{i=1}^{S^q} w_i^q y_i$, where $w_i^q = \frac{1}{\pi_i^q}$, is a biased estimator of the population total, Y_{P}. To see this, consider the population partitioned into $D = 2^Q - 1$ non-overlapping domains and $Y_{\mathrm{P}} = \sum_{d=1}^{D} Y_d$, where Y_d is the domain total, $d = 1, 2, \cdots, D$.

For dual frames, $Q = 2$, $\hat{Y}_{\mathrm{P}} = \sum_{q=1}^{2}\sum_{i=1}^{S^q} w_i^q y_i = \sum_{i=1}^{S^1} w_i^1 y_i + \sum_{i=1}^{S^2} w_i^2 y_i$, and $D = 2^2 - 1 = 3$. Domain $d = 1$ is the set of units covered only by A^1, domain $d = 2$ is covered only by A^2 and domain $d = 3$ is covered by both, A^1 and A^2. The population total is $Y_{\mathrm{P}} = \sum_{d=1}^{3} Y_d = Y_1 + Y_2 + Y_3$. Now, $\sum_{i=1}^{S^1} w_i^1 y_i$ is a unbiased estimator of A^1 total, which is domain $d = 1$ total plus $d = 3$ total, $Y_1 + Y_3$, and $\sum_{i=1}^{S^2} w_i^2 y_i$ is a unbiased estimator of A^2 total, which is $d = 2$ total plus domain $d = 3$ total, $Y_2 + Y_3$. Thus,

$E\hat{Y}_{\mathrm{P}} = E\sum_{i=1}^{S^1} w_i^1 y_i + E\sum_{i=1}^{S^2} w_i^2 y_i = Y_1 + Y_2 + 2Y_3$ and the bias of $\hat{Y}_{\mathrm{P}}$ is $B\hat{Y}_{\mathrm{P}} = E\hat{Y}_{\mathrm{P}} - Y_{\mathrm{P}} = Y_3$.

A screening approach is followed in FAO (1996, 1998), where the single frames are pre-screened to remove overlap, so that domains with two o more frames are empty and, as a result, the weight estimator is unbiased: for dual frames, $d = 3$ is empty, $Y_3 = 0$, and hence $B\hat{Y} = 0$. However, screening operations are resource-consuming and a number of more cost-efficient alternatives can be found in the literature (Lohr, 2011). Cost-efficiency was the motivation of Hartley (1962, 1974) to propose first multiple frame estimators. Skinner and Rao (1996) and Lohr and Rao (2000, 2006) proposed pseudo-maximum likelihood multiple frame estimators. Bankier (1986) and Kalton and Anderson (1986) proposed standard single-frame estimators for multiple frame survey.

Adjusted-weight estimators

Most of these alternatives look for an adjustment, m_i^q, of the sampling weight w_i^q in such a way that using $\tilde{w}_i^q = m_i^q w_i^q$ instead of w_i^q, the adjusted-weight estimator $\hat{Y}_{\mathrm{P}} = \sum_{q=1}^{Q} \sum_{i=1}^{S^q} \tilde{w}_i^q y_i$ is unbiased. This can be achieved using for each frame and domain a fixed set of adjustment such as $\forall i \in d$, $m_i^q = m^{(q,d)}$, with the restrictions $m^{(q,d)} > 0$ (if domain d is not part of A^q, then $m^{(q,d)} = 0$) and $\sum_{q=1}^{Q} m^{(q,d)} = 1$ for $d = 1, 2, \cdots, D$. The adjusted-weight estimator $\hat{Y}_{\mathrm{P}} = \sum_{d=1}^{D} \hat{Y}_d$, where $\hat{Y}_d = \sum_{q=1}^{Q} \sum_{i=1}^{S^q} \tilde{w}_i^q \delta_i(d) y_i = \sum_{q=1}^{Q} m^{(q,d)} \sum_{i=1}^{S^q} w_i^q \delta_i(d) y_i$ and $\delta_i(d) = 1$ if $i \in d$ and $\delta_i(d) = 0$ otherwise, is unbiased .

For dual frames, a fixed weight adjustment is: if $i \in (d = 1)$ then $m_i^1 = m^{(1,1)} = 1$ and $m_i^2 = m^{(2,1)} = 0$, if $i \in (d = 2)$ then $m_i^1 = m^{(1,2)} = 0$ and $m_i^2 = m^{(2,2)} = 1$ and if $i \in (d = 3)$ then $m_i^1 + m_i^2 = m^{(1,3)} + m^{(2,3)} = 1$. The adjusted-weight estimator is $\hat{Y}_{\mathrm{P}} = \sum_{d=1}^{3} \hat{Y}_d$, where $\hat{Y}_1 = \sum_{q=1}^{2} \sum_{i=1}^{S^q} \tilde{w}_i^q \delta_i(1) y_i = \sum_{q=1}^{2} m^{(q,1)} \sum_{i=1}^{S^q} w_i^q \delta_i(1) y_i = m^{(1,1)} \sum_{i=1}^{S^1} w_i^1 \delta_i(1) y_i + m^{(2,1)} \sum_{i=1}^{S^2} w_i^2 \delta_i(1) y_i = \sum_{i=1}^{S^1} w_i^1 \delta_i(1) y_i$, $\hat{Y}_2 = \sum_{i=1}^{S^2} w_i^2 \delta_i(2) y_i$ and $\hat{Y}_3 = m^{(1,3)} \hat{Y}_3^1 + m^{(2,3)} \hat{Y}_3^2$, where $\hat{Y}_3^1 = \sum_{i=1}^{S^1} w_i^1 \delta_i(3) y_i$ and $\hat{Y}_3^2 = \sum_{i=1}^{S^2} w_i^2 \delta_i(3) y_i$. Often, it is taken $m^{(1,3)} = m^{(2,3)} = \frac{1}{2}$ and, as a result, $\hat{Y}_3 = \frac{1}{2} \hat{Y}_3^1 + \frac{1}{2} \hat{Y}_3^2$.

Optimal estimators

Hartley (1962) proposes this other fixed set of adjustments: if $i \in (d = 1)$ then $m_i^1 = m^{(1,1)} = 1$ and $m_i^2 = m^{(2,1)} = 0$, if $i \in (d = 2)$ then $m_i^1 = m^{(1,2)} = 0$ and $m_i^2 = m^{(2,2)} = 1$ and if $i \in (d = 3)$ then $m_{i,\theta}^1 = m_\theta^{(1,3)} = \theta$ and $m_{i,\theta}^2 = m_\theta^{(2,3)} = 1 - \theta$, where $0 \le \theta \le 1$. The adjusted-weight estimator is $\hat{Y} = \sum_{d=1}^{3} \hat{Y}_d$, where $\hat{Y}_1 = \sum_{i=1}^{S^1} w_i^1 \delta_i(1) y_i$, $\hat{Y}_2 = \sum_{i=1}^{S^2} w_i^2 \delta_i(2) y_i$ and $\hat{Y}_3 = \theta \hat{Y}_3^1 + (1-\theta) \hat{Y}_3^2$, so that $\hat{Y}_{\mathrm{P}} = \hat{Y}_1 + \hat{Y}_2 + \theta \hat{Y}_3^1 + (1-\theta) \hat{Y}_3^2$. The value $\theta = \frac{1}{2}$ is often used and the estimator is internally consistent. However, the optimal value is $\theta_H = \dfrac{V\hat{Y}_3^2 + Cov\left(\hat{Y}_3^2, \hat{Y}_2\right) - Cov\left(\hat{Y}_3^1, \hat{Y}_1\right)}{V\hat{Y}_3^1 + V\hat{Y}_3^2}$ and changes with the survey variable, so that it is internally inconsistent. In practice, internal consistency requires that one set of weights be used to estimate all survey variables: Pseudo-maximum likelihood estimators are internally consistent (Lohr, 2011).

Single frame estimator

Kalton and Anderson (1986) propose an adjustment weight, which treats all observations as though they had been sampled from one frame: if $i \in (d=1)$, then $m_{i,S}^1 = 1$, if $i \in (d=2)$ then $m_{i,S}^2 = 1$ and if $i \in (d=3)$ then $m_{i,s}^1 = \frac{w_i^2}{w_i^1 + w_i^2}$ and $m_{i,s}^2 = \frac{w_i^1}{w_i^1 + w_i^2}$. If $i \in (d=3)$ then $\tilde{w}_i^1 = \tilde{w}_i^2 = \frac{1}{\pi_i^1 + \pi_i^2}$. This estimator is internally consistent.

Multiplicity-adjusted estimators.

Singh and Mecatti (2011) and Mecatti and Singh (2014) propose to adjust for multiplicity the survey variable value, instead of the sampling weight. The multiplicity of a population unit, $j \in \mathrm{P}$ ($j = f,h,l$ and $\mathrm{P} = F,H,L$), is the number of sampling units, $m_j = \sum_{q=1}^{Q} m_j^q$, to which it is associated, $jj \in \mathrm{P}$ where $m_j^q = \sum_{i=1}^{A^q} I_{ij}^q$ is the multiplicity within A^q, where $I_{ij}^q = 1$ if the population unit is associated to the sampling unit $i \in A^q$, and $I_{ij}^q = 0$ otherwise. The population total is $Y_{\mathrm{P}} = \sum_{q=1}^{Q} \sum_{i=1}^{A^q} \tilde{y}_i^q$, where $\tilde{y}_i^q = \sum_{j=1}^{\mathrm{P}} \alpha_{ij}^q y_j$ is the multiplicity-adjusted value of the survey variable in the i^{th} sampling unit, where $\alpha_{ij}^q = \frac{I_{ij}^q}{m_j}$.

The weight multiplicity-adjusted estimator, $\hat{Y}_{\mathrm{P}} = \sum_{q=1}^{Q} \sum_{i=1}^{S^q} w_i^q \tilde{y}_i^q$, is unbiased and internally consistent.

Note that the adjustment, $\frac{1}{m_j}$, applies to the survey variable value, y_j, instead to the sampling weight, w_i^q, and it consists in sharing y_j among the number of sampling units to which $j \in \mathrm{P}$ is associated.

In terms of the population units, the multiplicity-adjusted estimator can be written as an adjusted-weight estimator, $\hat{Y}_{\mathrm{P}} = \sum_{q=1}^{Q} \sum_{j=1}^{S_{\mathrm{P}}^q} \tilde{w}_j^q y_j$ where $\mathrm{S}_{\mathrm{P}}^q = \left\{ j \in \mathrm{P} \middle| i \in \mathrm{S}^q \wedge I_{ij}^q = 1 \right\}$ is the set of population units associated to S^q and $\tilde{w}_j^q = \frac{1}{m_j} \sum_{i=1}^{S^q} w_i^q$. The size of $\mathrm{S}_{\mathrm{P}}^q$ is $\mathrm{n}_{\mathrm{P}}^q$.

Linkage

To ensure the required linkage between farms and households, we define the link $I_{fh} = 1$ if at least one person from the household $h \in H$ works for the farm $f \in F$ and $I_{fh} = 0$ otherwise. A parcel is linked to the farm which it belong and to the households through the linkage between farms and households: $I_{lf} = 1$ if l belongs to f and $I_{lf} = 0$ otherwise. If f is included in S_F^1 (see section 2), then the set of households $\mathrm{S}_H^1 = \left\{ h \in H \middle| f \in S_F^1 \wedge I_{fh} = 1 \right\}$ linked with f are included in the household sample. If f is included in S_F^2, then the set of households $S_H^2 = \{h \in H | f \in S_F^2 \wedge I_{fh} = 1\}$ linked with f are included in the household sample.

If the household h is included in S_H^3, then the set of farms $S_F^3 = \{f \in F | h \in S_H^3 \wedge I_{fh} = 1\}$ linked with h are included in the farm sample. If f is in $\{S_F^q; q = 1,2,3\}$, then the set of parcels $L_f = \{l \in L | I_{fl} = 1\}$ are included in the sample. This sampling procedure is related with both, network sampling and indirect sampling [Falorsi (2014), Singh and Mecatti (2011), Mecatti and Singh (2014)].

The parameter to be estimated is the population total, $P = \{L, F, H\}$: over land, $Y_L = \sum_{l=1}^{L} Y_l$, over farms, $Y_F = \sum_{f=1}^{F} Y_f$, and over households, $Y_H = \sum_{h=1}^{H} Y_h$. Given the links (I_{lf}, I_{fh}) between (l, f, h), (i) the multiplicity of the parcel l is $m_l = \sum_{q=1}^{Q} m_l^q$, where $m_l^1 = \sum_{i=1}^{A^1} I_{il}^1$, $m_l^2 = \sum_{i=1}^{A^2} I_{if}^2 I_{lf} = m_f^2 I_{lf}$ and $m_l^3 = \left(\sum_{h=1}^{H} m_h^3 I_{fh}\right) I_{lf}$; (ii) the multiplicity of the farm f is $m_f = \sum_{q=1}^{Q} m_f^q$, where $m_f^1 = \sum_{i=1}^{A^1} I_{if}^1$, $m_f^2 = \sum_{i=1}^{A^2} I_{if}^2$ and $m_f^3 = \sum_{h=1}^{H} m_h^3 I_{fh}$; and the multiplicity of the household h is $m_h = \sum_{q=1}^{Q} m_h^q$, where $m_h^1 = \sum_{f=1}^{F} m_f^1 I_{fh}$, $m_h^2 = \sum_{f=1}^{F} m_f^2 I_{fh}$ and $m_h^3 = \sum_{i=1}^{A^3} I_{ih}^3$.

The total over land is $Y_L = \sum_{q=1}^{Q} \tilde{Y}_{Lq}$, where $\tilde{Y}_{Lq} = \sum_{i=1}^{A^q} \tilde{y}_{Li}^q$, where $\tilde{y}_{Li}^1 = \sum_{l=1}^{L} I_{il}^1 \frac{y_l}{m_l}$, $\tilde{y}_{Li}^2 = \sum_{f=1}^{F} I_{if}^2 \sum_{l=1}^{L} I_{lf} \frac{y_l}{m_l}$ and $\tilde{y}_{Li}^3 = \sum_{f=1}^{F} \left(\sum_{h=1}^{H} I_{ih}^3 I_{fh} \right) \sum_{l=1}^{L} I_{lf} \frac{y_l}{m_l}$ are the multiplicity-adjusted values of the survey variable associated to the i^{th} sampling unit in each frame. The total over farms is $Y_F = \sum_{q=1}^{Q} \tilde{Y}_{Fq}$, where $\tilde{Y}_{Fq} = \sum_{i=1}^{A^q} \tilde{y}_{Fi}^q$, where $\tilde{y}_{Fi}^1 = \sum_{f=1}^{F} I_{if}^1 \frac{y_f}{m_f}$, $\tilde{y}_{Fi}^2 = \sum_{f=1}^{F} I_{if}^2 \frac{y_f}{m_f}$ and $\tilde{y}_{Fi}^3 = \sum_{f=1}^{F} \left(\sum_{h=1}^{H} I_{ih}^3 I_{fh} \right) \frac{y_f}{m_f}$. The total over households is $Y_H = \sum_{q=1}^{Q} \tilde{Y}_{Hq}$, where $\tilde{Y}_{Hq} = \sum_{i=1}^{A^q} \tilde{y}_{Hi}^q$ and $\tilde{y}_{Hi}^1 = \sum_{f=1}^{F} I_{if}^1 \sum_{h=1}^{H} I_{fh} \frac{y_h}{m_h}$, $\tilde{y}_{Hi}^2 = \sum_{f=1}^{F} I_{if}^2 \sum_{h=1}^{H} I_{fh} \frac{y_h}{m_h}$, and $\tilde{y}_{Hi}^3 = \sum_{h=1}^{H} I_{ih}^3 \frac{y_h}{m_h}$.

The multiplicity-adjusted estimator, $\hat{Y}_P = \sum_{q=1}^{Q} \sum_{i=1}^{S^q} w_i^q \tilde{y}_{Pi}^q$, is unbiased and its variance is $V\hat{Y}_P = \sum_{q=1}^{Q} \sum_{i=1}^{A^q} \sum_{i'=1}^{A^q} \left(\pi_{ii'}^q - \pi_i^q \pi_{i'}^q \right) \frac{\tilde{y}_{Pi}^q}{\pi_i^q} \frac{\tilde{y}_{Pi'}^q}{\pi_{i'}^q}$. The variance estimator is $\hat{V}\hat{Y}_P = \sum_{q=1}^{Q} \sum_{i=1}^{S^q} \sum_{i'=1}^{S^q} \frac{\pi_{ii'}^q - \pi_i^q \pi_{i'}^q}{\pi_{ii'}^q} \frac{\tilde{y}_{Pi}^q}{\pi_i^q} \frac{\tilde{y}_{Pi'}^q}{\pi_{i'}^q}$.

The multiplicity-adjusted estimator can be written in terms of population units as an adjusted-weight estimator, $\hat{Y}_{\mathrm{P}} = \sum_{q=1}^{Q}\sum_{j=1}^{S_{\mathrm{P}}^{q}} \tilde{w}_j^q y_j$, where $\tilde{w}_j^q = \frac{1}{m_j}\sum_{i=1}^{S^q} w_i^q$.

4. Multiple frame regression estimators

To use auxiliary information, we specify a regression model in terms of population units, $y_j = \mathbf{x}_j\boldsymbol{\beta}+\varepsilon_j$, where $\mathbf{x}_j$ is the $(1\times p)$ vector of auxiliary variables, including the constant 1, $\boldsymbol{\beta}$ is a $(p\times 1)$ vector of regression parameters, $E\varepsilon_j = 0$, and $V\varepsilon_j = \sigma^2$. The model in terms of sampling units is, $\tilde{y}_i^q = \tilde{\mathbf{x}}_i^q\boldsymbol{\beta} + \tilde{\varepsilon}_i^q$, where $\tilde{\mathbf{x}}_i^q = \sum_{j=1}^{S_{\mathrm{P}}^q}\alpha_{ij}^q\mathbf{x}_j$, $\tilde{\varepsilon}_i^q = \sum_{j=1}^{S_{\mathrm{P}}^q}\alpha_{ij}^q\varepsilon_j$, $E\tilde{\varepsilon}_i^q = 0$, $V\tilde{\varepsilon}_i^q = \sigma^2\sum_{j=1}^{S_{\mathrm{P}}^q}\left(\alpha_{ij}^q\right)^2$.
Lu (2014) proposes four methods to estimate $\boldsymbol{\beta}$. We consider the probability weighted least square estimator, $\hat{\boldsymbol{\beta}}_{\tilde{w}} = \min_{\boldsymbol{\beta}}\sum_{q=1}^{Q}\sum_{i=1}^{S^q}\tilde{w}_i^q\left(\tilde{y}_i^q - \tilde{\mathbf{x}}_i^q\boldsymbol{\beta}\right)^2$, where $\tilde{w}_i^q = w_i^q\tilde{\alpha}_i^q$ and $\tilde{\alpha}_i^q = \frac{1}{\sum_{j=1}^{S_P^q}\left(\alpha_{ij}^q\right)^2}$: it is

$\hat{\boldsymbol{\beta}}_{\tilde{w}} = \left(\tilde{\mathbf{X}}^{\mathrm{T}}\mathbf{D}_{\tilde{w}}\tilde{\mathbf{X}}\right)^{-1}\tilde{\mathbf{X}}^{\mathrm{T}}\mathbf{D}_{\tilde{w}}\tilde{\mathbf{y}}$, where $\tilde{\mathbf{X}}$ is the $\left(\sum_{q=1}^{Q}S^q\times p\right)$ multiplicity-adjusted auxiliary data matrix,

$\tilde{\mathbf{y}}$ is the $\left(\sum_{q=1}^{Q}S^q\times 1\right)$ vector of multiplicity-adjusted survey variable data,

and $\mathbf{D}_{\tilde{w}} = diag\left\{\tilde{w}_i^q; i=1,2,\cdots,S^q; q=1,2,\cdots,Q\right\}$.

$\hat{\boldsymbol{\beta}}_{\tilde{w}}$ is a design-consistent estimator of the regression parameter values in the finite population, $\boldsymbol{\beta}_N = \left(\tilde{\mathbf{X}}_N^T\tilde{\mathbf{X}}_N\right)^{-1}\tilde{\mathbf{X}}_N^T\tilde{\mathbf{y}}_N$, where $N = \sum_{q=1}^{Q}A^q$ is the number of sampling units in the multiple frame, $\tilde{\mathbf{X}}_N$ is the $(N\times p)$ matrix of multiplicity-adjusted auxiliary variable values, and $\tilde{\mathbf{y}}_N$ is the $(N\times 1)$ vector of the multiplicity-adjusted survey variable values.

The Multiplicity-adjusted Generalized Regression estimator (MGREG) is $\hat{Y}_{MGREG} = \sum_{q=1}^{Q}\sum_{i=1}^{A^q}\tilde{\mathbf{x}}_i^q\hat{\boldsymbol{\beta}}_{\tilde{w}}$: it is a design-consistent estimator of the population total, Y , and its asymptotic design-variance can be estimated using $\hat{V}\hat{Y}_{MGREG} = \hat{V}\left(\sum_{q=1}^{Q}\sum_{i=1}^{S^q}w_i^q\hat{e}_i^q\right)$g, where $\hat{e}_i^q = \tilde{y}_i^q - \tilde{\mathbf{x}}_i^q\hat{\boldsymbol{\beta}}_{\tilde{w}}$ (Fuller, 2009; Kim and Rao, 2012).
Ranalli et al (2014) propose calibration estimators. Deville and Särdal (1992) and (Fuller, 2009) show how calibration estimators can be approximated by regression estimators.

Integrating survey and register data

The MGREG estimator is useful to integrate survey and register data. To see this, we assume that there is a set of values $\left(y_j, \mathbf{x}_j\right)$ associated with each population unit: y_j is the survey variable value and $\mathbf{x}_j$ are register values. We assume that the choice of $\mathbf{x}_j^q$ differs among single frames (registers) and we use a different working model in each register, $\tilde{y}_i^q = \tilde{\mathbf{x}}_i^q \boldsymbol{\beta}^q + \tilde{\varepsilon}_i^q$, where $\tilde{\mathbf{x}}_i^q = \sum_{j=1}^{S_P^q} \alpha_{ij}^q \mathbf{x}_j^q$, $\tilde{\varepsilon}_i^q = \sum_{j=1}^{S_P^q} \alpha_{ij}^q \varepsilon_j$, $E\tilde{\varepsilon}_i^q = 0$, $V\tilde{\varepsilon}_i^q = \sigma^{2,q} \sum_{j=1}^{S_P^q} \left(\alpha_{ij}^q\right)^2$. To observe data on $\left(y_j, \mathbf{x}_j^q\right)$, we consider Q^1 frames of the target population, , and we select independently from each one a sample, $\left\{S^q; q = 1, 2, \cdots, Q^1\right\}$. We consider Q^2 registers as independent large samples, $\left\{S^q; q = 1, 2, \cdots, Q^2\right\}$, selected from , where we observe only data on $\mathbf{x}_j^q$.

To estimate regression parameters, $\boldsymbol{\beta}^q$, we use data from Q^1 and the probability weighted least square estimator, $\hat{\boldsymbol{\beta}}_{\tilde{w}}^q = \min_{\boldsymbol{\beta}^q} \sum_{i=1}^{S^q} \tilde{w}_i^q \left(\tilde{y}_i^q - \tilde{\mathbf{x}}_i^q \boldsymbol{\beta}^q\right)^2$, which is $\hat{\boldsymbol{\beta}}_{\tilde{w}}^q = \left(\tilde{\mathbf{X}}^{qT} \mathbf{D}_{\tilde{w}}^q \tilde{\mathbf{X}}^q\right)^{-1} \tilde{\mathbf{X}}^{qT} \mathbf{D}_{\tilde{w}}^q \tilde{\mathbf{y}}^q$, where $\tilde{\mathbf{X}}^q$ is the $\left(S^q \times p^q\right)$ multiplicity-adjusted auxiliary data matrix, $\tilde{\mathbf{y}}^q$ is the $\left(S^q \times 1\right)$ vector of multiplicity-adjusted survey variable data, and $\mathbf{D}_{\tilde{w}}^q = diag\left\{\tilde{w}_i^q; i = 1, 2, \cdots, S^q\right\}$.

We use data from Q^2 to estimate $\sum_{i=1}^{A^q} \tilde{\mathbf{x}}_i^q$, using $\sum_{i=1}^{S^q} w_i^q \tilde{\mathbf{x}}_i^q$. The MGREG estimator is

$\hat{\hat{Y}}_{MGREG} = \sum_{q=1}^{Q^2} \sum_{i=1}^{S^q} w_i^q \tilde{\mathbf{x}}_i^q \hat{\boldsymbol{\beta}}_{\tilde{w}}^q$, and its error is

$$\hat{\hat{Y}}_{MGREG} - Y = \hat{\hat{Y}}_{MGREG} - \sum_{q=1}^{Q^2} \tilde{\mathbf{x}}_{N^q}^q \boldsymbol{\beta}_{N^q}^q = \sum_{q=1}^{Q^1} \sum_{i=1}^{S^q} \left(\tilde{y}_i^q - \tilde{\mathbf{x}}_i^q \boldsymbol{\beta}_{A^q}^q\right) + \sum_{q=1}^{Q^2} \left(\sum_{i=1}^{S^q} w_i^q \tilde{\mathbf{x}}_i^q - \tilde{\mathbf{x}}_{A^q}^q\right) \hat{\boldsymbol{\beta}}_{\tilde{w}}^q + \left(\tilde{\mathbf{x}}_N - \sum_{q=1}^{Q^1} \sum_{i=1}^{S^q} w_i^q \tilde{\mathbf{x}}_i^q\right) \left(\hat{\boldsymbol{\beta}}_{\tilde{w}}^q - \boldsymbol{\beta}_{A^q}^q\right)$$

, where $\tilde{\mathbf{x}}_{A^q}^q = \sum_{i=1}^{A^q} \tilde{\mathbf{x}}_i^q$, $\tilde{\mathbf{x}}_N = \sum_{q=1}^{Q^2} \tilde{\mathbf{x}}_{A^q}^q$, $\boldsymbol{\beta}_{A^q}^q = \left(\tilde{\mathbf{X}}_{A^q}^{qT} \tilde{\mathbf{X}}_{A^q}^q\right)^{-1} \tilde{\mathbf{X}}_{A^q}^{qT} \tilde{\mathbf{y}}_{A^q}^q$, $\tilde{\mathbf{X}}_{N^q}^q$ is the $\left(A^q \times p^q\right)$ matrix of multiplicity-adjusted auxiliary variable values, and $\tilde{\mathbf{y}}_{A^q}$ is the $\left(A^q \times 1\right)$ vector of the multiplicity-adjusted survey variable values.

$\hat{\hat{Y}}_{MGREG}$ is design-consistent and its asymptotic design-variance can be estimated using $\hat{V}\hat{\hat{Y}}_{MGREG} = \hat{V} \sum_{q=1}^{Q^1} \sum_{i=1}^{S^q} w_i^q \hat{\tilde{e}}_i^q + \sum_{q=1}^{Q^2} \hat{\boldsymbol{\beta}}_{\tilde{w}}^{qT} \left(\hat{\mathbf{V}} \sum_{i=1}^{S^q} w_i^q \tilde{\mathbf{x}}_i^q\right) \hat{\boldsymbol{\beta}}_{\tilde{w}}^q$, where $\hat{\tilde{e}}_i^q = \tilde{y}_i^q - \tilde{\mathbf{x}}_i^q \hat{\boldsymbol{\beta}}_{\tilde{w}}^q$. The elements of the covariance matrix, $\hat{\mathbf{V}} \sum_{i=1}^{S^q} w_i^q \tilde{\mathbf{x}}_i^q$, can be estimated using the HT variance estimator. If $A^q \in Q^2$ is complete, then $\sum_{i=1}^{A^q} \tilde{\mathbf{x}}_i^q$ is known and all terms in the covariance matrix related with A^q are nulls.

Analysis of complex surveys: sampling design informativeness

Linear (regression) and generalized linear models are useful tools for analyzing survey data. Deaton (1997) shows how they can be used with household surveys and with linked farm-household surveys (Singh et al., 1986). Most land use models are generalized linear models (Ambrosio et al., 2008), useful for analysing linked farm-parcel surveys. Relative little work has been done on 'sustainometrics' models (Todorov and Marinova, 2010), for analysing linked farm-household-parcel surveys.

Typically, the analysts fit these models assuming that the sampling design is 'non informative'. However, complex sampling design leads usually to informative samples and, as a result, model parameters estimator are inconsistent (Binder et al, 2005). The weighted estimator is consistent and its asymptotic distribution is normal, and can be used for hypothesis testing and prediction [Fuller (2009)].

5. Concluding remarks

To collect data for designing sustainable policies, we integrate agricultural and household sampling frames in a multiple overlapping frame. This sampling frame provides the required reporting units: the farm as economic unit, the household as social unit, and the parcel as environmental unit. We apply this strategy in three Latin America countries.

Due to overlapping, the sum of the usual single frame weight estimator over the multiple frames is biased. The multiple frame estimators proposed in the literature consist in an adjustment of the single frame weight estimator by adjusting either the sampling weight (adjusted-weight estimators) or the survey variable (multiplicity-adjusted estimators). We focus on multiplicity-adjusted estimators because they are internally consistent and take into account the linkage among sampling units in a simple way.

Regression estimators have received considerable attention in the literature, but mainly for single frames. We extend this single frame estimator to the multiple frame case, highlighting the usefulness of multiple frame regression estimators to integrate register and survey data.

Linear (regression) and generalized linear models are useful tools for analysing survey data, and we suggest using weighted estimators to estimate model parameters, in order to take into account the sampling design informativeness. Hypothesis testing and prediction can be carried out using the asymptotic normal distribution of these estimators.

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THEMATIC SET

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METHODOLOGICAL CHALLENGES AND PROPOSALS FOR THE NEXT AGRICULTURE CENSUS ROUND

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ABSTRACT

The FAO World Programme on the Census of Agriculture 2020 (WCA 2020), that will be published in 2015, will be the tenth decennial census programme. It is an international standard that is expected to drive the implementation of agricultural censuses in all countries in the period between 2016 and 2025. The WCA 2020 is occurring at a time when demand increases for integrated, synergetic and cost-- efficient national agriculture statistical systems. Some of the main features of the new WCA 2020 are: • Close linkages to the Global Strategy to Improve Agricultural and Rural Statistics and the emphasis on the integration of the census of agriculture within the overall framework of the system of integrated agricultural censuses and surveys. • Two methodological approaches are recognised namely the classical (a single one-- off complete enumeration) and the modular approach (combining complete and sample enumeration) while noting the increased use of registers and administrative records as a source of census data. • The distinction between 'essential', 'frame' and 'additional' census items. Essential items are recommended to be collected by all countries, frame items are used for the construction of sampling frames while additional items are for more in-- depth data. • An increased emphasis on the use of information technology in the collection, processing and dissemination of census data. The objective of the session is to discuss the efforts that countries are making to conduct censuses within a more integrated, synergetic and cost-- efficient agriculture statistical system. Possible topics for papers in this session include: 1. Integration of agricultural census with other major statistical operation such as population census and economic census 2. Combined approaches that use statistical and administrative sources to meet the data needs of the census of agriculture 3. Frames for the agricultural census and dealing with outdated frames 4. The use of information technology to reduce the time lag between census data collection and analysis and to facilitate user-- friendly dissemination to support informed-- decision making. 5. Types of census enumeration: complete enumeration, sample--based enumeration, combination of approaches, rolling enumeration. 6. Innovative research uses of census data, e.g. for agri-- economic and environmental estimates: water consumption for agriculture, sustainable agriculture, farm typologies.

LIST OF PAPERS

Armenian experience on agricultural census
M. S. Mnatsakanyan | National Statistical Service of the Republic of Armenia | Yerevan | Republic of Armenia
A. Safyan | National Statistical Service of the Republic of Armenia | Yerevan | Republic of Armenia
DOI: 10.1481/icasVII.2016.f37

Comparison between agricultural holdings in the farm register and agricultural holdings in the business register
E. Wixe | Swedish Board of Agriculture | Jönköping | Sweden
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Strategy for agricultural statistics 2020 and beyond: for the future European Agricultural Statistics System (EASS)

A. Lazar | Eurostat | Luxembourg | Luxembourg
J. Selenius | Eurostat | Luxembourg | Luxembourg
M. Jortay | Eurostat | Luxembourg | Luxembourg

DOI: 10.1481/icasVII.2016.f37c

Harnessing data revolution for cost-effective agricultural censuses in the 21st century with widely accessible and used results

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Armenian Experience on Agricultural Census

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ABSTRACT

The first Agricultural Census in Armenia was conducted in 2014. The legal basis to conduct the Agricultural Census was RA Law "On State Statistics" (2000), Three-year state statistical work program, RA Law "On Agricultural Census» (2008), RA Government Decree on 25 April 2013 "On implementation of Armenia Agricultural Census in 2014 and Pilot Agricultural Census in 2013". Totally 107 documents (55 Resolutions of the State Council on Statistics of RA) have been adopted.
The methodology of Agricultural Census includes the selection of time period for the census implementation, objectives and coverage of indicators, general population (census units) and methods (exhaustive and sampling), accounting period and census phases.
The Agricultural Census units were all legal persons dealing with agricultural production, individual entrepreneurs, group farms (correctional institutions, military units, orphanages, organizations of social services for the elderly and disabled, education, research and experimental units), individual households in rural and urban areas, and in horticultural companies, communities. Preparatory work has been done through the development of lists of farms in communities and organization plans, recruitment, staff training and publicity campaign.
The Census has been implemented by preliminary visit, control visit and publicity campaign. These activities have been followed by the acceptance of documents by checking/coding of questionnaires responses, questionnaires data entry and obtaining of output tables.

Legislation, methodology and standards have been developed by recommendations of international experts: UN FAO, US Department of Agriculture, EU/Eurostat (Denmark and Sweden) within the EU Twinning Project “Forwarding Armenian Statistics through Twinning” (2011-2013), as well as studying Agricultural Census experience in USA, Denmark, Sweden, Russia, Moldova, Georgia, and other countries. The funds have been provided by the World Bank, Austrian Development Agency/UNDP, EU/budget support, USAID.
Agricultural Census will enable to improve agricultural statistics, form complete statistical data system on agriculture, establish statistical registers for units engaged in agricultural activities, and ensure data international comparability.

Keywords: Agriculture, statistical data, households, questionnaire.

1. Introduction

Since the establishment of the United Nations (UN) in the second half of 20th century, humanity started worldwide the development of accounting systems and maintenance of statistics in accordance with unified and comparable definitions, classifications and methodology. This refers to all spheres of human activities, including agriculture, which is considered as one of the most important fields.
Many countries, including Armenia compile agricultural statistics based on reports from local authorities, because of lack of resources. This method of data collection affects on data quality and that is why an agricultural census is an irreplaceable tool to provide valuable information for agriculture statistics.
According to the World Programme for the Census of Agriculture 2020 (WCA 2020), “A census of agriculture is a statistical operation for collecting, processing and disseminating data on the structure of agriculture, covering the whole or a significant part of a country. Typical structural data collected in a census of agriculture are size of holding, land tenure, land use, crop area, irrigation, livestock numbers, labour and other agricultural inputs. In an agricultural census, data are collected at the holding level, but some community-level data may also be collected”.
UN Member States are required to conduct an Agricultural Census at least every 10 years in accordance with the guidelines defined by the FAO.

2. Need to conduct Agriculture Census in the Republic of Armenia

Statistical data on agriculture in the Republic of Armenia are collected, summarized and published by the National Statistical Service of the Republic of Armenia (NSS RA). Agriculture statistics is guided by the annual state statistical work program, according to the main strategic directions of statistics development that are stated in three-year state statistical work programs. Statistical data are collected directly (sampling) by direct enumeration of agricultural holdings and commercial enterprises engaged in agricultural activities, as well as from administrative registers (Ministry of Agriculture of RA, Ministry of Nature Protection of RA, Cadastre Committee), communities (866 rural and 49 urban). Statistical data on agriculture are presented monthly, quarterly and annually based on the current reports.
Until 2014 an agricultural census has not been conducted in the Republic of Armenia.
According to the existing methodology the Agricultural Census is statistical operation for collecting, processing and disseminating exhaustive data on the structure of agriculture, agricultural lands, livestock, agricultural machinery and buildings, existing resources (human and material) and their utilization.

Meanwhile the Agricultural Census was important for the Republic of Armenia, as the collected statistical data will be used for:

- poverty monitoring,
- food security monitoring,
- planning of agriculture and development of strategy in this area,
- gender statistics,
- improving current agricultural statistics,
- providing users with more comprehensive information and so on.

Conducting Agricultural Census in Armenia was also important because agriculture is considered as one of the most important sectors of economy, and the share of new value in Gross Domestic Product (GDP) during the recent years is 16-20%, and the number of employees in this field is about 37 % of the total employed population.

There are many and various economic entities in the field of agriculture, the majority of them are agricultural holdings (rural households). 90 % of GDP in agriculture belongs to these holdings and they may be described as follows:

- small sizes,
- lack of internal accounting,
- law marketability level (45 % of the products are produced for own consumption, 20 % belongs to in-kind payments and barters and only in average 35 % is monetized),
- low degree of specialization,
- small, limited amounts of investments and incomes,
- high level of changeability of economic activity and intra-sectoral activities (including seasonal).

Implementation of Agricultural Census will give a possibility to create overview of agriculture in Armenia characterized not only by internationally comparable disaggregated indicators, but also it will clarify the detailed structure and composition of agriculture as a field of entrepreneurship (type of economic activity). As a result, it will become possible to form new organizational and legal forms for 340,000 households engaged in agricultural activities, which will be a basis for administrative registration, and thus this field will be no more described as “informal activity”. According to the survey results in 2009 (“The Informal Sector and Informal Employment in Armenia” Country Report), the agriculture sector had the highest rate of informal employment (98.6%). The informal employment rate in agriculture has not been changed and was 99.3 % in 2015 according to the Labour Force Survey.

3. Legal basis for conducting Agricultural Census in the Republic of Armenia

Law on Agricultural Census was adopted in 2008, and that is in line with methodological approaches of the international practice.

This law stipulates the following provisional requirements for the Agricultural Census: objectives, units of the agriculture census and their obligations, bodies conducting Agricultural Census and their obligations, financing, liabilities for violation of the Agricultural Census legislation, etc.

According to the given Law the objectives of Agricultural Census are as follows:

- collection of information on agriculture structure, agricultural land, machinery, constructions, available resources (human, material) and their use at the republican, regional and community level,
- formation of complete statistical data system on agriculture,
- formation of statistical register for agricultural holdings,
- ensuring comparability with international statistical data.

4. Activities necessary for the preparation and organization of Agricultural Census in Armenia

The following activities have been defined to conduct the Agricultural Census in Armenia for the first time:

- to establish commissions (Republican and regional) for the preparation and conducting Agricultural Census,
- to prepare and adopt legal acts and documents (instruction, questionnaire, list, enumerators notebook),
- to develop a publicity campaign program (TV, radio, slogans, posters, booklets, messages, website, social network, etc.),
- to prepare budget estimates,
- to recruit and train staff,
- to prepare and conduct Pilot Agricultural Census (testing),
- to conduct Agricultural Census,
- to code questionnaires, checking, data entry, verification and aggregation,
- to publish and disseminate Agricultural Census data.

5. Preparation and organization of Agricultural Census in Armenia

Agricultural Census Department has been established in May 2013 for the preparation and conduction of the Agricultural Census.

The Pilot Agricultural Census has been conducted on 10 - 30 November 2013 to test the census procedures.

The Main Agricultural Census has been implemented on 11-31 October 2014.

Agricultural Census units were:

- all legal persons dealing with agricultural production,
- individual entrepreneurs,
- group farms (correctional institutions, military units, orphanages, organizations of social services for the elderly and disabled, education, research and experimental units),
- individual households in rural and urban areas, and in horticultural companies,
- communities.

The list of individual households was compiled in the following way:

- in rural communities with the population less than 2000 the lists of units have been formed by the village heads, based on data records of rural communities,
- in urban and rural communities with the population of 2000 or more, by specially hired employees to make a listing, based on the schematic plans of communities.

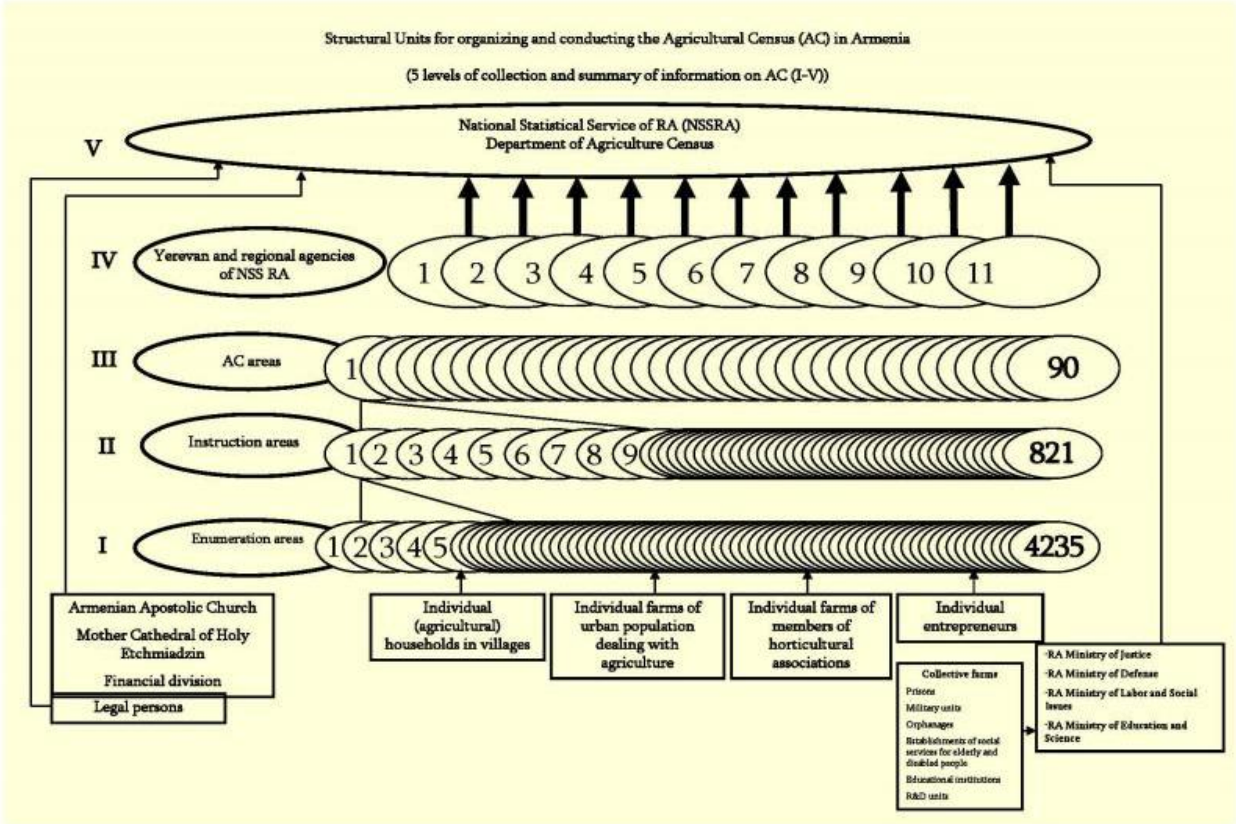
Data collection has been implemented by the completion of relevant questionnaires.

Around 250 characteristics have been included in the questionnaires, in particular the main recommended by FAO are:

- household address,
- household`s head gender, age, education, etc.,
- legal status of the household,
- the main purpose of production,

- land size, sowing areas, perennial areas,
- irrigated land and irrigation methods,
- fisheries,
- the availability and use of agricultural machinery,
- plant protection means and fertilizers,
- labour force,
- agro tourism, etc.

Figure 1: *Management scheme of the Agricultural Census in Armenia*



According to the organizational plan for 2014, 90 census areas, 821 instruction areas and 4235 enumeration areas have been established on the whole territory of the country.
Agricultural Census has been prepared and implemented by the following three stages:

1. Preparatory work
   - compilation of lists of farms in communities,
   - development of organization plans,
   - recruitment and staff training,
   - publicity and awareness campaign.
2. Carrying out of Agricultural Census
   - preliminary visits to households (farms),
   - carrying out of Agricultural Census,
   - conducting of sample control visit,
   - publicity and awareness campaign.
3. Acceptance of documents and information processing
   - acceptance of documents,
   - checking/coding of responses in questionnaires,
   - questionnaires data entry,
   - deriving of output tables.

To ensure the completeness and quality of daily collected data, operational controls of field work were carried out. The data field work was monitored in the following way. Enumerators work was monitored by instructors-supervisors, and their work by heads of census areas and their assistants, whose work in its turn by coordinators. The overall control has been implemented by heads of regional agencies of the NSS RA and the ones responsible for territorial units. International experts also participated in the field work monitoring process.
For data editing and imputation special software was developed using CSPro (Census and Survey Processing System) and SPSS that were localized and improved by international experts, taking into account the peculiarities of Agricultural Census implemented in Armenia.

6. Post- enumeration survey

Highlighting the importance of data quality, after the data collection, the post-enumeration survey has been implemented from 28 November to 14 December 2014 that comprised 3.5% of general population. Random sampling was carried out in 134 urban and rural communities of country's 10 regions.
Data are not yet finalized, and therefore at this stage it is not possible to reveal differences with other available sources.
It is foreseen to publish the Agricultural Census final results in the 4th quarter of 2016.

7. Donors support

The legislation, methodology and standards, questionnaires, publicity campaign materials, deriving of output tables, preliminary data release, etc. for 2014 Agricultural Census have been developed based on the FAO guidelines, recommendations and support of international experts, such as Mr. Michael Steiner, Expert, USDA, Mr. Rolf Selander, Senior Adviser, Statistics Sweden, Mr. Kristian Hulsager, Head, Agricultural Statistics Department, Statistics Denmark, Mr. Karsten Larsen, Head, Agricultural Statistics Division, Statistics Denmark, Mr. Thomas Bie, Resident Twinning Adviser, European Union (EU) Twinning Project “Forwarding Armenian Statistics Through Twinning” and Mr. Giorgi Kvinikadze, Mr. Oleg Cara, Mr. Vasile Petre, Experts, FAO, as well as with the support of staff of the Ministry of Agriculture of RA.
In the course of the Agricultural Census preparation, organization, implementation and data aggregation the NSS RA has studied the experience on Agricultural Census in USA, Denmark, Sweden, Russian Federation, Moldova, Georgia, Italy and Austria, and other countries. A delegation from the NSS RA visited FAO Headquarters in Rome to participate in meetings on the development of the agricultural statistics system in Armenia.
Funds have been provided by the World Bank, Austrian Development Agency/implementing agency UNDP jointly with FAO, EU budget support/ the European Neighborhood Program for Agriculture and Rural Development (ENPARD/ implementing agency FAO, United States Agency for International Development (USAID)/ implementing agency USDA.
The census budget amounted to $ 5.1 million. The number of accounted farms was 418 880. The costs per unit were $ 12.1.

8. Conclusion

Agricultural Census in the Republic of Armenia will improve current statistics, form complete statistical data system on agriculture, establish statistical registers for entities engaged in

agricultural activities, improve sample statistical tools and ensure their comparability with existing international standards, identify trends of changes in agricultural infrastructures throughout the years.
Agricultural Census will provide a wealth of new and reliable information to the Ministry of Agriculture for strategy formulation, policy making and focused action plans.
Challenges of Agricultural Census:

- lack of funds to conduct regular censuses
- lack of administrative registers
- lack of legal definition of farm, criteria for determining the farm (land size, heads of livestock, etc)
- difficulties on recruitment of large number of qualified enumerators and supervisors.

Recommendations:

- to create Farm Register
- to introduce agricultural statistics system based on Farm Register
- to introduce new methods of data collection.

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Comparison between agricultural holdings in the Farm register and agricultural holdings in the Business register

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ABSTRACT

In Sweden and in the EU there are two main sources for statistics about number of agricultural holdings and their type of farming. One is the Farm register (FR) and one is the Business register (BR). The aim of this paper is to examine and compare these two sources to find out if there is a possibility to use the BR as a source in the next agricultural census and as a consequence reduce the response-burden for some agricultural holdings and lower the total administrative cost of the census.

To achieve the aim of the study, micro level data from the FR and the BR in Sweden have been merged by the social security number or organisation number. All agricultural holdings in the FR were included and all economic activities classified as agriculture were included from the BR.

The resultsshow that the number of agricultural holdings differ between the registers and not all of the holdings in the FRare possible to match with the BR. The Swedish typology for classification of type of farming does not fully harmonize with the NACE codes (Statistical classification of economic activities in the European Community)in the BR, which complicates the comparison.

The main conclusion of the research is that the FR and the BR have different purposes and are regulated in different EU legislations which makes the use of the BR in the agricultural census difficult. However, the results show that it is possible to reduce the response-burden for someagricultural holdings in the FR and also possibilities to improve the quality in both registers.

Keywords: Farm register, Business register, agricultural holdings

1. Introduction

In Sweden and in the EU there are two main sources for statistics about number of agricultural holdings and their type of farming. One is the Farm register (FR) and one is the Business register (BR). Depending on which source is used, the number of agricultural holdings and the characteristics of the holdings differ, which makes statistics on agriculture incoherent and difficult to use.This paper explains the differences between these sources and investigates the possibilities of exchanging information between the registers.

In Sweden, an agricultural holding is seen as an entrepreneurial activityjust like any other entrepreneurial activity. That means for example that they are taxed in the same way. Also both farmers and other businesses have the same type of identifiers (social security- or organisation numbers) that would imply that the possibilities to coordinate the registers are good.According to Wallgren, A., Wallgren, B. (2014) the use of registers will “reduce the costs for both respondents and statistics producers” and also registers have “almost complete coverage of population”. Watt (2010) has studied the possibility to use the New Zealand (NZ) business frame for agricultural statistics. Watt points out that for NZ there are some significant benefits,like cost-efficiency and use of the frequently updated information in the BR, but also some challenges.

Both the FR and the BR are widely used by policymakers in Sweden. Alsofor research, in public debates and in decision making. There is a need for coherent statistics on the number of agricultural holdings and their type of farming. In the agricultural census, the agricultural holding is defined in (EC) No 1166/2008 as “a single unit both technically and economically which has a single management”. The threshold is based on number of hectares of arable land and animals and the type is decided in a typology especially developed for agricultural activities. The concepts of theagricultural census are in line with the guidelines in the World Programme for the Census of Agriculture (WCA) provided by the Food and agriculture organization of the United Nations (FAO).In Sweden the census results are used to form a FR. The BRis regulated in (EC) No 177/2008. The register consists of “all enterprises carrying on economic activities contributing to the gross domestic product (GDP) and their local units”. The agricultural activities are classified in accordance with the NACE classification comparable to other entrepreneurial activities.
In this paper micro level data from the FR and the BR have been merged to examine and compare the differences of the registers. Initially, it was not expected that all agricultural holdings would match between the FR and the BR, nor that the number of agricultural holdings would be equal between the registers.

This paper will discuss if:

- the BR can be used as a source in the next agricultural census round to possibly get faster, cheaper and more complete data
- the information in BRcan improve the quality in the FR and vice versa
- the response-burden can be reduced in the agricultural census.

2. Concepts and definitions

Each member state in the European Union (EU) shall carry out surveys on the structure of agricultural holdings, the Farm Structure Survey (FSS), according to Regulation EC No 1166/2008. The aim of the FSS is to provide statistics on the structure of agricultural holdings and enable the study of trends at the European Community level. Since the results from the FSS are in line with the guidelines in WCA,the statistics are comparable in all FAO member states. WCA has a key role in the system of integrated agricultural statistics. According to EC No 1166/2008 the surveys shall cover all agricultural holdings reaching one of the physical thresholds specified below:

- More than 2.0 hectares of arable land
- More than 5.0 hectares of agricultural land
- At least 200 m² under glass
- At least 2500 m² outdoor horticultural cultivation
- Possessed at least: 10 cattle or 10 sows or 50 pigs or 20 ewes or 1000 poultry (incl. chickens) on the reference day in June

The FSS is the main source to form the Swedish Farm register (FR). The information in the census is collected both through postal questionnaires and administrative registers. In the FR information about the holder, the area of different crops and number of animals is included. Other information is also included in the census regarding other gainful activities directly related to the holding (OGA) and people working on the agricultural holding.

The Business register (BR) is regulated in (EC) 177/2008 aiming at “a common framework for business registers for statistical purposes in the European community”. According to Council Regulation (EEC) No 696/93 the register shall be compiled of “all enterprises carrying on economic activities contributing to the gross domestic product (GDB), and their local units”. In Sweden this means that the register contains all legal persons and natural persons who fulfill at least one of the following criteria, and estates of deceased persons fulfilling at least one of the first two of the following criteria:

- Registered for VAT
- Registered as employer
- Having a registered firm
- Registered for F-tax (business tax)

The Swedish BR is a part of Statistic Sweden's (SCB) business database. It is mainly used as a population register, sample frame and as a co-ordination tool within Statistics Sweden.
The BR is mainly updated with information from the Swedish National Tax Board, other administrative registers, statistical surveys and external users.

2.1.1 Type of farming

In the FR, type of farming and the size of the agricultural holding are defined by the Swedish typology. The typology is based on standard labour requirement. These estimates are based on hectares of different crops and number of animals. The holdings are then differentiated by the scale of production.

In the BR, the economic enterprises are classified in accordance with the Standard for Swedish Classification of Economic Activities (SNI 2007). The classification is in line with NACE and generally with International Standard Industrial Classification of All Economic Activities (ISIC),which makes the register comparable with other EU and UN member states.

2.1.2 Other gainful activity directly related to the holding (OGA)

In the FR, OGA is an economic activity, but not an agricultural activity, in which the resources from the agricultural holding are used. The resources could for example be land, buildings, machines or products. Forestry is not an OGA.

In the BR,each firm can register several economic activities. In this research, activity one through five are included. The first (primary) activity has the most economic importance to the firm. The definition is therefore wider in the BR compared to the FR.

2.1.3 Employment

All persons, 15 years or older, who worked at least one hour onthe agricultural holding during one year are classified as employed in the FR, regardless of economic compensation. They can be either family members, or other permanently or temporarily persons.

In theBR, the number of employees does not have a key role. It is only used to decide the size of the company based on employment. Due to this, the register of Labour statistics based on administrative sources (RAMS) was merged with the FR. RAMS is the main source oflabour statistics in Sweden. It contains all enterprises which have at least one employed person.To be classified as employed at a specific enterprise, the activity at the enterprise must be that person's main employment, i.e. no other employment that generates a higher income for that person in November. It can be either the business owners, such as sole traders that has declared an active firm, or employed persons according to the income statement (KU). Persons between 16 – 74 years old can be classified as employed.This means that the definition is narrower in RAMS than in FR.

3. Method

3.1 Input

In this research all agricultural holdings in the FR were included for year 2010 and 2013. In the BR, all economic activities classified within NACE A1 Crop and animal production, hunting and related service activities, except 1.7 Hunting, trapping and related service activities, are included. A company can register several economic activities and the firstthrough fifth activity are included. The micro level data pertains to year 2010 and 2013.

As mentioned above,RAMSwas used in the matching process. All enterprises classified as agricultural holdings (NACE 1.1–1.6) with at least one employed person are included.

3.2 Data processing

To achieve the aim of the study, micro level data from the FR and the BR have been merged using the social security number or organisation number. This unique identifier is essential in order to link the information successfully. In the FR an agricultural holding can contain several persons, for example several family members. Primarily it is the holder that has been used in the merging and secondarily it is some other person, e.g. wife/husband, family member or other persons. Due to this, there is no one-to-one match between the registers. If several family members are registered as sole traders, this will result in two or more enterprise units in the BR but only one holding in the FR. This challenge also corresponds to the findings of Watt (2010).

4. Result

4.1 Number of units and matching result

The total number of agricultural holdings in the FR was 67 146 in 2013. That is a decrease by 6 % in number of holdings compared with 2010.

The number of agricultural holdings in the BR includes all economic enterprisesclassified within an agricultural activity (NACE 1.1–1.6), first activity through fifth activity. The total number were 130 242 in 2013. That is an increase by 10 % compared with 2010.

Table 1: *Number of agricultural holdings*

Farm register		71 091	67 146	-3 945
Business register		118 599	130 242	11 643
- of which:	active[1]	116 440	128 456	12 016
	primary activity[2]	102 923	109 774	6 851

The number of agricultural holdings in the BR that could be matched with the FRwas 61 370 or 47 % in 2013. In the FR, 79 % of the agricultural holdingscould be matched withthe agricultural holdings in the BR in 2013.

Table 2: *Number of units distributed by matching result*

	Hit against									
	Physical person		Legal person		Wife/ husband		Other persons		Total	
Register	2010	2013	2010	2013	2010	2013	2010	2013	2010	2013
FR in BR	47 355	46 702	4 018	4 096	1 483	1 483	1 011	869	53 867	53 150
BR in FR	56 304	57 083	4 196	4 287	.	.	.	.	60 500	61 370

4.2 Type of farming

The agricultural holdings in the FR and BR are divided by type of farming. In the FR,type of farming is based on the Swedish typology which is not fully consistent with the types in the SNI/NACE. In the FR almost 24 500 holdings or 36 % are classified as Small farms in 2013. Small farm means that standard labour requirement is less than 400 hours per year. In the BR about 50 % of the enterprises are classified as Mixed farming which includes a combined production of crops and animals but no specialised production.

Table 3: *Type of farming in the Farm register and in the Business register*

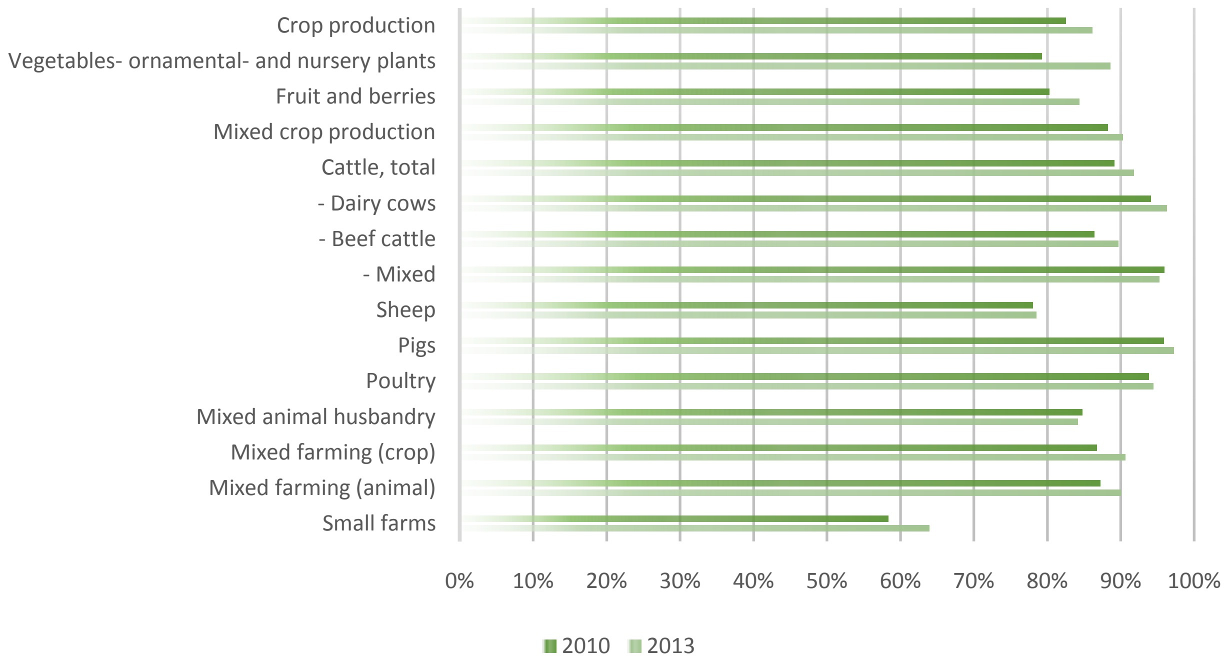
The Farm register				The Business register			
Main-, basic-, Detailed type (Swedish typology)	2010	2013	Diff.	**Division, Group, Class (SNI/NACE)**	2010	2013	Diff.
1. Crop production	20 310	18 668	-1 642	**1.1 Growing of non-perennial crops**	24 174	23 703	-471
- 11 Field crops	18 596	16 753	-1 843	**1.2 Growing of perennial crops**	682	791	109
- 12 Vegetables- ornamental- and nursery plants	741	885	144	**1.3 Plant propagation**	509	534	25
- 13 Fruit and berries	370	403	33	**1.4 Animal production**	27 564	28 103	539
- 14 Mixed crop production	603	627	24	**Including**			
2. Animal husbandry	20 687	19 679	-1 008	**- 1.41 Raising of dairy cattle**	6 693	6 574	-119
- 21 Cattle	15 459	13 770	-1 689	**- 1.42 Raising of other cattle and buffaloes**	8 958	8 892	-66
211 Dairy cows	5 032	4 042	-990	**- 1.43 Raising of horses and other equines**	4 162	4 199	37
212 Beef cattle	10 060	9 307	-753	**- 1.44 Raising of camels and camelids**	16	36	20
213 Mixed	367	421	54	**- 1.45 Raising of sheep and goats**	3 016	3 231	215
- 22 Sheep	2 874	3 597	723	**- 1.46 Raising of swine/pigs**	1067	1 000	-67
- 23 Pigs	599	501	-98	**- 1.47 Raising of poultry**	501	538	37
- 24 Poultry	194	180	-14	**- 1.49 Raising of other animals**	3 151	3 633	482
- 25 Mixed animal husbandry	1 561	1 631	70	**1.5 Mixed farming**	60 450	70 093	9 643
3. Mixed farming	5 048	4 301	-747	**1.6 Support activities to agriculture and post-harvest crop activities**	5 220	7 018	1 798
9. Small farms	25 046	24 498	-548				
Total	71 091	67 146	-3 945	**Total**	118 599	130 242	11 643

Figure 1 presents the share of agricultural holdings, in the FR, in each type of farming that is possible to match against the BR. Among the agricultural holdings with pig production or dairy

[1] In the Business Register an enterprise is regarded as active if it is registered for VAT and/or has employees and/or if it is registered for F-tax (business tax).
[2] The number includes both enterprises classified as active and not active.

cows, 97 % and 96 % respectively could be matched against the BR in 2013. Almost 24 500 agricultural holdings in the FR are classified as Small farms. Among this type of farming only 64 % was found in the BR.

Figure 1:*The share of each type of farming in the FR, obtained by matching FR and BR*

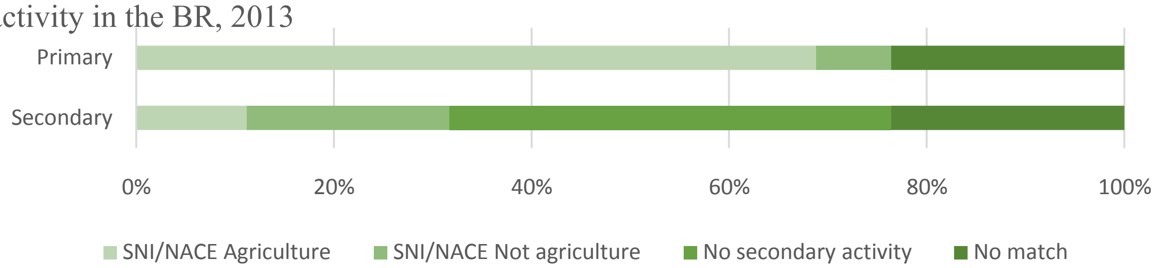


Type of farming may not be the same in the FR and in the BR due to the different classification methods. Among the 97 % holdings with pig production in the FR that could be matched with the BR, 64 % were found in the corresponding economic activity of 1.4.6 Raising of swine/pigs in the BR. 30 % of the holdings with pig production was classified as 1.5.0 Mixed farming. In total, 39 % of the agricultural holdings in the FR thatcould be matched against the BR are found in 1.5.0 Mixed farming in 2013. Bear in mind that the FR has several mixed farming types, see Figure 1. Among the 39 % of the agricultural holdings in the FR that were found in the economic activity of 1.5.0 Mixed farming, about 50 % are classified in some of the mixed farming types.However, the remaining part had a more specified type of farming in the FR compared with the BR.

4.3 Other gainful activities

In the BR, 55 165 agricultural holdings or 42 % had an activity that is not agriculture. The type of farming where the highest share had another activity was Raising of horses, 67 % of the holdings, followed by Support activities for crop production and animal production. In the FR,25 059 or 37 % of the agricultural holdings had registered an OGA in 2013. Mixed crop production and Poultry had the highest share of holdings with OGA, 51 % each. Figure 2 presents the share of agricultural holdings in the FRwithout OGA distributed by primary or secondary activity in the BR. 76 % of the agricultural holdings *without* OGA in the FRcould be matched with the BR. 69 % of the holdings have agriculture as primary activity and the remaining 7,5 % have a primary activity that is not agriculture.

Figure 2: The share of agricultural holdings in the FR without OGA distributed by primary and secondary activity in the BR, 2013



4.4 Employment

In the FR, a total number of 105 543 persons were employedin 2013, not including the business owner.The total number of employees was 57 124 persons in 2013 according to RAMS.

Table 4: *Number of employed in the Farm register and in RAMS*

		Farm register		RAMS	
Number of		2010	2013	2010	2013
Agricultural holdings		71091	67 146	40060	39031
Employment		107837	105543	57487	57124
- of which:	sole traders	92071	88463	41874	41049
	limited company	15766	17079	15613	16075

5. Discussion and conclusion

5.1 Discussion

The results of this paper indicate that the populations in the FR and the BR differ.This is mainly due to the different purposes. The BR is supposed to contain all enterprises witheconomic activities.Meanwhile, in the FR, all agricultural holdings need to be within the specified thresholds to be in the register, regardless of economic impact. In Sweden, the number of agricultural holdings in the BR are significantly higher than in the FR. This indicates that there is a lot of enterprises with relatively small agricultural activities in the BR who are not meeting the minimum thresholds conditions of the FR. Also, a number of enterprises in the BR are, for example, enterprises that have anagricultural income from renting out land. Therefore, contrary to one of the challenges that Watt (2010) struggled with, the thresholds are lower in the BR than in the FR. In the BR, there are also enterprises that raise horses and other animals, including reindeer and pets, included but they are not in the FR. Also, one holding in the FR can be linked to several economic enterprises in the BR.Due to these differences,the number of agricultural holdings is not consistent. Table 1 shows that there is an increase in the number of agricultural holdings in the BRbetween 2010 and 2013. The main reason for this is methodology changes regarding activity status. In 2010 a large number of enterprises were disconnected from their economic activity (NACE).In 2011 the rules changedagain meaning that most of the disconnected enterprises werereconnected to the economic activity, increasing their numbers.Thisindicatesthat a number of the enterprises contributes very little to GDP and that they areone the vergeof beingexcluded from the BR.

Table 3 presents that a large share of the agricultural holdings in the BR are classified as Mixed farming (NACE 1.5). Also, 39 % of the holdings in the FR thatcould be matched against the BR were classified as Mixed farming while at least half of them had a more specified type of farming in the FR. This means that the NACE classification quality in the BR can be improved by using the FR data on type of farming. Table 3 also presents the number of holdings with dairy cows.

In the FR, the number of holdings with dairy cows is collected from administrative registers at the Swedish Board of Agriculture. These are extremely reliable because each head of cattle is labeled and belongs to a given place of production and the cattle register has been merged with registers of agricultural holdings delivering milk. Table 3 indicates that the BR probably overestimatesthe number of holdings with dairy cows, perhaps due to lack of updated NACE codes. Figure 1 presents that almost all of the holdings with milk cows in the FR are found in the BR. This example also indicates that the NACE classification quality in the BR canbe improved by using the FR data.

Comparing the total share of holdings with OGA in the FR to economic activities beyond agriculture in the BR,there are no big differences between the registers.Figure 2 presents that 7.5 % of the agricultural holdings in the FR that did not report an OGA in the agricultural census did have a primary activity which was not agricultural in the BR. This indicates that there is a possibility to improve the OGA variable for some of these agricultural holdings. It also indicates that there is a possibility to reduce the response burden and improve the quality of OGA for each of the agricultural holdings in the FR that can be matched with the BR due to the information on primary and secondary activities.

Table 4 presents thatthe number of employees in limited companies are quite similar in FR and RAMS. This can be explained by the fact that limited companies to a greater extent are registered firms with payed employees. This makes it possible to reduce the response burden and increase the quality of the employment variable in limited companies.

5.2 Conclusion

In order to use information from the BR in the next agricultural census round, the ideal situation would be if the registers where completely harmonised. However, that is not realistic to expect due to:

- the FR and the BR having different purposes,
- different base regulationsand thresholds andtherefore
- the definition of an agricultural holding, type of farming etc. is not identical.

However, the resultsof this paper show that:

- It is possible to improve the quality in NACE classification of enterprises in the BR with the information from the FR and in that way facilitate the merging of the registers
- The information on non-agriculturalactivities in the BR can be used to reduce the response-burden regarding OGA for some agricultural holdings in the agricultural census and possibly reduce the non-response rate
- It is possible to use the number of employees in limited companies from RAMS to reduce the response-burden in the agricultural census

The results also show that users need to be aware of the differences between the registers in order to make evidence-based decisions on agriculture.

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Strategy for Agricultural Statistics 2020 and beyond: for the future European Agricultural Statistics System (EASS)

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ABSTRACT

Many important policies of the European Union, such as the Common Agricultural Policy, depend on agricultural statistics. These statistics need to be of high quality, coherent, comparable and flexible, and should be produced efficiently based on users' needs in order to best serve evidence-based policy making and monitoring. The current EU agricultural statistics system does not fulfil these requirements well enough. To address this, Eurostat launched the "New legislation on Agricultural Statistics for a strategy towards 2020 and beyond" initiative in 2014. It aims to introduce two new legal frameworks stepwise: an "Integrated Farm Statistics" Regulation which will provide the basis for collecting farm level micro-data, based on a modular approach with core, module and ad hoc surveys; and a "Statistics on Agricultural Input/Output" Regulation which will provide aggregated statistics in tabular form. These frameworks will contain basic elements such as scope, precision and quality requirements and will use common definitions and classifications, while more technical elements will be covered by secondary legislation. EU Member States will be free to choose data sources, including administrative and other new data sources.

This paper presents the Strategy for agricultural statistics 2020 and beyond and shows its suitability to meet technical and methodological requirements as well as to successfully navigate the complex institutional, legal and political context within the European Union and its 28 Member States. It can therefore serve as an instructive example for a cross-border implementation of the United Nations Global Strategy to improve agricultural and rural Statistics.

Keywords: Global Strategy to improve agricultural and rural statistics, modernisation, flexibility, comparability

1. Context of European Union agricultural statistics

The current European Agricultural Statistics System (EASS) has been developed since the early 1950s. Agricultural statistics are the oldest European Union (EU) statistics still being produced, many of them provided under legal obligations. The EASS covers more than 50 data sets sent to Eurostat, the statistical authority of the EU, by National Statistical Institutes (NSIs) or other national statistical authorities (ONAs). It consists of seven statistical domains: structural data, agri-monetary statistics, crop production, organic farming, permanent crops, animal products and livestock, and agri-environmental indicators. The Farm Structure Surveys (FSS) with a decennial agricultural census and regular interim sample surveys form the backbone of the EASS, because they are its biggest individual collections and provide reliable data on the structure of agricultural holdings in the EU. This makes it possible to analyse the state of EU agriculture, monitor changes, trends and policy impacts, and build statistical farm registers.
The main aim of the EASS is to support decision-making, policy design, implementation, monitoring and evaluation in several policy areas related to agriculture, such as the EU Common Agricultural Policy (CAP), climate change and environmental policies. Agriculture accounts for almost 40% of the EU's institutional budget (currently about 59 billion Euro annually), the EU's single highest common expenditure area, and covers 47% of the EU's territory, resulting in a very high environmental impact.

The EASS needs to fulfil a number of **requirements** because it is a part of global, regional (EU) and national agricultural statistics systems. In order from global to national, these are:

- Implement the United Nations **Global Strategy** to improve agricultural and rural statistics. This initiative aims to improve the availability and use of agricultural and rural data necessary for evidence-based decision making by 1) producing a minimum set of core data, 2) better integrating agriculture into national statistical systems and 3) improving governance and statistical capacity building (GSARS 2016).
- Support the monitoring and evaluation of the **United Nations Sustainable Development Goals** (SDG) by providing high-quality, coherent and comparable agricultural data for the SDG indicator framework (ECOSOC 2016).
- Serve **users' information needs** by producing high-quality, coherent, comparable and flexible agricultural data for the effective and efficient design, implementation, monitoring and evaluation of policies, laws and other interventions. These users are mainly policy- and decision makers at EU, national and regional levels, but also scientific researchers, businesses and citizens.

In addition, certain global, regional and national changes are acting as **problem drivers** for the EASS, exerting pressure on it to respond in order to continue fulfilling its main functions. These drivers are:

- **Changes in world agriculture** such as volatility in prices and food safety and security, changing dietary habits, e.g. Asia's growing appetite for dairy and meat, a growing and increasingly less poor world population requiring more food (60% more by 2050, according to the Food and Agriculture Organization of the United Nations (FAO)), increasing urbanisation leading to significant consequences for food consumption and food flows, and increasing agricultural concentration. These phenomena are particularly important for the EU, as agricultural exports from its 28 Member States amounted to 120 billion Euro in 2013 (in particular value-added products), with imports of just over 100 billion Euro (concentrated around animal feed and tropical products). The increasing global interconnectedness of agricultural production structures, prices, yields and supply chains can lead to complex "butterfly effects" and calls for detailed data in this area to make rapid crisis responses and generally more effective policy making possible.

- **Climate change and environmental effects** will impact food security, while more frequent extreme weather events such as droughts, floods and ensuing possible conflicts are expected to lead to food shortages and volatile prices. As agriculture has a strong environmental and climate change impact and is itself strongly affected by climate change, a thorough knowledge of what is produced where by whom and how is needed to target agricultural, environmental and related policy interventions to where they are most needed. Therefore, good data on these aspects of agriculture is needed to enable environmentally sustainable action, such as a low-carbon transition in rural areas. Moreover, the links between agriculture, the environment and the climate are complex and dynamic, and the impact of agricultural practices and products on human and animal health and welfare is strong, but not fully understood yet. Depicting all these interlinkages requires a lot from statistics.
- **The CAP has recently been reformed** and will continue to be reformed in response to changing national, European and global conditions and evolving policy. Some examples are the growing popularity of organic food, the abolition of milk quotas, and the increasing diversity of EU agriculture. The European Commission's recent work on developing the CAP for 2014-2020 demonstrated the central role of statistics in designing, implementing, monitoring and evaluating this policy. Reforms of the CAP and other relevant EU policies should therefore be reflected in agricultural statistics data collection.
- **Official statistics are also changing**. New data sources such as administrative data, various registers, results of research projects and Big Data have become more readily available. Information and communication technology and other new technologies enable modernised data collection. At the same time, national and EU budgets are more constrained, and calls to reduce the burden of data collection and production are becoming more frequent. These changes in the sources and ways of collecting and producing data require changes in the framework for agricultural statistics so they can stay up to date and avoid becoming obsolete, inaccurate or too costly.

All these developments put pressure on adapting the EASS to respond to the important growing and changing requirements and objectives. But despite many integration and modernisation efforts, the **EASS has not changed enough** yet, as a recent ex-post evaluation and problem analysis found:

- New and emerging data needs are not addressed adequately because their provision is not included in the legislative acts, the acts are not flexible and integrated enough to respond to new needs in a timely manner, and changes in official statistics are not accounted for;
- The EASS is not flexible enough and is not reacting quickly enough to emerging needs, partly due to the inherent functioning of statistics, partly due to the way the regulations have been set up, but also because of a lack of budgetary and human resources;
- The data collections are not harmonised and coherent enough because new data needs are emerging, legislation has been developed separately over many years, and there are partly different definitions, concepts and aims in different agricultural domains;
- Agricultural statistics could be produced more efficiently if the legislation is adapted so that various sources of information can be used and if Member States adopt more modern technology, but the burden and cost are appropriate considering the substantial budget of the CAP and its impact on the social, economic and environmental situation in agriculture;
- The burden of providing data is perceived as high because data needs are increasing, data collection is not harmonised, and resources continue to shrink both at EU and national level.

If these problems remain unaddressed, and the requirements detailed above therefore only partly fulfilled, continuing changes in global agriculture, the global climate, the CAP and official statistics will make the current EASS progressively obsolete and less useful. This will have more and more urgent and far-reaching consequences for Eurostat, the EU and Member States' policies, reputations and positions in a highly dynamic global order.

Therefore, the **legal basis of the EASS** needs to be updated to respond to these challenges. This is because European statistics are produced within the European Statistical System (ESS), a partnership between Eurostat and the NSIs for the development, production and dissemination of European statistics. In general, NSIs and/or ONAs collect and produce these statistics according to EU-wide statistical regulations prescribing variables, deadlines, methodologies and other aspects of statistics production in order to achieve harmonisation, comparability and full coverage. The NSIs then disseminate the data and send them to Eurostat, which validates them and disseminates official European statistics on its website. Within this system, new proposals for statistical regulations at EU level are discussed at expert, director and Head of NSIs level before they are adopted by the European Commission, the EU's executive. The draft proposal then enters the "ordinary legislative procedure" of the EU, in which the European Parliament (elected representatives from all EU Member States) and the Council of the European Union (ministers of the concerned departments from all EU Member States) discuss, possibly change and agree on laws so they can enter into force. In addition, assigned committees and the Commission can adopt "implementing acts" specifying implementing rules and details of EU laws, and the Commission is additionally empowered to adopt "delegated acts", i.e. acts that supplement or amend non-essential elements of legislative acts.

2. Strategy for Agricultural Statistics 2020 and beyond

2.1. Objectives

In response to the requirements, problem drivers and problems of the EASS and to benefit its main stakeholders, Eurostat developed the agricultural statistics strategy for 2020 and beyond in 2014, with the following specific objectives:

- Produce high-quality statistics that meet users' needs efficiently and effectively. The EASS needs to deliver the statistical knowledge base needed for the CAP and other important EU policies, while reacting to evolving data needs. The scope of agricultural statistics should be widened to include e.g. land cover, and the data must be validated in a streamlined way.
- Increase the flexibility and reaction speed of the agricultural statistics system. It should be possible to introduce new needs, statistics and methodological approaches in an easier and more responsive way. In line with the subsidiarity principle, the exact form of data collection, e.g. the choice of preferred data sources and survey methods, is up to the Member States.
- Improve the integration between agricultural, forestry, land use and environmental statistics. The EASS needs to interact with and be linked to other statistical domains, for example primary production, environmental, social and economic statistics.
- Develop a responsive and responsible governance structure for agricultural statistics. The EASS needs periodic performance assessments to ensure that it is fit for purpose, delivered within a proactive and efficient governance structure that represents the interests of data users and data providers in the ESS context.
- Improve the harmonisation and coherence of European agricultural statistics. The EASS needs a solid shared basis of common definitions and concepts to link the existing statistical domains. Furthermore, statistical thresholds need to be recalibrated to improve coverage and lower the burden of data collection, and administrative and other data need to be reused.

- Produce more statistics while lowering the burden on respondents by exploring alternative data sources and possibilities to improve efficiency. Data sets that are possibly no longer needed should be deleted, and modern information and communication technology should be used to lower the perceived burden of data collection and production.

2.2. Two-step integration approach

To achieve these objectives, Eurostat developed several possible policy options and formally analysed them based on several criteria such as legal, technical and political feasibility, coherence with other EU policy objectives, and effectiveness and efficiency. In the end, it was determined that a two-step integration process for agricultural statistics would best achieve the stated objectives.

This means that two new framework regulations will be introduced stepwise: an Integrated Farm Statistics regulation (IFS) to be in place before the end of 2018 to ensure the agricultural census scheduled for 2020, and another framework regulation on Statistics on Agricultural Input and Output (SAIO) to be adopted and in place before 2022. Together, both framework regulations will cover all aspects of the new statistical programme for agriculture and replace nine current laws. The basic legal acts include common objectives and definitions (periodicity, scope, precision etc.) and also specify, in general, the required core statistical outputs. Secondary legal acts will define technical elements necessary for a harmonised implementation of the basic acts such as descriptions of characteristics. The European Commission will have the power to amend non-essential elements of the basic act in order to ensure the flexibility needed to respond to changing policy and data needs.

The IFS regulation will provide a legal basis for the structural data on farms, including certain more detailed data on permanent crops. In addition, parts of agri-environmental statistics, for which data are needed at farm level (such as irrigation, manure or nutrient use), will be integrated into this framework regulation, as they are presently not under legislation. All IFS data will be sent to Eurostat as micro-data.
The SAIO regulation will contain aggregated crop and animal production statistics, agri-environmental statistics on fertilisers, nutrient balances and pesticides, and potentially agricultural price statistics. All these data are aggregated statistics, and no micro-data will be sent to Eurostat. They deal with agricultural inputs (prices of feed, pesticides etc.) and outputs (crop and animal production and prices). The data can be collected from farms, administrative sources, intermediaries, wholesale entities, market organisations and other sources, and can include a certain amount of expert estimates.

2.3. Methodology

Following the approach recommended by the FAO's World Programme for the Census of Agriculture 2010 (FAO 2005), both framework regulations will consist of (i) a core set of data (essential structural and production variables, e.g. farm size and land use, crops, livestock), which are to be sent to Eurostat with regular frequency (i.e. every three years), depending on the domain, either resulting from a census or a sample survey, on farms above a minimum threshold; (ii) modules that are subsamples of the core and focus on certain thematic aspects from the current list of variables (such as animal housing, irrigation or vineyards) that are needed either at lower frequency (i.e. every six or every ten years), for smaller samples, or at different thresholds than the core, but which can be directly linked to the core data and shall always be conducted together with the core; and (iii) flexible ad-hoc surveys that focus on special topics which are not traditionally part of the EASS, i.e. surveys which aim to cover the variables that fulfil new and emerging data

needs. Their exact contents will be determined later, prior to their implementation, and they are not planned to be carried out at a fixed frequency, but may be repeated as needed.
An agricultural census is needed because it is still the most appropriate way to update information on the full agricultural population in the EU. The census is the only data collection instrument that produces sufficiently reliable statistical information on farms at the lowest geographical level, and is therefore an essential source of information for governments and decision-makers. The FAO also expects its member countries to follow the standards, concepts and definitions guidelines of its World Programme for the Census of Agriculture 2020 in order to achieve harmonised and internationally comparable results and allow countries to benchmark their performance against other countries, among other advantages (FAO 2015). This and other international obligations detailed above are further reasons explaining the need for an agricultural census. However, in order to reduce the burden on the countries with a high number of very small farms, or rather households, it is planned not to oblige carrying out a census on these small units, but to allow carrying out a sample survey instead. In addition, the core, module and ad-hoc survey structure is expected to lead to a reduction of the burden of data collection on all EU Member States while fulfilling all obligations. For the census carried out under IFS, these actions are expected to lead to a reduction in the number of farms surveyed of around 30% overall (3.5 of 12 million farms), and to a reduction of the total required budget of around 18% (56 of 320 million Euro).
In order to further reduce the burden on the farmers and other respondents, the various elements of agricultural statistics should form a statistical system. i.e. data collected for production statistics, permanent crops statistics and organic farming statistics should also be used for farm structure surveys. Member States are also encouraged to use administrative data sources and to set up farm registers, and efforts are being made to harmonise definitions and reference periods across data sources. For this systematic approach to work, definitions need to be identical, and unique farm identification numbers should be introduced.

3. The future European Agricultural Statistics System

The two-step integration of agricultural statistics serves to create an effective and efficient future EASS by fulfilling the requirements and the objectives detailed above, while navigating various complex contexts and constraints, in the following manner.

Table 1: *Requirements, objectives and responses of the agricultural statistics strategy 2020*

Requirement	Response
Implement the UN Global Strategy to improve agricultural and rural statistics	– Collection of better integrated core data – Improved governance and self-assessment
Support monitoring and evaluation of the UN Sustainable Development Goals	– Collection of new and emerging data needs – Focus on data quality and validation – More legal flexibility, coherence and speed
Serve information needs of EASS users	– Collection of new and emerging data needs – Focus on data quality and validation – More legal flexibility, coherence and speed – Frequent, regular exchanges with stakeholders
Navigate the legal system of the EU	– Two-step instead of single-step integration to achieve needed new FSS legislation faster – Balanced legal architecture respecting concerns

	– Frequent, regular exchanges with stakeholders – Improved governance and self-assessment
Respect subsidiarity and proportionality	– Strategy confined to minimum required – Method of data collection left up to Member States
Objective	**Response**
Produce high-quality statistics that meet users' needs efficiently and effectively	– Collection of new and emerging data needs – Method of data collection left up to Member States – Focus on data quality and validation – More legal flexibility, coherence and speed
Increase the flexibility and reaction speed of the agricultural statistics system	– More legal flexibility, coherence and speed – Method of data collection left up to Member States
Improve ntegration between agricultural, forestry, land use and environmental statistics	– Common definitions and documentation – Unique identifiers and new data sources – Frequent, regular exchanges with stakeholders
Develop a responsive and responsible governance structure for agricultural statistics	– Improved governance and self-assessment – Frequent, regular exchanges with stakeholders – More legal flexibility, coherence and speed
Improve the harmonisation and coherence of European agricultural statistics	– Common definitions and documentation – Unique identifiers and new data sources
Produce more statistics while lowering the burden on respondents by exploring alternative data sources and possibilities of efficiency improvement	– Core, modules and ad-hoc survey system – New thresholds and special sample surveys – More use of IT, new data sources, fewer variables – Frequent, regular exchanges with stakeholders

4. Conclusions

The following general conclusions and recommendations can be drawn from the European Commission's experience in developing and starting to implement the agricultural statistics strategy 2020.

- Bold reform can lead to better outcomes than a more incremental approach, even in a complex political, legal and financial context. This also gives a better opportunity for needed changes and improvements.
- Change is necessary to remain relevant. Agricultural statistics are affected by many important and significant global developments, and the world is becoming much more interconnected and complex. This requires faster and more flexible reactions, tools and procedures from official statistics, or they risk becoming obsolete and not fulfilling their data users' needs.
- Even in statistics, political considerations need to be taken into account when designing new laws and initiatives. For example, EU Member States are sceptical of European Commission powers to adapt elements of the legislation, but these are needed to ensure the required flexibility of the agricultural statistics strategy 2020. Therefore, a compromise was struck to preserve flexibility while ensuring easier legislative passage of the IFS initiative.
- The difficult resource situation of many national governments and NSIs needs to be taken into account from the beginning in designing, implementing and evaluating statistical systems so the best possible performance, flexibility and data quality can be ensured even under heavy constraints. The EASS' Strategy 2020 is meant to accomplish

this with its structure of core, module and ad-hoc surveys and several other actions. A plan not adapted to such conditions, while possibly more attractive on paper, may not be able to deliver as well as a system better adapted to reality.

- Comparable and coherent outputs count for more than homogenous inputs, especially in a highly diverse situation as in the EU with 28 Member States that have very different agricultural, social and economic development levels, survey methods, databases and data sources, statistical traditions etc. Data collection can be conducted with the subsidiarity principle in mind in ways that are best suited to regional or national conditions, while harmonisation and comparability can be achieved by common definitions and validation at supranational or intergovernmental level.
- Cooperation and a good working atmosphere can go a long way towards making even difficult decisions more palatable than if they had been presented as *faits accomplis*.

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Harnessing data revolution for cost-effective agricultural censuses in the 21st century with widely accessible and used results

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ABSTRACT

Data revolution is defined as *'an explosion in the volume of data, the speed with which data are produced, the number of producers of data, the dissemination of data, and the range of things on which there is data, coming from new technologies such as mobile phones and the 'internet of things' and from other sources such as qualitative data, citizen-generated data and perceptions data'*. The other associated feature is '*a growing demand for data from all parts of society*'[1].

This emerging development will have a growing impact on all major statistical data production activities in coming years, including the Census of Agriculture. The Data Revolution raises challenges but also offers unprecedented opportunities to modernize the process of conducting a Census of Agriculture. In this 21st Century, statisticians have access to a variety of methods and tools that was not available before for conducting a census of agriculture. If used appropriately, they can generate significant efficiency savings and provide timelier and better quality data which can be widely accessed and used by a variety of users.

In a context of growing demand for more diversified and frequent data and at the same time the scarcity of resources for census taking, the new tools and methods can be used to address the new challenges for ensuring that the census is conducted in the most relevant and cost-effective way. This requires taking a fresh look at the concept of census of agriculture, the overall strategy and

[1] The UN Secretary-General's Independent Expert Advisory Group on a Data Revolution for Sustainable Development (IEAG) report A World That Counts: *Mobilising The Data Revolution for Sustainable Development*.

modalities of designing and conducting a census of agriculture in order to use innovative options for more relevant and efficient census operation.

The availability of digital and mobile computing tools for data capture using smartphones or tablets, geo positioning tools such as handheld GPS devices and more precise and cheaper remote sensing images can provide cost-effective alternatives to traditional way of collecting, centralizing and processing data depending on country situation. Also the increasing use of other sources of data such as administrative sources in a growing number of countries can complement (or even partially replace field data collection for a number of items) and reduce census burden and cost.

The FAO World Programme for Census of Agriculture 2020 in its forthcoming Volume 2 on Operational Guidelines on Implementing the Census of Agriculture will provide specific guidance on various modalities for conducting the Census in the next decade as well as the use of new tools and methods.

This paper will discuss the challenges and opportunities of the Data Revolution and its potential impact for designing and implementing a cost effective Census in the 21st Century in a context of growing demand for more complex and inter-linked data particularly for monitoring the newly adopted Sustainable Development Goals by the United Nations. The paper will refer to selected country experiences of agricultural censuses using new and innovative methods that take advantage of the on-going data revolution.

Keywords:

Data revolution, Census of Agriculture, Cost effectiveness, open data

Introduction

Data revolution is defined as ‘an explosion in the volume of data, the speed with which data are produced, the number of producers of data, the dissemination of data, and the range of things on which there is data, coming from new technologies such as mobile phones and the ‘internet of things’ and from other sources such as qualitative data, citizen-generated data and perceptions data’. The other associated feature is ‘a growing demand for data from all parts of society’[2].

However, the (UN report, 2014) indicates that ‘People, economies and societies are adjusting to a world of faster, more networked and more comprehensive data – and all the fears and dangers, as well as opportunities, that it brings’ . To remain relevant and cost effective, the implementation of an Agricultural Census in coming decades must take into account this new data and technological environment. Some of the dimensions and features of the data revolution relevant for census of agriculture include: (i) The availability of multiple data sources and their potential use in agricultural census, (ii) the use of technological innovation for data collection and faster processing (iii) the availability of tools and methods for wider dissemination, faster, easier and safer access to census data (aggregated and microdata) and metadata. The sections below will discuss some aspects of these three features as they relate to the census of agriculture.

[2] The UN Secretary-General’s Independent Expert Advisory Group on a Data Revolution for Sustainable Development (IEAG) report *A World That Counts: Mobilising The Data Revolution for Sustainable Development*.

1. Availability of multiple data sources and census modalities

One of the main features of the ongoing data revolution is the increasing number of data producers and data sources in general. This new data environment has an impact on data production strategies to better respond to the challenge of limited resources for statistical activities and growing demand for more quantity and diversified data to be produced more frequently. This challenging data requirement implies the use of multiple data sources and data collection modalities.

The new 2030 Sustainable Development Agenda (SDA) adopted by the UN in September 2015 defines 17 Sustainable Development Goals (SDGs) and 169 individual targets, including 19 multidimensional agricultural-related SDG targets and 25 global indicators for monitoring the progress towards the goals and targets. Many of these indicators require a diversified data sources for their compilation beyond traditional censuses and surveys. Administrative records for example will be an important source of some data requirement.

The changing environment and data requirements have led some countries to conduct a detailed review of their agriculture statistics programme, including alternative options for conducting the agricultural census. For example, a report by Statistics Canada on agriculture statistics program review (StatCan, 2012) includes a detailed evaluation of several options for conducting the census of agriculture within the agriculture statistics program. The evaluation uses criteria based on the six main dimensions of data quality[3] and other criteria such as respondent burden, cost, operations[4] and acceptability by user community and respondent community. The study concludes that the census of agriculture remains relevant and necessary but, regardless of the option chosen, changes are needed in order to render the program more efficient. The changes proposed include increasing the use of administrative data to gradually replace survey data and increasing utilization of remote sensing applications with a view to replacing survey items or entire surveys over the longer term.

The guidelines for the new World Programme for Census of Agriculture 2020 prepared by FAO also takes into account the new data and technology environment and proposes various modalities and data sources for conducting the census of agriculture in the next decade. The guidelines recommend that the census of agriculture may be carried out using different approaches and in various ways, depending on available resources and national conditions. The following four modalities for conducting a census of agriculture are recommended:

(i) *classical approach* in which a census is conducted as a single one-off operation in which all the census information is recorded;

(ii) *modular approach with a* core module by complete enumeration and supplementary module(s) on sample basis, using information collected in the core module as the frame for the supplementary module(s) and conducted shortly after the core module ;

(iii) *integrated census and survey modality* with a census core module (which could be lighter than in the modular approach) to be carried out on a complete enumeration basis and rotating thematic modules to be conducted annually or periodically on sample basis over a longer period between two censuses (usually ten years) through a permanent agricultural survey programme such as the Agricultural Integrated Survey programme (AGRIS); and

(iv) *combined census with* use of registers and administrative records as a source of part of the census data.

It is considered that regardless of the census modality and way of conducting a census, the crucial principle is to achieve the main objectives[5] of a census of agriculture depending on country

[3] Relevance, accuracy, coherence, timeliness, interpretability, and accessibility

[4] Defined as ability to react quickly to new demand, ability to conduct large occasional surveys, timing and compliance with StatCan Business architecture.

[5] To provide **data on the structure of agriculture, especially for small administrative units**, to provide **data to use as**

statistical capacity, national preferences and the availability of resources and data sources. The increasing use of multiple sources in census programmes is one of the changes that will be adopted by many countries in coming agricultural censuses.

2. Use of technological innovation for more relevant and cost effective census

Another important feature of the data revolution is the explosion of technological innovations. The following tools and emerging technologies are some of the innovations that are directly relevant to the design and conduct of agricultural census. They have the potential to allow faster, better quality data collection and processing during an agricultural census at reduced cost. The upcoming FAO guidelines and many recently published guidelines under the Global Strategy initiative and other sources provide practical guidance on the use of these tools and technology. This section discusses some of the main tools and technology relevant to the conduct of agricultural census.

Remote sensing (RS)

Remote Sensing refers to 'images acquired with a conventional camera or electronic sensors from aircraft or satellites. The techniques applied to process and interpret remote sensing imagery include visual photo-interpretation and a wide range of numeric algorithms' (Global Strategy, MSF, 2015).

According to (Delince, J, 2015), there are five main areas of use of Remote Sensing (RS) and aerial photos for agricultural statistics:

- Monitoring Land cover/Land use
- Frame construction
- Support to field work of censuses/surveys
- Crop area estimation
- Crop yield forecasting/monitoring**.**

The most relevant uses of RS and aerial photos for the census of agriculture are cartography and frame building, supporting field work and crop area estimation.

<u>Census frame construction and updating</u>*:* Many countries use enumeration area (EA) maps derived from the cartography work of the population and housing census (PHC) as basis for building the frame for the agricultural census. One of the main products of the PHC cartography and mapping work is a set of EA maps which are large scale maps delineating accurately the area of work of enumerators and covering the entire country. Also, a listing operation is usually conducted during the cartography of PHC. Recent and high resolution satellite images or aerial photos can provide enough details (population density, infrastructure etc..) to support the preparation and updating of EA maps. They facilitate observance of the usual enumeration area properties such as completeness, non-overlap, respect of administrative divisions, accurate delineation and allocation of attributes (Delince, J. 2015). These EA maps from PHC cartography, together with all other information collected (for example number of households or households practicing agriculture) can be used for building the frame for agricultural census based on list frame when this operation is conducted not too far from the PHC.

Satellite images can be also used to identify and subdivide the agricultural land (stratify) by intensity of land use and other land cover characteristics and therefore help in the construction of area sampling frames when this type of frame is used in the agricultural census.

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benchmarks and to provide **frames for agricultural sample surveys**.

As indicated in (Global Strategy, MSF, 2015) recent developments have seen the emergence of some companies in the information technology sector that produce public-access images with global coverage **(Google Earth, Bing)**. A major advantage is these images are available and easily accessible, with an efficient interface. Most agricultural areas of the world are covered by Very High Resolution (VHR) images which is a significant advance, especially for countries that could not access such images in the past.

Support to field work*:* Recent advances regarding Satellite images or aerial photos can help the enumerator to optimize his travel and facilitate localization of farmers and fields during the field work of the agricultural census. Aerial photos or very high-resolution imagery can help the enumerators to access the land and/or locate the holder. Used as paper prints or on a tablet, imagery can also be used to check on farmer's declaration and minimise measurement errors.

Crop area estimation**:** The two main methods used to derive crop area statistics from remote sensing (Delince J, 2015) are: Pixel counting which is the more direct way of area estimation and Calibration methods for integration of field surveys data and image classification results. However, todate, the operational use of these methods remain limited.

During the recent census of agriculture of Morocco (2015/2016), an extensive use of orto-photos was made during data collection as these photos were considered precise enough (spatial resolution of 30 cm) to identify boundaries of holdings and their plots[6]. The scale of the orto photos was 1/5000, with photos covering an area of 3 km X 4.5 km (about 1350 ha). Below is an example of orto-photo displaying the delineation of one holding composed of one parcel and plot.

Source: Ministère de l'agriculture et de la pêche du Maroc (2015)

[6] The average farm-size is 1.6 hectares in Morocco, according to (USAID Country profile for Morocco: http://www.usaidlandtenure.net/sites/default/files/country-profiles/full-reports/USAID_Land_Tenure_Morocco_Profile.pdf)

Global Positioning System (GPS)

The global positioning system (GPS) is the oldest and best known global navigation satellite systems (GNSS). A GNSS is a system based on a network of navigation satellites that is controlled by ground stations on Earth which continuously transmit radio signals – captured by receivers – to determine the receiver's geographical location (longitude, latitude, and elevation) on the Earth's surface (Global Strategy, MSF, 2015).

The expanded availability, low cost and improved accuracy of handheld GPS devices provide an opportunity to support field activities during a census of agriculture: geo-referencing plots, household or headquarters of holdings; locating sample units or measuring the area of a plots.

Geo-referencing **:** In addition to its use during the cartographic operations to geo-reference boundaries of EAs, GPS can support enumerators during data collection. For each enumeration area, headquarters of holding units can be identified using GPS coordinates on handheld GPS devices or mobile digital device equipped with GPS. When integrated in EA maps, this information can significantly facilitate the field work of the enumerators. A more extensive elaboration on the use of GPS is available in the (UNSD, 2009).

Measuring plots with GPS: GPS is very useful to measure the area of plots on the field and recent studies (Carletto et al., 2015) suggest that technological advances with moderate-priced GPS have led to significant improvements in accuracy of measurements even for small plots. GPS can also be used as a tool for quality control, for point location control in objective yield surveys when used during the census.

Computer Assisted Personal Interview (CAPI) on laptops or notebooks, tablets and Smartphones:

With increased capacity of mobile electronic devices (such as laptop computers, tablets, Smartphones, etc..), large geographical coverage of internet and mobile phone networks and availability of suitable packages, data collection activities during censuses and surveys does not have to rely only on paper questionnaires. In fact, a comprehensive study conducted by (Caeyers, B. and all, 2010) using a randomized survey experiment among 1840 households, designed to compare pen-and-paper interviewing (PAPI) to computer-assisted personal interviewing (CAPI) found 'that PAPI data contain a large number of errors, which can be avoided in CAPI'. A growing number of countries are now using CAPI in data collection activities. An overview of the use of CAPI for agricultural census is provided below[7].

Data capture: Mobile electronic devices with adequate CAPI software can be used to directly capture data in the field, using electronic questionnaires. The electronic questionnaires usually contain the same questions types like on paper questionnaires, but also some new question types not available with PAPI. Some CAPI applications allow the capture of the geo-coordinates of the statistical units, take photos, and scan and record barcodes of items which are present within the statistical unit.

Field data editing and validation: The use of CAPI facilitates the implementation of skip patterns through 'enablement conditions' which are pre-programmed instructions, activating or deactivating questions based on the answer to a previous question. CAPI also provides census and survey designers with validation conditions which are pre-programmed instructions that anticipate an answer to be in a certain range and showing a message in case the answer does not fall in the range.

[7] The main source of information used for this overview is a technical paper prepared in May 2016 by Michael Rahija, Research Officer at the Global Office of FAO Global Strategy as input to World Programme for Census of Agriculture 2020 Volume 2 (forthcoming).

Data transmission and centralization: The use of CAPI, allows a quick transmission of census data captured to a centralized database for further processing. Data is usually transmitted over cell phone and Wi-Fi networks (available in most tablets) . Some tablet devices offer a slot for a SIM card to access cell phone data networks. Finally, some CAPI applications also offer tools for offline data transmission.

Other use of CAPI include: Geo referencing statistical units using tablet with GPS and use for optimizing logistics and supporting enumerators, using GPS and paradata for monitoring survey progress.

An important benefit of CAPI is the savings in costs related to the use of paper questionnaire: paper and printing cost, logistics and storage cost, cost of computers and personnel for data entry. However, equipment and software costs for CAPI should be considered when comparing to paper questionnaires. This cost may be substantial for a comprehensive operation such as a census of agriculture. Equipments may be also re-used in subsequent surveys resulting in additional savings. Data quality should also be improved thanks to field editing and validation features. Finally, timeliness should be also enhanced with quick transmission and centralization and the absence of any further data entry work.

There may be also some limitations in the use of CAPI for census of agriculture in terms of operational constraints, particularly in developing countries, such as limited field personnel able to operate the electronic devices, poor internet and cellular phone network coverage, poor electricity availability in rural areas for recharging batteries and difficult operating conditions (sun, dust, rain poor light etc.). Other limitations reported include poor visibility of screens, slow processing when volume of data increases. A detailed study and testing is recommended before adopting CAPI in a wide scale operation such as a census of agriculture.

Iran was one of the first countries that have successfully implemented its agricultural census using CAPI on tablets; this was during its fourth Iranian Census of Agriculture carried out from 27 September to 9 November 2014 [SCI, 2014]. In order to collect data from the estimated 4.3 million holdings of Iran, 5550 enumerators were mobilized and 7500 tablets were procured. It is reported that there was substantial cost savings and considerable reduction in time lag between data collection and data availability (preliminary results were available within 6 months). Also, the tablets were to be re-used for several other future surveys (Keita, N. 2015).

Computer Assisted Telephone Interview (CATI) and Computer Assisted Web Interview (CAWI[8])

With the considerable developments in ICT during the past decades, remote data collection methods are increasingly being used in countries where the conditions are favourable, reducing considerably the cost of data collection. CATI and CAWI are two such methods. In CATI, data is collected via telephone interview (respondents are contacted by phone and data is entered into electronic questionnaires) while in CAWI, census notice is sent to respondents with instructions on how to access the web (online) questionnaires with their secure access code, phone number to call for help and how to complete it online. The web questionnaire usually includes navigational help information, drop-down menus and online edits similar to the one based on CATI questionnaires. Skip patterns are built in the web questionnaires so only questions related to the type of farm operations are presented to respondents.

[8] Also known as CASI: Computer Assisted Self Interview

Several countries such as Iceland, Spain, Canada, Poland have used these remote data collection methods in a mixed mode (combined with other data collection methods) during their census of agriculture.

3. Wider access to aggregated data, safe access to micro data and open data

The current environment is characterised by a phenomenal development in computer and software capacity, wider internet connectivity and emergence of standards, protocols, methods and tools for data archiving, safe and on-line access to macro-data and micro data. This new environment has opened a new era for potentially accessing census data both in aggregated form and micro data on an unprecedented scale.

There are now digital preservation standards that make it possible to archive and manage digital data over the long term. More detailed guidance on these standards are available from the International Household Survey Network (IHSN) [9] Principles and Good Practice for Preserving Data.

In addition to the traditional paper publications of aggregated census results, a wide variety of electronic products can be made available and easily accessed as stand alone or via internet to satisfy the needs of a wide range of users.

Macro-data aggregated in statistical tables, in graphical or cartographic forms can be made available to the general public online in databases or on the web pages of the census agencies. Aggregated data may also be disseminated through optical disks (CD-ROM or DVD-ROM) and/or on a pen drives. Data can be visualised (often interactively) using appropriate GIS packages and on cartographic supports such as atlases in printed or electronic format.

There is a growing demand for more open data with possible access to micro-data. For a long time this was not possible in many countries, due to the constraints resulting from the statistical laws (confidentiality of individual information) and lack of standards and technical tool to avoid the risks of statistical disclosure. Nowadays, guidance is available for adopting an adequate legal and policy framework which respects the confidentiality provisions in the statistical law for safe access to micro-data (see see http://www.gsars.org/providing-access-to-agriculture-microdata-a-guide/). Moreover, a lot of progress has been made in terms of technical tools for controlling the risks of statistical disclosure through anonymisation of micro-data to respect confidentiality requirements. Finally a variety of methods for formatting data files for safe access to micro data is available, including Public Use Files, Licensed use files, Remote Access Facilities, Data enclaves, Deemed Employee. Further details on these methods of access can be found at: http://www.icpsr.umich.edu/icpsrweb/content/deposit/guide/chapter5.html

4. Concluding remarks

There are features of the current data revolution that can be an opportunity for conducting cost effectively agricultural censuses in this 21st century to respond to the needs of a wide range of data users. Depending on country conditions, tailored census modality may be considered and technological innovations can facilitate timely data collection and processing. Developments in computer and software capacity, wider internet connectivity and emergence of standards, protocols, methods and tools for data archiving, online access to macro-data and safe access to micro data have created a completely new data and technological environment. This new environment has

[9] International Household Survey Network (IHSN) 2009, Working Paper No 003, Principles and Good Practice for Preserving Data

opened a new era for potentially accessing census data both in aggregated form (macro-data) and micro data on an unprecedented scale. Detailed guidelines are also available on the use of these innovations for agricultural censuses and sample surveys.

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THEMATIC SET

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POST-DISASTER NEEDS ASSESSMENTS AND RAPID ASSESSMENTS TOOLS

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ABSTRACT

As the frequency of hydro-climatic natural disasters increases so do the financial, human and economic costs in the agricultural sector. Over the past several decades, billions of dollars of private and public sector flows have been spent to reduce the impact of such disasters on populations exposed to them. There are both domestic and international sources for such flows. Estimating the requirement for these flows, as well as looking at the responsiveness of these different forms of support and their impact in mitigating the impact of disaster and aiding recovery are important areas of study. This session will be concerned with some of the key issues surrounding financial flows to support agricultural livelihoods in natural disaster contexts. Included within the scope of the session be questions concerning the measurement of damage and loss in the agricultural sector due to natural disasters. As such papers are invited which focus on the following topics and areas:

- What is the evidence for the responsiveness of public aid flows to different kinds of disasters affecting agriculture and how can we measure the impact of these flows on recovery?
- With globalization and the rise of the internet, private remittance flows are becoming a moreand more important component of disaster relief. How can remittances be measured systematically? What kinds of support do they provide to people living in rural areas? What are the critical conditions determining the effectiveness of remittances as a way of reducing vulnerability and aiding recovery from disasters in agriculture?
- What role can social insurance play in disaster mitigation and prevention for agriculturalcommunities, particularly in contexts where formal insurance and credit markets do not work well or at all. How can the impact of such forms of insurance be measured?
- The financial implications of disasters in agriculture and the subsequent needs in terms of thedollar value of recovery are commonly estimated using Post Disaster Need Assessment (PDNA) methodology. What are the limitations of this approach and how can post disaster assessment techniques be improved in practical ways?"

LIST OF PAPERS

Rethinking livestock safety in natural disasters: the way forward with improved social insurance in disaster management in India

S. Nath | Jawaharlal Nehru University | New Delhi | India
S. K. Nath | Central Statistical Organization | Government of India | New Delhi | India
DOI: 10.1481/icasVII.2016.f38

Macro-scale assessment and response to natural disasters. An ODA approach

M.C. Bramati | Sapienza University | Rome | Italy
N. Marsland | FAO | Rome | Italy
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Understanding the impact of post-disaster needs assessment on agriculture sector recovery

D. Barelli | FAO | Rome | Italy
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R. Zapata-Martí | European Union | Brussels | Belgium
N. Singh | Middle East Research Institute | Erbil | KRI | Iraq
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A methodology to assess damage and losses from natural hazard-induced disasters in agriculture

N. Lombardi | FAO | Rome | Italy
S. Baas | FAO | Rome | Italy
K. Caprazli | FAO | Rome | Italy
P. Conforti | FAO | Rome | Italy
C. Raisaro | FAO | Rome | Italy
S. Ramasamy | FAO | Rome | Italy
DOI: 10.1481/icasVII.2016.f38d

Parallel Session 33: Post-disaster needs assessments and rapid assessments tools

Rethinking Livestock Safety in Natural Disasters: The Way Forward with Improved Social Insurance in Disaster Management in India

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ABSTRACT

While animals are an integral component of rural economy, India's disaster management laws and policies magnifies vulnerability of livestock. Every year, India faces hydro-climatic natural disasters such as floods and cyclones which expose the existing vulnerability of livestock. It is expected that the disaster management programme of the government of India will include livestock protection in recognition of their contribution to the agricultural sector. Legal instruments of disaster management hardly take into account the plight or impact of livestock washed away, injured or dead. The anthropogenic neglect of animals is not only an ethical neglect but also increases the vulnerability of the already vulnerable.

A careful review of the Disaster Management Act 2005, Compendium of Laws on Disaster Management 2015, and National Policy on Disaster Management 2009, throws light on the absence of mention of social insurance for livestock. The Disaster Management Act makes no clear legal obligation towards animals during emergencies, and the Compendium of Laws on Disaster Management does not speak of livestock

protection during natural disasters. The National Policy provides for proper and speedy disposal of animal carcasses and recommends planning appropriate measures with the community for livestock protection during and after disasters. In all these, there is a conspicuous lack of social insurance for livestock in post-disaster recovery phase.

Under the 10th and 11th Five Year Plans, the Livestock Insurance Scheme was launched by the Ministry of Agriculture, Government of India, on a pilot basis. In the subsequent years, more districts came to be included under this scheme. The Livestock Insurance Scheme is an illustration of social insurance that offers monetary indemnification to farmers and cattle-rearers in case of livestock death. Since the premium of the Livestock Insurance Scheme is subsidized by the government, it aims to work well for Indian agricultural communities which are often poverty-stricken so that formal insurance and credit markets are no viable for them.

There is a need to integrate social insurance for livestock into disaster management. It indicates mainstreaming livestock protection into disaster management design, planning, and implementation. The Livestock Insurance Scheme employs both “Area approach” and “Individual approach” to determine livestock loss due to natural disasters. These approaches should be extended to cover social insurance for notified livestock. Furthermore, India requires an appropriate database of livestock. The Ministry of Agriculture, in cooperation with different state governments, conducts Livestock Census on a periodic basis. However, it has limitations which make impact assessment problematic.

Impact assessment of the social insurance scheme for livestock may be improved with three innovations. Firstly, mapping notified livestock according to area – the lowest unit of area could be “village” at rural level and “municipality wards” for urban areas. Secondly, costing of social insurance should be estimated based on affected areas for which time-series data of natural calamities need to be used. Thirdly, developing loss function based on various parameters which need to be worked out.

Thus, this paper intends to present a blue print of improved social insurance of livestock in India based on available data.

Keywords: Livestock Insurance Scheme, NGOs, Subsidy, Premium

1. Introduction

During disaster management, it has been observed that animals are generally marginalised. Animals need as much protection as human beings in disaster situations. In India, natural disasters like floods and cyclones are common. Abandoned animals display a natural tendency to instinctively move away from flash flood waters. They move to higher grounds wherever available. In doing so, they are exposed to risks of drowning, injury, and death. Evacuation, rescue and rehabilitation of animals will depend on the extent of commitment and human-animal bond. In this paper, animals refer mainly to livestock.

Even as animals are integral to rural economy, India’s disaster management laws and policies magnifies vulnerability of livestock. The disaster management programme hardly takes into account plight or impact of livestock washed away, injured or dead. This anthropogenic neglect of animals increases vulnerability of the already vulnerable. The Ministry of Agriculture (MoA), Government of India (GoI), had flagged of the

Livestock Insurance Scheme wherein half of the premium was subsidized by the Central Government. This scheme offered monetary indemnification to farmers and cattle-rearers in case of livestock death. This paper intends to present a blue print of improved social insurance of livestock viable in rural India. To this extent, the paper has been divided into five sections- Place for animals in Disaster Management Laws and National Policy, Livestock Insurance Scheme, Critical Evaluation of Livestock Insurance Scheme, Strategy for Improvement of Social Insurance for Livestock Safety from Natural Disasters, and Conclusion.

2. Place for animals in Indian Disaster Management Laws and National Policy

2.1 Disaster Management Act 2005

Enacted by the Parliament in 2005, the Disaster Management Act does not deal with animal protection. There is no mention of the word 'animal' so that Central and State Governments have no explicit legal obligation towards animals during disasters. **This anthropogenic neglect of animals is an ethical neglect.** Take the case of Himalayan Tsunami in 2013. Though the disaster affected human beings *and* animals, search and rescue teams were mainly dispatched for people as the death toll reached triple digits. It became difficult to count the number of animals which perished or struggled to survive. Non-governmental organizations (NGOs) such as People for Animals (PFA) and Humane Society took the responsibility to rescue and provide relief to trapped and injured mules and livestock (Lobo 2013). Even then, the role of NGOs seemed peripheral to that of the Central and State Governments and the National Disaster Response Force (NDRF). Since the Disaster Management Act does not mention "animals" and makes the provisions very general that these animals get marginalised, their agony ignored, and their rescue, relief, and treatment side-lined. Hence, the Act is embedded in a parochial bias that legitimises survival of the highest (and fittest) form of life.

2.2 Compendium of Laws on Disaster Management 2015

Interestingly, the Compendium hinted at animal safety in case of biological disasters. The Ministry of Health and Family Welfare (MoH&FW) was declared as the nodal ministry for the management of biological disaster. The MoH&FW would cooperate and coordinate with the Ministry of Agriculture (MoA) if animals and crops were affected. Compared to the Disaster Management Act 2005, the Compendium may be seen as an improvement that takes animals into account. Nevertheless, it came as a surprise that the Compendium did not have laws that would cater to animal protection during natural disasters as well as other kinds of man-made disasters. Post Phailin in 2013, NGOs like Action for Protection of Wild Animal (APOWA) found "The unspeakable misery of animals cannot be described in words" (Ranjan 2013). The International Fund for Animal Welfare – Wildlife Trust of India (IFAW-WTI) initiated its Rapid Action Projects and Emergency Relief Networks (ERN) to bring together over 400 animal rehabilitators from across the country.

2.3 National Policy on Disaster Management 2009

In two chapters, the National Policy cites animals in disasters. In chapter 5 entitled "Disaster Prevention, Mitigation and Preparedness" and chapter 7 entitled "Response".

In the former, under Section 5.2.9 it states "Proper and speedy disposal of dead bodies and animal carcasses deserves due weightage" (National Policy on Disaster Management 2009: 20). Except for reference to animal carcasses, this chapter has no other reference to animals. Instead of animal protection, efficient disposal of animal carcasses receives "due weightage". In doing so, it prioritises animal carcasses over animal lives. In the latter chapter, section 7.10.1 caters to "Animal Care". This section fares better than its predecessor. It takes cognizance of animals, domestic and wild, that vulnerable to the effects of natural and man-made disasters. It recommends planning appropriate measures to protect, shelter, and feed them during and after disasters. It suggests community effort as much as possible for the above because communities have demonstrated compassion to animals during disasters.

3. Livestock Insurance Scheme

One of the popular ways to tackle risks is by way of insurance. Insurance can become an effective tool to brave the risks posed to livestock by natural disasters. In India, the Department of Animal Husbandry, Dairying & Fisheries, Ministry of Agriculture, Government of India implemented the Livestock Insurance Scheme (LIS) first as a as a pilot study in 100 selected districts for two years from 2005 to 2007 (10th Five Year Plan and 11th Five Year Plan) and then on a regular basis in 100 newly selected districts of the country from 2008 to 2013. Thereafter, LIS was extended to 300 selected districts in the states. India has a total of 675 districts of which LIS covered 500- a remarkable achievement indeed! This Centrally Sponsored Scheme (CSS) would be carried out by the State Implementing Agencies (SIAs). States without SIAs would depend on the State Animal Husbandry Departments for implementation of LIS.

LIS has twin objectives that cater to farmers and cattle rearers and the insurance sector. It intends to provide protection mechanism to the former in the event of animal loss due to death and popularize livestock insurance in order to attain qualitative improvement in livestock and their products. Initially, it covered only crossbred and high yielding cattle and buffaloes but later aimed to include indigenous cattle, yak & mithun. The insurance amounts to maximum of the current market price of the insured animal. The insurance premium is subsidized whereby 50% is borne by the Central Government for a maximum of 2 animals per beneficiary for a policy of maximum of 3 years. The broad guidelines of LIS may be found in
http://uldb.org/pdf/Guidelines_for_Livestock_Insurance_Scheme.pdf,
http://dahd.nic.in/sites/default/files/Advisory%20LIS%20%202_0.pdf.

4. Critical Evaluation of Livestock Insurance Scheme

Despite the benefits and scale of coverage of LIS, there are concerns which require attention. Firstly, the insurance scheme does not consider cases of missing livestock in times of natural disasters. Secondly, there is no subsidy on premium against disability of livestock due to natural calamities. As the subsidy on premium is restricted only against death of livestock, the entire cost of premium against disability will have to be borne by beneficiaries. Thirdly, LIS is meant for high yielding cattle and buffaloes which directly pertain to commodification of animals and exclusive of cultural and ethical dimensions. Livestock may not be high-yielding due to nutritional deficiencies in poor households or arid regions in the country or both. They may not be productive for the market but their yield may be enough for daily household consumption. In addition to being a form of wealth, animals also become part of the household. Humans develop an emotional bond with animals that is part of everyday culture. It is quite common to see animal worship in India, particularly *Gau-Mata*. Their lives are revered as much as the lives of human beings which explain why it is unethical to neglect them during natural catastrophes. The emphasis on high yielding milch animals indicates the worth of livestock is measured in terms of market value. Those which are not market-worthy are not eligible for protection at all. For India, this is a very problematic stance that entirely omits cultural and ethical value of livestock. Lastly, this scheme does not address issues that contribute to incidents of moral hazard or fraud often complained by insurance companies.

The Livestock Insurance Scheme employs both “Area approach” and “Individual approach” to determine livestock loss due to natural disasters. Better known as homogeneous area approach, here homogeneous livestock area is assumed as the unit for estimation of yield and payment of compensation. The area is homogeneous in terms of livestock and annual variability in livestock yield. The unit area of insurance, that is, the aforementioned selected districts is decided by the Central Government. The Central Government permits only one insurance company to handle livestock insurance in a state normally, however, in case two or more companies bid the same premium rate then the area is equally divided in terms of Revenue Divisions or in absence of Revenue Divisions, region wise (Livestock Insurance Scheme 2013). This approach has the provision of data on yield variations (Singh 2010). In the individual approach, the farmer or cattle rearer is compensated fully for the losses suffered. The LIS mandates that the method of settlement of claim should be very simple and prompt to preclude unnecessary obstacles to the insured. It clearly states that only four documents would be required by insurance companies for settling claims- First Information Report with the Insurance Company, Insurance Policy, Claim Form and Postmortem Report. All insurance claims must be settled within 15 days positively after submission of requisite documents. Documents or forms for insuring and settling claims must be made available by the insurance agency in local language and English language. It is highly recommended that these approaches be extended to cover social insurance for notified livestock.

Finally, India requires an appropriate database of livestock. The Ministry of Agriculture, in cooperation with different state governments, conducts Livestock Census on a periodic basis. However, it has limitations which make impact assessment problematic. The recent 19th livestock census report do not match with the National Sample Survey Office (NSSO) survey report. The former pegged the number of sheep and goats at 200 million in 2012-13 while the 70th round of National Sample Survey represented a steep fall in their numbers to 99 million. The former also showed the number of poultry at 729 million in 2012-13 while the latter survey reported a huge decline to 255 million. The discrepancy in figures is unsettling since the livestock sector contributes almost 25.6 per cent (at current prices) of total value of output in agriculture, fishing and forestry sector while the overall contribution remained at 4.11 per cent of total Gross Domestic Product at current prices during 2012-13. The trends also differed between livestock census and the NSSO report. Agro-experts were of the opinion that mismatch of data on livestock was nothing new. The mismatch happened even in 1982, 1992, 1997 but the concerned ministry never rectified it (Choube 2015).

5. Strategy for Improvement of Social Insurance for Livestock Safety from Natural Disasters

To begin with, impact assessment of LIS needs to be improved. This may be done in three ways. Firstly, mapping notified livestock according to area – the lowest unit of area could be "village" at rural level and "municipality wards" for urban areas. Secondly, costing of social insurance should be estimated based on affected areas for which time-series data of natural calamities need to be used. Thirdly, developing loss function based on various parameters that need to be worked out.

A holistic strategy to enhance livestock safety from natural disasters requires active participation of civil society in addition to LIS. As discussed earlier, NGOs play a very crucial role in post-disaster animal recovery, rehabilitation and treatment. Livestock safety can be delegated to dedicated NGOs at the pre-disaster stage itself. Coordinating with the respective State Disaster Management Authority (SDMAs), State Animal Husbandry Departments, and SIAs, the NGOs can be deployed to evacuate livestock to animal shelters that are specially built keeping in mind their needs. General trends in evacuation show that owners are compelled to leave their animals behind. NGOs can prevent death, disability or missing of animals and, thereby, they can reduce overall loss of animal wealth.

The package called LIS should include safety net against disability or missing of animals. It is rightly argued that the number of claims per time period, will rise as the range of claims which the scheme is authorised to handle is increased (Mosley 1989: 7). However, the number of claims will not increase drastically with livestock safety planning and active intervention of NGOs at the pre-disaster stage itself. This helps to thwart fears of insurance companies and expand current protection mechanisms.

Insurance companies often complain of moral hazards or frauds in livestock insurance claims. Frauds arise when it becomes difficult to determine whether the animal in the claim is the insured cattle (Dalal et al. 2012: 5). The cause has been attributed to identification problems of the correct animal. The real problem lies elsewhere. Based on the amount of premium paid by the farmer and cattle rearer, they wish to maximize the returns from it. Since the subsidized premium is valid only for two animals, insurance for more than two animals will entail full payment of premium by them. Poverty makes it unaffordable to insure more animals. Little wonder, economic rationality appropriates loopholes in identification of insured animals to claim compensation for uninsured assets. Thus, frauds emerge not because rural poor are malicious but out of constraints of poverty and subsidy limitations in LIS.

A way out may be modeled on the logic of donor-funded "food for work" programme. Here, it may be re-designed to a donor-funded "insurance for risk reduction work" programme (Linnerooth-Bayer 2009: 391). Such a programme has the potential to become a significant source of insurance for farmers and cattle rearers with more than two animals. Income from this source will assist to finance premium on more animals. LIS is valid for a maximum period of three years. In case of no death of livestock in three years, farmers and cattle rearers do not get either the insurance amount or a refund of the premium amount. This factor can lead to reluctance towards LIS or contribute to negligence of animals during disasters. This challenge can be grappled in this way- the insurance company can reduce the amount of premium based on the accumulated insurance amount which will act as incentive for farmers and cattle rearers to insure more livestock. Along with the "insurance for risk reduction work" programme, farmers and cattle rearers will be in a position to afford further insurance. In return, insurance companies get more business as well as lower cases of fraud. Given the role of NGOs in livestock safety, it will help to lower cases of real claim too.

6. Conclusion

Different beings experience disasters and vulnerabilities differently. Compared to human beings, animals including livestock are greatly vulnerable so much so the number of injured, missing, and dead may exceed that of human beings in disasters. This study shed light on the disaster laws and national policy to mitigate disaster risks to livestock. The need of the hour requires a direct approach to livestock emergency preparedness and response. It is strongly recommended mainstreaming livestock protection into disaster management at central and state levels. Mainstreaming would transform their marginality and induce greater sensitivity into disaster management design, planning, and implementation. Simultaneously, the government should train animal owners to be self-reliant with respect to livestock safety and evacuation (Heath 2001: 1904).

The Central Government sponsored LIS addresses death of livestock due to natural calamities like floods and droughts. However, this scheme is not foolproof which restricts impact assessment and a holistic conception of livestock safety during natural disasters. It was suggested that the role of NGOs be recognized and encouraged at pre-, during, and post-disaster stages. Additionally, it was proposed to introduce donor-funded "insurance for risk reduction work" programme and trim down premium on accumulated insurance amount which will act as incentive for farmers and cattle rearers to insure more livestock. These measures would decrease incidents of fraud and expedite the growth of insurance sector in rural India.

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Macro-scale assessment and response to natural disasters An ODA approach[1]

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Abstract. Climate driven disasters are increasing in frequency and intensity due to climate change. These events affect countries causing severe damages and injuries. In rural areas, climate related disasters cause signmificant disruption to lives and livelihoods. A recent FAO study estimated that 25% of all damage and loss due to natural disasters was absorbed by the agriculture sector. In relation to drought, this figure rises to a staggering 84% . Humanitarian aid and other financial flows are mobilised to support those affected by disasters, such flows are intended to reduce the effects of disasters on households. But how responseive are these flows to the occurrence of disasters and what effect or impact do they have on recovery? In order to examine this, we have analysed time series data on significant flooding events, as provided by the Dartmouth Observatory repositories, the FAO land-cover database, and the ODA yearly data. Other demographic and economic variables are also included in the analysis. The responsiveness of donors to floods is measured by looking at the volume of aid comitted and disbursed following a major flood event from 1985 onwards. In addition, the effectiveness of the response in recovery from these shocks is evaluated using outcome variables related to sources of rural livelihood, of thse the most important is the change in land cover and land under different types of crops.

Keywords: Natural disaster, Vulnerability, Land cover, Panel data

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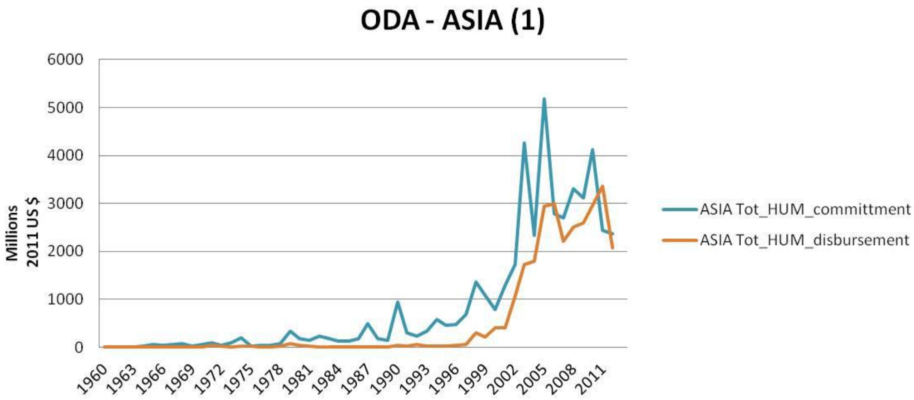
1 Introduction

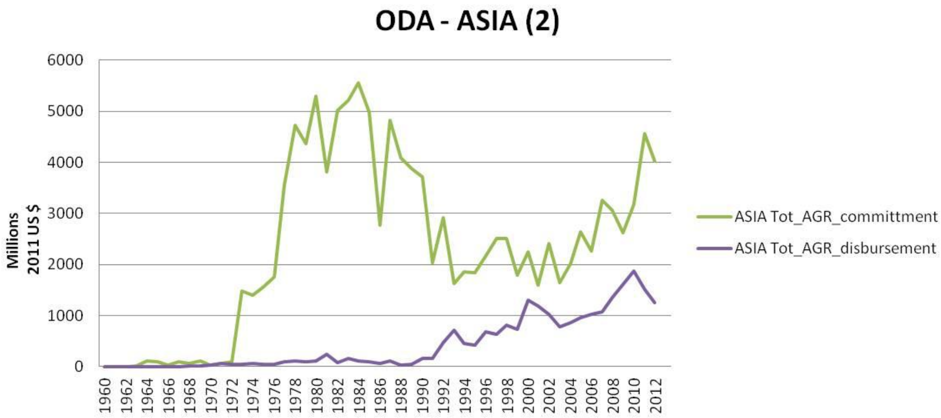
The relationship between humanitarian aid and need has been the subject of much debate in the past decade and has been one of the main motivating factors behind the so-called *Transformative Agenda* of the Inter-Agency Stranding Committee[4]. The lack of a clear relationship between aid and need was a clear conclusion of a seminal paper by Darcy and Hoffman in 2003 who concluded that *international humanitarian financing is not equitable, and amounts allocated across various contexts do not reflect comparative levels of need*.

Charting the relationship between aid flows and severity and magnitude of disasters is an important tool to inform policy in this field.

In a similar vein, there has been considerable sceptiscism regarding the impact of humanitarian aid flows on the populations whom they are intended to assist. This is partly due to the inherent difficulties in attributing changes in income and food security after a disaster with particular aid flows. It is also, however, partly due to the absence of commonly accepted measures of impact.

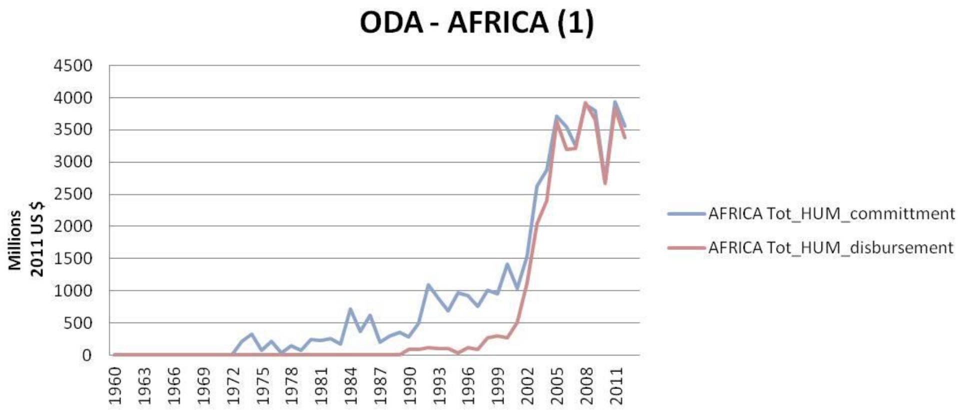
ODA deflated disbursements in Asia

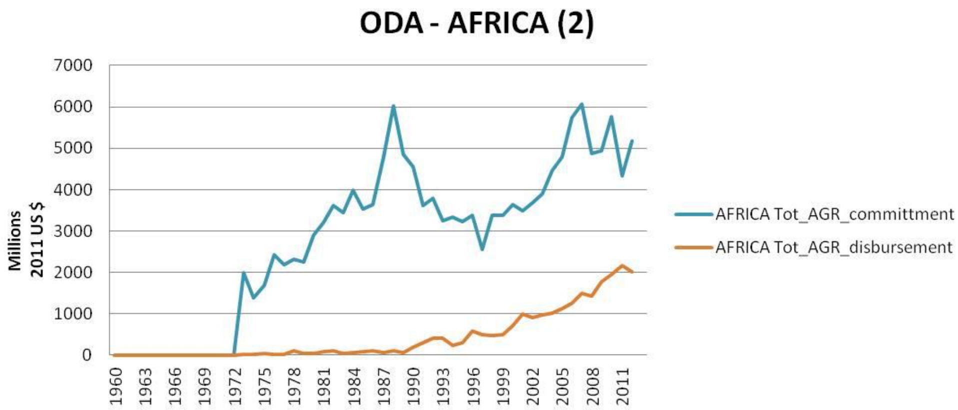




4 The Inter-Agency Standing Committee (IASC) is the primary mechanism for inter-agency coordination of humanitarian assistance.

ODA deflated disbursements in Africa





Recent studies present a mixed picture of the relationship between aid flows and disasters. Focusing specifically on hurricane responses, Yang (2008) concludes that foreign aid and foreign remittance flows seem to increase, whereas private flows turn negative (“capital flight”). Looking at a broader set of disasters, Stromberg (2007) finds that over a 10 year period (1995 – 2004) DAC donors were more likely to give relief the larger the disaster and the poorer the potential recipient country and if the disaster is in the news. Conversely, David (2010) finds that whilst international aid to low-income countries increases following geological disaster shock, in more general circumstances, the responses of aid flows to natural disaster shocks are not statistically significant. In particular, no relationship was found between aid flows and climatic natural disasters. The lack of aid response to climatic shocks is supported by evidence from Raddatz (2007 and 2009).

As a field of research, the economics of disasters can be best described as nascent. The 1969 book entitled “The Economics of Natural Disasters: Implications for Federal Policy” by Dacy and Kunreuther is often regarded as the fields pioneering work, though there have been relatively few subsequent studies. Cavallo and Noy (2009) state that *compared to the vast amount of research done in natural sciences and other social sciences, economic research on natural disasters and their consequences is fairly limited*.

Whilst the field is limited, a few important strands can be identified.

One strand looks at the effects of disasters on economic growth. Within this some studies consider the short-run effects on GDP while the second examines the long-run effects of disasters on economic growth. The short-run studies include: Albala-Bertrand (1993), Kahn (2005), Anbarci et al. (2005), Bluedorn (2005), Raddatz (2007), Strobl (2008), Loayza et al. (2009), Noy (2009), Rodriguez-Oreggia et al. (2009), Leiter et al. (2009), Mechler (2009) and Hochrainer (2009); while long-run studies include: Skidmore and Toya (2002), Noy and Nualsri (2007), Cuaresma et al. (2008), Jaramillo (2009), Raddatz (2009) and Hallegatte and Dumas (2009). Compared to the many short-run studies there have been fewer long-run studies conducted in the literature.

The conclusions of these different studies are variable depending on the data sets and the methodology used, however most studies conclude that disasters have negative consequences on both short and long term growth prospects. Exceptions are Skidmore and Toya (2002) and Kim (2010).

Another strand looks at the responsiveness of different types of capital flows to disasters. Within this group, the most widely cited paper is that of Yang (2008) who uses the incidence of hurricanes to examine the consumption smoothing role of international financial flows and concludes that foreign aid and foreign remittance flows seem to increase following hurricanes, whereas private flows turn negative ("capital flight"). Raddatz (2007) using a panel VAR methodology, finds that aid flows do not respond significantly to the occurrence of natural disasters. Mohapatra, Joseph and Ratha (2009) present micro evidence from household surveys and some macroeconomic results indicating that remittances have a positive role in preparing households against natural disasters and in mitigating economics losses afterwards. These authors find that remittances increase in the aftermath of natural disasters in countries that have a large number of migrants abroad. Of this strand of the literature, the paper with the widest scope is probably that of David (2010) who looks at a range of international financial flows and examines the relationship between these and different types of disasters over the period 1970 – 2005 for a large panel of developing countries. The results show that remittance inflows increase significantly in response to shocks to both climatic and geological disasters. The models suggest a nuanced role for foreign aid. While the responses of aid flows to natural disaster shocks in general tend not to be statistically significant, international assistance to low income countries increases following geological disaster shocks does increase. Furthermore, the results show that typically, other private capital flows (bank lending and equity) do not attenuate the effects of disasters and in some specifications, even amplify the negative economic effects of these events.

The overall conclusion from the literature is that appears to be a large degree of disagreement over (a) whether aid flows respond in a statistically significant way to the incidence of disasters and (b) whether the effects of aid flows on post disaster recovery are statistically significant (positive) or negligible. At one level, our work represents a further study which examines these two questions. What appears to us to be new about our approach is the following

- Greater disaggregation of types of ODA: We distinguish not only between humanitarian aid and non –humanitarian aid, but disaggregate both categories of aid to search for differential responsiveness and impact . Within humanitarian we look at food aid vs general humanitarian aid and within overall development ODA we focus on aid to the agricultural sector.
- Greater disaggregation in terms of impact: We go beyond looking at impacts on GDP growth to focus on the agricultural sector using different measures of impact.
- Temporal disaggregation: We look at the differences between pre – 2005 and post 2005 responsiveness and impact. The choice of 2005 is important as this was the year of major reform in both humanitarian sector (the transformative agenda) and the development sector (the Paris declaration).

This current paper examines similar questions to earlier work, however due to access to extensive and specific data sets, the paper is able to focus explicitly on emergency related aid flows following major flooding events and agriculture. In this sense it allows, for the first time, a very detailed analysis to be undertaken of relationships between a particular type of international aid a particular type of disaster (floods) and a particular productive sector: agriculture.

The study investigates two key questions:

• (a) Is there a statistically robust relationship between the scale and severity of disaster and emergency aid flows to agriculture?

• (b) Is there a relationship between disbursed aid and recovery in the agriculture sector following a disaster?

The paper is organized as follows: after the Introduction containing a short review of the literature, data are illustrated in Section 2. Section 3 contains the model setup and the results. The main conclusions of the research carried out, with strengths and limitations of the approach are briefly discussed in Section 4, which concludes the paper.

2 Data

Several datasets have been merged to build the panel used for the analysis carried out in this paper. Since we focus on flood events, the reference dataset we selected concerns worldwide floods occurred from 1985 on. This repository in made available by the Dartmouth College in the US. The statistics presented in the *Dartmouth Flood Observatory Global Archive of Large Flood Events* are derived from a wide variety of news and governmental sources. The quality and quantity of information available about a particular flood is not always in proportion to its actual magnitude, and the intensity of news coverage varies from nation to nation. In general, news from floods in low-tech countries tend to arrive later and be less detailed than information from 'first world' countries. Here below the list of variables in the dataset.

• DFO# - An archive number is assigned to any flood that appears to be "large", with, for example, significant damage to structures or agriculture, long (decades) reported intervals since the last similar event, and/or fatalities.

• GLIDE# - GLobal IDEntifier Number. A globally common Unique ID code for disasters.

• Country - Primary country of flooding. Other affected countries are listed in three separate fields to the right of the main Country column.

• Locations - Includes names of the states, provinces, counties, towns, and cities.

• Rivers - Names of rivers.

• Begin - Ended - Occasionally there is no specific beginning date mentioned in news reports, only a month; in that case the DFO date will be the middle of that month. Ending dates are often harder to determine - sometimes the news will note when the floods start to recede. An estimate is made on the basis of a qualitative judgment concerning the flood event.

• Duration - Derived from start and end dates.

• Known Dead - News reports are usually specific about this, but occasionally there is only mention of 'hundreds' or 'scores' killed; in this case the estimate is: *hundreds*=300; *scores*=30; *more than a hundred* =110 (number given plus 10%). If there is information on the number of people 'missing', the DFO does not include them in the total of deaths. An exact number is provided for analytical purposes, but those numbers are never more than estimates.

• Number Displaced - This number is sometimes the total number of people left homeless after the incident, and sometimes it is the number evacuated during the flood. News reports will often mention a number of people that are 'affected', but this is not used. If the only information is the number of houses destroyed or damaged, then DFO assumes that 4 people live in each house. If the news report only mentions that "thousands were evacuated", the number is estimated at 3000. If the news reports mention that *more than 10,000* were displaced then the DFO number is 11,000 (number plus 10%). If the only information is the number of families left homeless, then DFO assumes that there are 4 people in each family.

• Damage (US $) - This number is never more than an estimate and no independent criteria are used for determining such. Instead it is retained the latest and apparently most accurate number available in all the relevant sources.

• Main Cause - One of eleven main causes is selected: Heavy rain, Tropical cyclone, Extra-tropical cyclone, Monsoonal rain, Snowmelt, Rain and snowmelt, Ice jam/break-up, Dam/Levy, break or release, Brief torrential rain, Tidal surge, Avalanche related. Information about secondary causes is in the Notes and Comments section of the table.

• Severity Class - Assessment is on 1-2 scale. These floods are then divided into three classes. Class 1: large flood events: significant damage to structures or agriculture; fatalities; and/or 1-2 decades-long reported interval since the last similar event. Class 1.5: very large events: with a greater than 2 decades but less than 100 year estimated recurrence interval, and/or a local recurrence interval of at 1-2 decades and affecting a large geographic region (> 5000 sq. km). Class 2: Extreme events: with an estimated recurrence interval greater than 100 years.

• Geographic Flood Extents (sq km) - This is derived from our global map of news detected floods. Polygons representing the areas affected by flooding are drawn in a GIS program based upon information acquired from news sources. Note: These are not actual flooded areas but rather the extent of geographic regions affected by flooding.

• Magnitude (M) - Flood Magnitude =log(Duration x Severity x Affected Area).

Net Official Development Assistance (ODA) per capita consists of disbursements of loans made on concessional terms (net of repayments of principal) and grants by official agencies of the members of the Development Assistance Committee (DAC), by multilateral institutions, and by non-DAC countries to promote economic development and welfare in countries and territories in the DAC list of ODA recipients; and is calculated by dividing net ODA received by the midyear population estimate. It includes loans with a grant element of at least 25 percent (calculated at a rate of discount of 10%).

The database is entirely based on OECD-CRS Aid Activity database, which is currently the most comprehensive when considering the allocation of assistance to agriculture, as well as other relevant sectors, by recipient country and region at the activity level. CRS database has drastically increased its coverage on multilateral donors in the last decade. It provides a consolidated methodology when more than one donor is involved on the aid delivery process, which avoids double-counting. It includes both ODA and OOF made by bilateral and multilateral donors to developing countries in terms of commitments and disbursements for the period from 1973 to 2011. The ODA database covers agriculture in the broad sense (agriculture, forestry and fishing) and also all the sectors and purposes that are relevant to FAO's strategic objectives like: food and nutrition security, food aid, agro-industries, rural development, water and environment protections. The amounts are expressed in both current and constant USD millions. The embedded DAC deflators are used. Official Development Assistance (ODA) is defined as:

- flows to the DAC list of aid recipients;
- provided to official agencies, including state and local governments, or by their executive agencies;
- administered with the promotion of the economic development and welfare of developing countries; and
- concessional in nature i.e. it contains an element of grant that is at least 25% Other Official Flows (OOF) are transactions by official donors with the list of aid recipients which do not meet the eligibility criteria as ODA either because they are not primarily aimed at development, or because they have a grant element of less than 25%.

Commitment is a firm written obligation by a government or official agency, backed by the appropriation or availability of the necessary funds, to provide resources of a specified amount under specified financial terms, conditions and for specified purposes for the benefit of the recipient country. Disbursement is the placement of resources at the disposal of a recipient country or agency, or in the case of internal development-related expenditures, the outlay of funds by the official sector. It can take several years to disburse a commitment. ODA is further classified in four categories:

1. ODA Grants are transfers in cash or in kind for which no legal debt is incurred by the recipient. For DAC/CRS reporting purposes, it also includes debt forgiveness, which does not entail new transfers; support to non-governmental organizations; and certain costs incurred in the implementation of aid programmes.
2. ODA Grant-like flows comprise a) loans for which the service payments are to be made into an account in the borrowing country and used in the borrowing country for its own benefit, and b) provision of commodities for sale in the recipient's currency the proceeds of which are used in the recipient country for its own benefit.
3. ODA Loans are transfers for which the recipient incurs a legal debt and repayment is required in convertible currencies or in kind. This includes any loans repayable in the borrower's currency where the lender intends to repatriate the repayments or to use them in the borrowing country for the lender's benefit.
4. Equity investment comprises direct financing of enterprises in a developing country which does not (as opposed to direct investment) imply a lasting interest in the enterprise.

The main indicators used from the ODA database are overall disbursement and commitment flows. Commitments on General Programme Assistance and Humanitarian Aid Grouping are also retained

- development food aid and food security assistance, indicated with *committ_foodsec*

- agriculture, indicated with *agr_committ*
- emergency response, indicated with *emerg_committ*
- disaster prevention and preparedness, indicated with *disast_committ*.

Land cover and Food Aid Shipments are also used (FAOSTAT). Variables retained are displayed on Table 6 in the Appendix.

Our final dataset is obtained merging data from the various sources mentioned previously. As a first step of the work, some correlation analysis is carried out for the most relevant variables to our objectives. From pairwise correlations of ODA flows we notice that they are significantly positive correlated with permanent crops and total agriculture land. In particular, commitments for food security are strongly positively associated to arable land. Moreover, some specific sections of commitments related to emergency, agriculture and disaster prevention are mostly associated with higher levels of agricultural arable land. This can be explained not by the fact that commitment flows boost conversion of land for agricultural use, but also by the dramatic level of need of some countries which are depending mostly on agriculture for their livelihood. This is especially true when those countries are subject to extreme natural events, such as floods, which could drastically reduce the agricultural area, destroy crops and thus enhancing food security issues. This in principle should/could stimulate further commitments not only from the side of the country hit by the disaster, but also from DAC donors. Thus, for those reasons, the direction of causality between disbursement and change in land cover for agriculture cannot be clearly identified at this stage. Therefore any conclusions on the effectiveness of international ODA on recovery from flood disasters cannot be drawn. To this aim, more sophisticated models able to take into account feedback effects are needed. To get some insight on time issues related to the effect of past disbursement and commitment on agricultural areas, the correlation analysis is repeated on the same land cover variables observed at time t with disbursements and commitments at time $t-1$ and $t-2$, i.e. one year and two years before, respectively. Interestingly, there is a persistent positive correlation of past ODA flows with agriculture area, in particular with permanent crops area. Similar pattern is noticed for previous year food aid and security commitments against current arable areas. The list of variables used in the next sections is displayed in Table 1. Note, that the number at the end of the variable name indicates the time lag. For example, variables *all7_commitment_defl1* and *all7_commitment_defl2* are the deflated ODA commitments in Humanitarian Aid at 1-year and 2-year lag, respectively.

Table 1: Variables used in the models

Description	Notation
ODA Deflated committments in Humanitarian Aid (section 7)	all7_commitment_defl
ODA Deflated committments in Humanitarian Aid (section 7) after a disaster	all7_commitment_defl_dis
ODA Deflated committments in Humanitarian Aid (section 7) after a flood	all7_commitment_defl_nfl
ODA Deflated committments in Humanitarian Aid (section 7) after a severe flood	all7_commitment_defl_sev
ODA Deflated disbursements in Agriculture (section 3)	tot_agr_disbursement_defl
ODA Deflated disbursements in Agriculture (section 3) after a disaster	tot_agr_disbursement_defl_dis

ODA Deflated disbursements in Agriculture (section 3) after a flood	tot_agr_disbursement_defl_nfl
ODA Deflated disbursements in Agriculture (section 3) to Asian countries	tot_agr_disbursement_defl_asia
ODA Deflated disbursements in Agriculture (section 3) to African countries	tot_agr_disbursement_defl_afr
ODA Deflated disbursements in Agriculture (section 3) to American countries	tot_agr_disbursement_defl_am
ODA Deflated disbursements in Material Relief Assistance (section 72010)	disbursement_72010_defl
ODA Deflated disbursements in Material Relief Assistance (section 72010) after a disaster	disbursement_72010_defl_dis
ODA Deflated disbursements in Material Relief Assistance (section 72010) after a flood	disbursement_72010_defl_nfl
ODA Deflated disbursements in Emergency Food Aid (section 72040)	food_aid_disb_defl
ODA Deflated disbursements in Emergency Food Aid (section 72040) after a disaster	food_aid_disb_defl_dis
ODA Deflated disbursements in Emergency Food Aid (section 72040) after a flood	food_aid_disb_defl_nfl
ODA Deflated disbursements in Agricultural Development (section 31120)	disbursement_31120_defl
ODA Deflated disbursements in Agricultural Development (section 31120) after a flood	disbursement_31120_defl_nfl
ODA Deflated disbursements in Agricultural Policy (section 31110)	disbursement_31110_defl
ODA Deflated disbursements in Agricultural Policy (section 31110) after a flood	disbursement_31110_defl_nfl
Forest area	forest_area
Forest area (in growth rate)	forest_area_rel
Arable land and Permanent crops	agr_perm_crops
Arable land	agr_arable
Arable land (in growth rate)	agr_arable_rel
Interaction: Arable land * disb in Humanitarian Aid	agr_arable_disb7d
Interaction: Arable land * disb in Humanitarian Aid after disaster	agr_arable_disb7d_dis
Interaction: Arable land * disb in Humanitarian Aid after flood	agr_arable_disb7d_nfl
Interaction: Arable land * disb in Agriculture	agr_arable_disb3d
Interaction: Arable land * disb in Agriculture after disaster	agr_arable_disb3d_dis
Interaction: Arable land * disb in Agriculture after flood	agr_arable_disb3d_nfl
Permanent crops	perm_crops
Permanent crops (in growth rate)	perm_crops_rel
Interaction: Perm crops * disb in Humanitarian Aid	perm_crops_disb7d
Interaction: Perm crops * disb in Humanitarian Aid after disaster	perm_crops_disb7d_dis
Interaction: Perm crops * disb in Humanitarian Aid after flood	perm_crops_disb7d_nfl
Interaction: Perm crops * disb in Agriculture	perm_crops_disb3d
Interaction: Perm crops * disb in Agriculture after disaster	perm_crops_disb3d_dis
Interaction: Perm crops * disb in Agriculture after flood	perm_crops_disb3d_nfl
Rice Total shipped	rice
Cereals Total shipped	cereals
Time dummy indicating decade 2003-2012	dum_0312
Number of disasters in the year (EMDAT)	no_disasters

Number of dead (EMDAT)	deads2
Number of homeless (EMDAT)	no_homeless
Total amount of damages in US$ (EMDAT)	total_dam
Total affected surface (EMDAT)	total_affected
Number of displaced (DARTHMOUTH)	displaced2
Duration in days of flood (DARTHMOUTH)	durationsindays
Number of yearly floods with magnitude > 6(DARTHMOUTH)	max_of_totalannualflood_m61
Number of yearly floods with magnitude > 4(DARTHMOUTH)	max_of_totalannualflood_m41
Population (in logarithms)	lpop
GDP at constant prices (2005)	gdpconstant2005us
GDP yearly growth rate (2005)	gdpgrowthannual
Agricultural value added as % of GDP	va_agr_gdp

3 The econometric models

Three models are considered for assessing three main aspects: responsiveness, impact on livelihoods, impact on the economy based on agriculture. EMDAT dataset has been used in the analysis for including the occurrence of a general disasters.

3.1 ODA Response

As already mentioned in the Introduction, our first objective is to investigate if ODA disbursement levels are significantly increased after a flood event and whether the magnitude and severity of disasters have a positive significant impact on those flows. In this model we assess the response of disbursements in humanitarian aid after a general disaster and after a flood. This model is estimated using two dataset. The first is about general disasters (EMDAT) database, and the second about flood only (DARTMOUTH).

The econometric model is a fixed effects with autoregressive errors and takes into account the effects of

- current and past commitment flows (up to 4 years before),
- the severity and magnitude of disasters possibly occurred in the past year,
- food aid shipments (rice and cereals) in previous period,
- changes in land cover.

The response variable is deflated disbursements in section 7, and the explanatory variables are current and past deflated commitments in humanitarian aid, current and past deflated disbursements in agriculture with and without disaster or flood occurrence, variables related to magnitude and severity of disasters or floods. Control variables are current and $1-$lag agriculture and permanent crops area, forest area, previous area food aid shipment in rice and cereals, time dummy related to the period after 2005. The model is estimated after having tested the stationarity of the time series and against the hypothesis of poolability of the data. Moreover, both time and individual effects result significant and the overall variability of the data is quite well explained by the model specification, as confirmed by the overall R squared. From the coefficient estimates displayed in Table 3.1 we observe that commitments in section 7 are persistent (significant up to $4-$lag autocorrelations).

Table2: RESPONSIVENESS against general disaster or floods: FE Autoregressive on all countries

Variable	General Disaster		Flood	
	Coefficient	(Std. Err.)	Coefficient	(Std. Err.)
all7_commitment_defl	0.612 **	(0.036)	0.742 **	(0.013)
all7_commitment_defl1_dis1	0.107 **	(0.036)	-	-
all7_commitment_defl1_nfl	-	-	-0.069 **	(0.018)
all7_commitment_defl1	0.216 **	(0.010)	0.233 **	(0.013)
all7_commitment_defl2	0.030 *	(0.012)	0.060 **	(0.014)
tot_agr_disbursement_defl1	0.330 †	(0.198)	-0.081	(0.110)
tot_agr_disbursement_defl1_dis1	-0.203	(0.188)	-	-
tot_agr_disbursement_defl1_nfl1	-	-	0.213 †	(0.109)
tot_agr_disbursement_defl	14.581 **	(5.616)	19.071 **	(5.605)
tot_agr_disbursement_defl_asia	-14.416 *	(5.617)	-18.893 **	(5.605)
tot_agr_disbursement_defl_afr	-14.443 *	(5.616)	-18.912 **	(5.605)
tot_agr_disbursement_defl_am	-14.914 **	(5.618)	-19.013 **	(5.609)
forest_area	-0.035 **	(0.012)	-0.031 *	(0.012)
forest_area1	0.034 **	(0.012)	0.031 *	(0.012)
agr_perm_crops	0.020 **	(0.005)	-	-
agr_perm_crops1	-0.020 **	(0.005)	-	-
agr_arable	-	-	0.026 **	(0.005)
agr_arable1	-	-	-0.025 **	(0.005)
dum_0312	10.931 **	(4.045)	10.487 *	(4.216)
rice1	0.000 *	(0.000)	0.000 *	(0.000)
cereals1	0.000 **	(0.000)	0.000 *	(0.000)
no_disasters	-0.558	(0.759)	-	-
deads2	0.001 **	(0.000)	-	-
no_homeless	0.000	(0.000)	-	-
total_dam	0.000	(0.000)	-	-
total_affected	0.000	(0.000)	-	-
displaced21	-	-	0.000 †	(0.000)
max_of_totalannualflood_m61	-	-	0.445	(0.317)
max_totalannual_flood_m41	-	-	-0.143	(0.102)
Intercept	-23.688 **	(6.175)	-23.218 **	(6.506)
N	686		686	
Log-likelihood	-3334.087		-3346.459	
	$F_{(97,588)}$	229.494	$F_{(95,590)}$	246.268
Significance levels : † : 10% * : 5% ** : 1%				

Table 3: RESPONSIVENESS against flood (DARTMOUTH): FE Autoregressive on ASIAN and AFRICAN countries

Variable	Asia	Africa		
	Coefficient	(Std. Err.)	Coefficient	(Std. Err.)
all7_commitment_defl	0.599 **	(0.034)	0.775 **	(0.020)
all7_commitment_defl1	0.215 **	(0.022)	0.150 **	(0.034)
all7_commitment_defl1_nfl	0.032	(0.033)	0.035	(0.028)
all7_commitment_defl2	0.009	(0.025)	0.067 **	(0.020)
tot_agr_disbursement_defl1	-0.538	(0.473)	0.059	(0.090)
tot_agr_disbursement_defl1_nfl1	0.673	(0.457)	-0.175 †	(0.091)
tot_agr_disbursement_defl	0.238 †	(0.124)	0.077	(0.073)
forest_area	-0.022	(0.020)	-0.033 **	(0.012)
forest_area1	0.021	(0.020)	0.031 **	(0.012)
agr_arable	0.012	(0.009)	0.022 **	(0.005)
agr_arable1	-0.012	(0.009)	-0.018 **	(0.005)
dum_0312	1.275	(11.466)	8.962 *	(4.125)
rice1	0.000	(0.000)	0.000	(0.000)
cereals1	0.000	(0.000)	0.000 **	(0.000)
displaced21	0.000	(0.000)	0.000	(0.000)
durationindays1	0.107	(0.075)	-0.008	(0.048)
max_of_totalannualflood_m61	0.634	(0.730)	0.203	(0.274)
max_totalannual_flood_m41	-0.135	(0.238)	-0.048	(0.087)
Intercept	-15.461	(32.943)	-9.252	(5.841)
N	187	381		
Log-likelihood	-958.78	-1665.866		
	F $_{(40,146)}$	48.248	F $_{(56,324)}$	232.861
Significance levels : † : 10% * : 5% ** : 1%				

Concerning the response after a general disaster, as displayed in Table 3.1 in the last two columns, current aid grants are positively affected by past commitments in humanitarian aids (up to 2 years before), particularly when commitments are taken at the time of a disaster. Indeed, this has a positive effect of increasing current disbursements. On the other hand, when the disaster is a flood, past commitments in humanitarian aid seem to decrease their positive correlation with current disbursements. This means that the response in case of floods is less dependent on past commitments. This is related to the severity characterizing flood events on people and land. The most severe the flood is at the time commitment, the lowest the correlation with current disbursement (see Table 6 in the Appendix). Moreover, when flood occurs, to lower commitments taken at that time there will correspond higher disbursements in humanitarian aid the year after.

Grants disbursed for humanitarian and agriculture purpose move generally together, i.e. they vary in the same direction in time. This is especially true for Asian countries with high strength of the relation, lower for African ones (see Table 1) and very weak association for South-America and Caribbeans.

Disbursements in aid are responsive to past land cover in agriculture and permanent crops, and forest area. Increasing forest areas in the previous year is associated to higher current disbursements in aid, as well as previous year decrease in agriculture and permanent crops land. On the other hand, current increase in agricultural land is associated to higher disbursement, and lower forest area.

Moreover, there is a general deterministic upward trend in humanitarian aid disbursements in the past 10 years (from 2003 on).

In particular, previous year food aid shipments in rice and cereals increase are associated with increasing current aids. This means that on average, there is a continuity of aids in time under various forms. In general disasters, the variable more affecting the current amount of grants disbursed for aid is previous year number of dead, whereas in case of flood, it is the number of displaced people.

When the model is estimated for the various continents, we observe an higher persistence of past commitments on current aid, and a weak association between the various purposes of disbursements in agriculture and humanitarian aid. Moreover, previous year cereals shipments are highly associated with current humanitarian aids. The opposite is observed for Asian countries (see Table 1), where humanitarian aid is associated with past commitments only in the short run (i.e. 1−year lag), whereas current disbursements in agriculture are associated to humanitarian aid, which are not related to previous year food aid shipments. For Southern and Central America, Oceania and Europe, there are not enough observations to be able to extract robust insights from the analysis.

Flood variables included in the model are related to the previous year. The number of displaced people affects positively current disbursements. Concerning food aid shipments related to rice and cereals occurred the previous year, we observe that they both affect positively disbursement flows.

3.2 ODA Impact on Livelihood

However, errors appear to be strongly correlated with the explanatory variables, which is clearly due to still existing feedback effects. We believe that the endogeneity in our model could be explained by the fact that disbursements at time t, if effective, might give impulse to changes in land cover, especially related to land for agriculture. On the other hand, flood events affect the land cover and stimulate both commitments at time t and thus disbursement flows at time $t+1$. Since endogeneity makes coefficient estimates biased and inconsistent, we use dynamic approach to model the feedback effects of disbursement.

First, we try to model the relationship between ODA and land cover changes in a way which enables for causality reasoning. This is achieved when we 'control' for a set of other relevant variables which affect both ODA and the land cover changes.

Next steps of the analysis involve the estimation of the model using Blundell and Bond (1998) linear dynamic panel-data estimator. Linear dynamic panel-data models include p lags of the dependent variable as covariates and contain unobserved panel-level effects, fixed or random. By construction, the unobserved panel-level effects are correlated with the lagged dependent variables, making standard estimators inconsistent. Arellano and Bond (1991) derived a consistent generalized method of moments (GMM) estimator for this model. The Arellano and Bond estimator can perform poorly if the autoregressive parameters are too large or the ratio of the variance of the panel-level effect to the variance of idiosyncratic error is too large. Building on the work of Arellano and Bover (1995), Blundell and Bond (1998) developed a system estimator that uses additional moment conditions.

This estimator is designed for datasets with many panels and few periods. This method assumes that there is no autocorrelation in the idiosyncratic errors and requires the initial condition that the panel-level effects be uncorrelated with the first difference of the first observation of the dependent variable.

Table 4: IMPACT on LAND : dynamic model for impact of ODA on permanent crops, general disaster vs flood (EMDAT)

Variable	General Disaster		Flood	
	Coefficient	**(Std. Err.)**	**Coefficient**	**(Std. Err.)**
L.perm_crops_rel	0.106 *	(0.053)	0.110 *	(0.053)
gdpconstant2005us1	0.000	(0.000)	0.000	(0.000)
lpop	0.001	(0.003)	0.000	(0.003)
no_disasters1	0.000	(0.001)	0.000	(0.001)
deads21	0.000	(0.000)	0.000	(0.001)
total_affected1	0.000	(0.000)	0.000	(0.001)
total_dam	0.000	(0.000)	0.000	(0.000)
agr_arable_rel	0.296 †	(0.152)	0.296 †	(0.152)
disbursement_72010_defl1	0.000	(0.000)	0.000	(0.000)
disbursement_72010_defl1_dis1	0.000	(0.000)	-	-
disbursement_72010_defl1_nfl1	-	-	0.000 *	(0.000)
food_aid_disb_defl1	0.000	(0.000)	0.000	(0.000)
food_aid_disb_defl1_dis1	0.000	(0.000)	-	-
food_aid_disb_defl1_nfl1	-	-	0.000 **	(0.000)
dum_0312	-0.009	(0.008)	-0.010	(0.008)
forest_area_rel	-0.588	(1.208)	-0.660	(1.201)
Intercept	0.012	(0.050)	0.020	(0.049)
N	733		733	
$\chi^2_{(12)}$	27.185		48.709	
Significance levels : † : 10% ∗ : 5% ∗∗ : 1%				

Table 5: IMPACT on LAND : dynamic model for impact of ODA when flood disaster occurs on permanent crops vs arable land. (EMDAT)

Variable	**Permanent Crops**		**Arable Land**	
	Coefficient	**(Std. Err.)**	**Coefficient**	**(Std. Err.)**
L.perm_crops_rel	0.097 *	(0.043)	-	-
L.agr_arable_rel	-	-	0.117 *	(0.053)
lpop	0.000	(0.003)	-0.001	(0.003)
no_disasters1	0.000	(0.001)	0.000	(0.001)
deads21	0.000	(0.000)	0.000 **	(0.000)
total_affected1	0.000	(0.000)	0.000	(0.000)
total_dam	0.000	(0.000)	0.000 **	(0.000)
agr_arable_rel	0.214 †	(0.125)	-	-
perm_crops_rel	-	-	0.166 *	(0.082)
disbursement_72010_defl1	0.000	(0.000)	0.000 *	(0.000)
disbursement_72010_defl1_nfl1	0.000	(0.000)	0.000 **	(0.000)
disbursement_31120_defl1	0.000	(0.000)	-0.002 **	(0.001)
disbursement_31120_defl1_nfl1	0.000	(0.000)	0.001 *	(0.001)
disbursement_31110_defl1	-0.001 *	(0.000)	0.000	(0.001)
disbursement_31110_defl1_nfl1	0.001	(0.000)	0.000	(0.001)
dum_0312	0.001	(0.005)	0.006	(0.005)
forest_area_rel	0.401	(0.617)	0.882 †	(0.454)
Intercept	0.020	(0.056)	0.033	(0.044)
N	943		943	
$\chi^2_{(13)}$	40.388		53.974	
Significance levels : † : 10% $*$: 5% $**$: 1%				

In the model for assessing the impact of disaster and ODA disbursements on livelihoods, we use as response variable the change in the land used for agriculture: from the one hand the arable land, and from the other hand areas for permanent crops. The model is estimated using Arellano-Bover linear dynamic panel data estimator, controlling for the economic and demographic size of countries (1-lag GDP at 2005 prices and population in logs), the magnitude and intensity of the disaster or flood (duration, total people affected, estimated damages, etc.) and for the natural trend of agriculture land growth. The explanatory variables are changes in forest area and arable land (when the dependent variable is the rate of change of permanent crop), changes in permanent crops (when the dependent variable is the rate of change of arable land), deflated disbursements in Material relief assistance (section 72010), with and without disaster/flood occurrence, deflated disbursements in Emergency food aid (section 72040), with and without disaster/flood occurrence. Moreover, two different scenarios are considered: general disaster and flood event (dataset EMDAT combined with dataset DARTMOUTH). The main results are summarized here below.

- Changes in permanent crops have natural tendency to increase in time (current growth rate depending from previous year growth rate), approximately at 10% pace, and are positively associated with changes in agriculture arable land.
- When a general disaster occurs, it is very difficult to seize the impact of humanitarian aid disbursements on changes in land for permanent crops and agriculture. This could be explained by the extreme heterogeneity of the impact, magnitude and severity of a disaster which could require multiple interventions, of which humanitarian aid ODA grants are only a small fraction. On the other hand, when a flood occurs, the effect of disbursements in both material relief assistance and emergency food aid is to increase future permanent crop area. This figure is confirmed when only flood data are used (see Table 3.2).

Table 6: IMPACT on LAND: dynamic model for impact of ODA on arable land when Flood occurs (EMDAT), ASIA vs AFRICA

Variable	ASIA		AFRICA	
	Coefficient	(Std. Err.)	Coefficient	(Std. Err.)
L.agr_arable_rel	0.049	(0.063)	0.120 *	(0.056)
lpop	-0.007 **	(0.002)	-0.006	(0.005)
no_disasters1	0.001 †	(0.000)	-0.002	(0.002)
deads21	0.000 **	(0.000)	0.000	(0.000)
total_affected1	0.000	(0.000)	0.000	(0.000)
total_dam	0.000	(0.000)	0.000	(0.000)
perm_crops_rel	0.153	(0.128)	0.084 *	(0.036)
disbursement_72010_defl1	.000 **	(0.000)	0.000	(0.000)
disbursement_72010_defl1_nfl1	.000 **	(0.000)	0.000	(0.000)
disbursement_31110_defl1	-0.003 *	(0.001)	0.000	(0.000)
disbursement_31110_defl1_nfl1	0.003 *	(0.001)	0.001 †	(0.001)
forest_area_rel	-0.335	(0.931)	-0.227	(0.330)
Intercept	0.138 **	(0.040)	0.125	(0.088)
N	281		545	
$\chi^2_{(10)}$	130.979	$\chi^2_{(12)}$	39.029	
Significance levels : † : 10% * : 5% ** : 1%				

To disentangle the effectiveness of ODA in Agriculture with respect to ODA in humanitarian aid, two further versions of the model are estimated when a flood occurs: the first assess the impact of various ODA grants on permanent crops, distinguishing flood events from general disasters (Table

2). The second evaluates the impact on arable land (Table 3). From the estimates it is clear that

- it is not possible to seize and disentangle the effects on permanent crops of the various ODA in Agriculture. In absence of floods, it seems that higher grants disbursed in the previous year in Agricultural policy and administrative management (section 31110) are accompanied with a decrease in permanent crops (Table 2).
- Interestingly, ODA grants in agriculture seem to be more effective on arable land than on permanent crops. Indeed, when a flood occurs, previous year disbursements in Agricultural Development (section 31120) have positive effect on changes in arable land (Table 2). Moreover, material relief and assistance disbursements in the previous year affect positively the growth rate of arable land, and the positive effect is even higher when a flood occurred in the previous year. Interestingly, growth of forest areas moves in the same direction as arable land growth rate.
- When continents are considered separately, we observe that in Asian countries, disbursements in Material relief is effective when a flood occurs on the future growth of permanent crops. Moreover, material relief assistance is effective also on the growth of arable land. ODA grants in Agricultural policy and administrative management are effective in Asia in case of floods acting on the arable land (Table 3).
- As for Africa, effects of ODA on permanent crops is difficult to see in case of general disaster or flood event. The only exception is a general positive effect of Material relief and assistance, regardless flood events on permanent crops land growth . Same as for Asia, in African countries, arable land is more sensitive to increase in disbursements in Agricultural policy and administrative management in case of flood (Table 3).

3.3 ODA Impact on Agriculture

In this model the impact of disaster and the effectiveness of ODA disbursement s is measured on the economy through the value added from agriculture, as % of the country GDP. Thus, a dynamic panel is estimated using as response variable the value added from Agriculture (% of GDP). The model is estimated using GMM (Arellano-Bond linear dynamic panel estimator), where instruments are variables related to the magnitude and severity of the disaster/flood event occurred in the previous year, 1-lag food aid shipments in cereals and rice. Moreover, we control for the growth rate of agriculture value added, irrespectively of extreme events, the GDP growth, the natural growth of land resources (permanent crops, arable land and forest area) and last decade general trend. The explanatory variables are ODA grants disbursed in the previous year in humanitarian aid and agriculture interacted with land used for permanent crops or with agriculture arable land in the previous year. Moreover, the impact of grants disbursed in the past on current valued added from agriculture through permanent crops and arable land is considered separately in case of disaster/flood event.

Table 7: IMPACT on VA through permanent crops vs arable land variation after a general disaster (EMDAT)

Variable	Permanent Crops		Arable land	
	Coefficient	(Std. Err.)	Coefficient	(Std. Err.)
L.va_agr_gdp	0.006	(0.058)	0.009 *	(0.004)
gdpgrowthannual	-0.001	(0.001)	-	-
perm_crops_rel	0.165 †	(0.088)	0.198 **	(0.023)
agr_arable_rel	0.437 *	(0.191)	0.408 **	(0.024)
forest_area_rel	-0.589	(0.364)	-0.680 **	(0.048)
perm_crops1_disb7d1	0.000 *	(0.000)	-	-
agr_arable1_disb7d1	-	-	0.000 **	(0.000)
perm_crops1_disb7d1_dis1	0.000 *	(0.000)	-	-
agr_arable1_disb7d1_dis1	-	-	0.000 *	(0.000)
perm_crops1_disb3d1	0.000 †	(0.000)	-	-
agr_arable1_disb3d1	-	-	0.000 **	(0.000)
perm_crops1_disb3d1_dis1	0.000	(0.000)	-	-
agr_arable1_disb3d1_dis1	-	-	0.000 **	(0.000)
dum_0312	-0.025 †	(0.014)	-0.037 **	(0.005)
Intercept	0.066 **	(0.011)	0.072 **	(0.005)
N	648		630	
$\chi^2_{(10)}$	35.211	$\chi^2_{(8)}$	894.300	
Significance levels : † : 10% ∗ : 5% ∗∗ : 1%				

Table 8: IMPACT on VA through arable land variation after a FLOOD (EMDAT)

Variable	All countries		ASIA	
	Coefficient	(Std. Err.)	Coefficient	(Std. Err.)
L.va_agr_gdp	0.002	(0.004)	-0.239 **	(0.078)
gdpgrowthannual	-0.001 **	(0.000)	0.001 **	(0.000)
perm_crops_rel	0.209 **	(0.022)	0.026	(0.036)
agr_arable_rel	0.376 **	(0.026)	0.105 **	(0.024)
forest_area_rel	-0.645 **	(0.061)	-2.817	(2.789)
agr_arable1_disb7d1	0.000 *	(0.000)	0.000	(0.000)
agr_arable1_disb7d1_nfl1	0.000 †	(0.000)	0.000	(0.000)
agr_arable1_disb3d1	0.000	(0.000)	0.000 *	(0.000)
agr_arable1_disb3d1_nfl1	0.000	(0.000)	0.000 *	(0.000)
dum_0312	-0.037 **	(0.005)	-0.023 *	(0.011)
Intercept	0.075 **	(0.004)	0.087 **	(0.019)

N	628		175
$\chi^2_{(9)}$	1036.368	$\chi^2_{(9)}$	367.585
Significance levels : † : 10% * : 5% ** : 1%			

Table 9: IMPACT on VA through arable land vs permanent crops variation after a GENERAL DISASTER (EMDAT): ASIA vs AFRICA

Variable	ASIA		AFRICA	
	Coefficient	**(Std. Err.)**	**Coefficient**	**(Std. Err.)**
L.va_agr_gdp	-0.240	(0.147)	-0.027	(0.086)
gdpgrowthannual	0.001 *	(0.001)	-0.001	(0.001)
perm_crops_rel	0.021	(0.106)	0.208 †	(0.112)
agr_arable_rel	0.110	(0.067)	0.757 *	(0.325)
forest_area_rel	-2.672	(4.824)	-2.506	(1.645)
agr_arable1_disb7d1	0.000	(0.000)	-	-
perm_crops1_disb7d1	-	-	0.000 **	(0.000)
agr_arable1_disb7d1_dis1	0.000 †	(0.000)	-	-
perm_crops1_disb7d1_dis1	-	-	0.000 †	(0.000)
agr_arable1_disb3d1	0.000	(0.000)	-	-
perm_crops1_disb3d1	-	-	0.000 *	(0.000)
agr_arable1_disb3d1_dis1	0.000 †	(0.000)	-	-
perm_crops1_disb3d1_dis1	-	-	0.000	(0.000)
dum_0312	-0.025	(0.022)	-0.004	(0.023)
Intercept	0.086 *	(0.035)	0.078 **	(0.028)
N	175		353	
$\chi^2_{(10)}$	49.302	$\chi^2_{(10)}$	75.607	
Significance levels : † : 10% * : 5% ** : 1%				

The main findings are briefly summarized here below.

• In the last decade there is a general decreasing trend of agriculture value added.

• ODA grants in agriculture and humanitarian aid/material relief contribute to re-boost the economy through agriculture production in permanent crops and arable land, this regardless the presence of disasters/flood events (Table 3.3).

• If a general disaster occurs, ODA humanitarian/relief grants (section 7) increases future agriculture value added through both arable land and permanent crops, whereas grants disbursed in agriculture are effective in case of general disaster through arable land only (Table 3.3).

• When a flood event occurs, ODA grants in aid and agriculture do not generally affect agriculture value added through permanent crops. However, grants disbursed in humanitarian aid and disaster relief is effective on future agriculture value added increase through arable land, with additional positive impact in case of flood (Table 4).

• In Asia the contribution of grants to value added is mainly through arable land, whereas in Africa through permanent crops. For Asiatic countries, the impact of grants in section 3 and 7 on value added is positive in case of general disasters (Table 5), whereas for floods it is mainly grants in agriculture which help (Table 4). As for Africa, grants disbursed in reconstruction and humanitarian aid are mostly effective after a general disaster. There is no evidence for Africa of differential impact when the disaster is a flood, nor through the arable land.

• Positive changes in permanent crops or arable land are accompanied by lower growth rate of forest area and vice-versa.

4 Discussion

The objective of this study are to investigate the effectiveness of ODA flows on disaster recovery related to agricultural land. In particular, this is related to the extent of floods in terms of magnitude and severity across countries from 1985 on. To this aim we build an original panel of world countries merging several data from various sources.

Our research comprises the use of dynamic models to take into account existing feedbacks effects between aid response and changes in land cover. Moreover, a new release of ODA data has been made available by FAO and enables us to use more disaggregated data on commitments related to aid and disaster recovery in agriculture. In addition, we extend the analysis to other disaster types, such as droughts, earthquakes and tsunamis.

From the analysis carried out so far we can conclude that there is a persistent positive correlation of past ODA flows with agriculture land cover, in particular with permanent crops area. Moreover, past year commitments are significantly affecting current disbursements, especially commitments taken the year after a disaster significantly increase current disbursements. The latter usually occur with some delay with respect to the commitment taken, which can be possibly quantified about a 1-year period on average.

Moreover, we observe a differential impact of grants disbursed on agriculture value added through permanent crops and arable land. Interacting with arable land, humanitarian aid and disaster relief help to increase future value added in agriculture when there are floods. This is not true for grants in agriculture development, which help more in case of general disasters mainly through arable area.

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Appendix

Source: FAOSTAT

Food Aid Shipments		Land Cover	
Description	Name	Description	Name
Blended And Mix	blended	Country area	country_area
Bulgur Wheat Total	bulgur	Land area	land_total
Rice Total	rice	Agricultural area	agr_total
Butter Oil Total	butter	Agricultural area organic, total	agr_organic_tot
Cereals	cereals	Agricultural area certified organic	agr_organic_cert
Coarse Grains	coarse_grains	Agricult area in conversion to organic	agr_organic_conv
Dried Fruits Total	dried_fruits	Agricult area irrigated	agr_irrigated
Edible Fat Total	edible_fat	Arable land and Perm crops	arable_perm_crops
Fish & Products	fish	Arable land	arable_land
Meat & Products	meat	Arable land organic, total	arable_organic_tot
Milk Total	milk	Arable land certified organic	arable_organic_cert
Non-Cereals	non_cereals	Arable land converted to organic	arable_organic_conv
OtherDairy Products	other_dairy	Temporary crops	temporary_crops
Other Non-Cereals	Other	Temporary meadows and pastures	temporary_mead_pastur
Pulses Total	pulses	Fallow land	fallow_land
Sugar Total	sugar	Permanent crops	permanent_crops
Vegetable Oils	veget_oils	Permanent crops organic, total	permcrops_organic_tot
Wheat & Wheat Flour	wheat	Permanent crops area certified organic	permcrops_organic_cert
		Permanent crops in conversion to organic	permcrops_organic_conv
		Permanent meadows and pastures	permanent_pastures
		Permanent meadows and pastures organic, total	permpastures_organic_tot
		Permanent meadows and pastures area certified organic	permpastures_organic_cert
		Permanent meadows and pastures area in conversion to organic	permpasture_organic_conv
		Perm. meadows & pastures - Cultivated	permpasture_cultivated
		Perm. meadows & pastures - Nat. grown	permpasture_natgrown
		Forest area	forest_area
		Other land	other_land
		Inland water	inland_water
		Total area equipped for irrigation	totarea_equip_irrigation

RESPONSIVENESS against flood (DARTMOUTH): FE Autoregressive on all countries, adding SEVERITY

Variable	**Coefficient**	**(Std. Err.)**
all7_commitment_defl	0.735	(0.013)

	**	
all7_commitment_defl1	0.219 **	(0.011)
all7_commitment_defl1_sev1	-0.001 **	(0.000)
all7_commitment_defl2	0.035 **	(0.012)
tot_agr_disbursement_defl1	-0.044	(0.106)
tot_agr_disbursement_defl1_nfl1	0.178 †	(0.105)
tot_agr_disbursement_defl	18.084 **	(5.515)
tot_agr_disbursement_defl_asia	-17.862 **	(5.516)
tot_agr_disbursement_defl_afr	-17.838 **	(5.515)
tot_agr_disbursement_defl_am	-17.890 **	(5.520)
forest_area	-0.030 *	(0.012)
forest_area1	0.030 *	(0.012)
agr_arable	0.025 **	(0.005)
agr_arable1	-0.024 **	(0.005)
dum_0312	8.612 *	(4.158)
rice1	0.000 †	(0.000)
cereals1	0.000 **	(0.000)
displaced21	0.000 †	(0.000)
max_of_totalannualflood_m61	0.449	(0.313)
max_totalannual_flood_m41	-0.146	(0.100)
Intercept	-23.151 **	(6.530)
N	686	
Log-likelihood	-3337.223	
$F_{(95,590)}$	254.683	
Significance levels : † : 10% * : 5% ** : 1%		

Understanding the impact of post-disaster needs assessment on agriculture sector recovery

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ABSTRACT

The great majority of communities affected by disasters in developing countries are directly or indirectly dependent on agriculture for their livelihood. Climate change has been linked to a significant increase in the frequency and severity of disasters in the recent past, leading to natural hazardous events that have had several negative repercussions on the agriculture sector and sub-sectors (i.e. crops, livestock, fishery and aquaculture) and on the life of the people depending on them. The paper will firstly review the commonly used methods of assessing the damages and losses to the agriculture sector and its sub-sectors, with particular emphasis on the strengths and limitations of the Post-Disaster Needs Assessment (PDNA) methodology. After that, it will consider the financial implications of disasters and discuss the necessity of developing follow-up mechanisms to assess the proportion of disbursed funds required to implement response interventions. This will involve an analysis of the extent to which agriculture assistance is usually prioritized in the formal and informal sector, and the typology of targeted and assisted beneficiaries with an emphasis on the gender dimension. The paper concludes with recommendations aiming at improving the current standardized processes of assessing the impacts and effects of disasters, in order to enhance the effectiveness of needs assessment towards resource mobilization and recovery processes.

Keywords: Post-Disaster Needs Assessment (PDNA), Recovery, Livelihood and Gender Sensitivity Analysis, Agriculture Assistance and Disaster Response Mechanisms.

1. Introduction

The agriculture sector remains the backbone of the economy for the majority of developing countries. In Central African Republic, Ethiopia, Tanzania, Malawi, Sierra Leone, Kenya and Cambodia among others, this sector contributes to as much as 30 percent of the national GDP (WB, 2014).
Recurrent and prolonged natural hazardous events and disasters, such as drought, floods, storms, spread of pests and diseases and saltwater intrusion, have severe impacts on agricultural livelihoods. Climate change exacerbates these events and their impacts. According to data from the International Disaster Database – Centre for Research on the Epidemiology of Disasters (EM-DAT CRED), between 2003 and 2013, natural hazards caused USD 1.5 trillion in economic damage worldwide, affecting 2 billion people (FAO, 2015*a*). However, there are no clear indications of how much of this damage affected the agriculture sector.
The increasing complexity and frequency (going from 80 to 420 events recorded per year over the past 20 years; CRED et al., 2015) of these disasters, and the consequent negative impact on vulnerable populations requires post-disaster needs assessments and related monitoring and evaluation studies to enable better assistance for the recovery of affected populations.
Specific methodologies such as Post Disaster Needs Assessment (PDNA) have been developed to estimate the financial implications of natural disasters in order to identify recovery needs defined from a human, socio-cultural, economic, and environmental perspective. Nonetheless, there are no available studies or follow-up mechanisms in place to monitor the magnitude of financial assistance provided to support country recovery, particularly relating to the agriculture sector and sub-sectors (i.e. crops, livestock, fishery and aquaculture).
In order to plan for better assistance and allocate an adequate share of humanitarian and recovery funds to the agricultural sector, as well as to enhance the visibility and accountability of funding provision, it is important to categorize the share of support provided by donor communities *vis-à-vis* the governments of affected countries. This should include the description of mechanisms used to target beneficiaries, the type of assistance received (in-kind vs cash) and the funding gaps, in order to enhance the appeal and recovery processes.
This paper describes the main methodologies used to assess damages and losses in the agriculture sector and sub-sectors, elucidating the financial gaps and implications that need to be addressed in order to better support the recovery of both the formal and informal sectors. Additionally the paper seeks to describe the intended beneficiaries and affected population, with particular attention to gender equality.
The paper concludes by making recommendations to foster the establishment of monitoring and evaluation mechanisms that should be put in place throughout the post-disaster recovery process.

2. Methodologies for assessing agriculture damages and losses

Over the years, assessing the effects and impacts of disasters on the agricultural sector, covering crops, livestock, fisheries and aquaculture,[1] has been mainly done by agronomists or agricultural economists. Institutionally, the ministry or department of agriculture assesses damages and the losses based on the initial reports prepared by first responders, local authorities, or the national disaster or emergency management agencies.
Since the 1990s there have been efforts to agree on a standardized methodology with uniform concepts and means to measure the destruction of agricultural capital and assets and the ensuing production losses, be it through diminishing yields and returns or actual damage to crop and harvest. The best known early

[1] Forest exploitation, be it for logging, collection of plants and animal hunting or the environmental services provided by natural forests, is traditionally not included in the agricultural sector evaluations but dealt with separately, either as lumber industry or forest exploitation. Environmental services are assessed separately as the effects of disasters on the natural or intervened natural habitat.

methodology (called Damage and Loss Assessment - DALA) was developed by the United Nations Economic Commission for Latin America and the Caribbean (UN-ECLAC, see ECLAC, 2003; ECLAC, 2014) with the collaboration of the United Nations Food and Agriculture Organization (FAO).[2] This methodology was used by sector specialists in the Latin American and Caribbean region and others, in order to differentiate the sector production losses (as the production and income flows that have been lost due to the disaster) from the damage to the sector assets and capital (infrastructures such as silos, storage facilities, stables, etc. machinery and implements such as harvesters, tractors, boats, nets and fishing gear, in addition to animal stock such as cattle, bees or fish).

In parallel to this, attention was increasingly given to livelihood losses in the sector and the effect on human capital. This path was followed by FAO alongside the United Nations International Labour Organization (ILO) leading to the jointly FAO/ILO developed Livelihood Assessment Toolkit, LAT (FAO, 2009; FAO and ILO, 2009; ILO, 2011), as a means to approach the micro-impact of disasters on agriculture and rural households.

The DALA methodology was gradually internalized by national governments and international organizations and the sector methodology was incorporated and updated in the current Post-Disaster Needs Assessment (PDNA), following the joint agreement signed by the United Nations (UN), the World Bank (WB) and the European Union (EU) in 2008, to attain a common standard for assessment of and recovery from disasters (IRP, 2013*a*; UNDP, 2013; GFDRR, 2014, 2016). Aside from the purely economic aspects of the DALA, the PDNA aims at also assessing the effects of a disaster on the populations' livelihoods, taking into consideration the human, socio-cultural, economic and environmental perspective. As of today, the PDNA is an internationally accepted methodology, process and tool, used in dozens of specific disasters and has proven its adaptability to specific cases (including a range of types of disaster, economic structures and national characteristics).

The sector analysis of the agricultural related primary sector, i.e. crops, plantations, animal husbandry, bee production, fishing and fish farming, is intended to assess the value chain of the sector, from the farm gate to the market, thus differentiating the loss to actual agriculture farmers and labourers from the intermediate agriculture wholesale trade and the marketing. The latter two must be seen in the context of the commerce and trade sector and require a cross cutting and interconnected analysis that goes from the local market to the international export and import trade. The differentiated impact in terms of types of agricultural producers, gender and use of non-paid labour of family members is to be specifically analysed (IRP, 2013*b*; UN, 2014).

A cross cutting, integrated, holistic approach is part of the sector analysis in so far as food production and income losses in the sector may lead to malnutrition and food insecurity, with economic, social and health implications.

3. Financial Implication of disasters

When considering only climate-related disasters – i.e. floods, droughts, hurricanes, typhoons and cyclones (excluding geological hazards such as earthquakes, tsunamis and volcanic eruptions) – damages and losses recorded in the agriculture sector represent 25 percent of the overall economic impact (FAO, 2015*a*). In most cases of post-disaster recovery and reconstruction, international aid agencies provide technical and financial assistance for the disaster affected populations (Chang *et al.*, 2010). Hence, disbursement of funds and prioritization of resource allocation among the sectors affected by disasters is an important precondition to ensure a well targeted and sustainable reconstruction phase. Between 2003 and 2013, according to a FAO study (FAO, 2015*b*), about USD 4 billion was spent on humanitarian assistance to the agriculture sector, averaging nearly USD 375 million annually as indicated in Figure 1 below.

[2] At the time there was a joint ECLAC / FAO Agriculture Division that linked the ECLAC headquarters with the FAO Regional Office for Latin America, both located in Santiago, Chile.

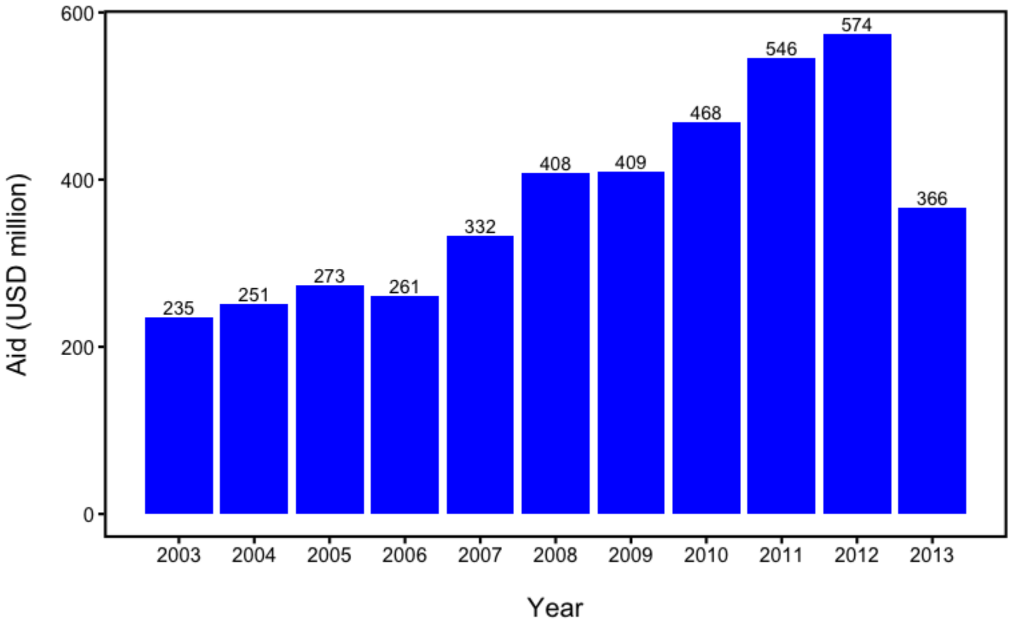

Figure 1: *Total humanitarian aid to the agriculture sector, by year (USD million)*

Considering that during this decade (2003-2013), roughly USD 121 billion was spent on humanitarian assistance for all types of disasters and crises, the proportion of funds allocated to the agriculture sector corresponds to only 3.4 percent of the total humanitarian funds (FAO, 2015a).
Despite this available data, there is no official and disaggregated information reporting allocation of rehabilitation / reconstruction funds to each of the agriculture sub-sectors usually affected by disasters. In fact, most of the available literature focuses on information related to the agriculture sector as whole. Besides, there are no mechanisms in place to assess the proportion of disbursed funds required to implement response interventions, against emergency appeals and pledges. For example, most of the PDNA processes are nowadays ending with the preparation of the Disaster Recovery Framework (DRF), which helps in articulating the recovery vision, defining the recovery strategy, prioritizing actions, fine-tuning planning, and providing guidance on financing, implementing and monitoring the recovery (GFDRR, 2016). However, it is very important to establish follow-up mechanisms that will allow monitoring, evaluating and recording the size and type of investments made to support the recovery of the agriculture sector and sub-sectors. This will enhance the availability of information necessary to communicate the results of the joint efforts and thus ensure a successful and transparent recovery process after the implementation of post-disaster assessments such as PDNA. Establishing monitoring mechanisms should also help in indicating and recording how financial resources were allocated, from which sources and disbursement mechanisms they were obtained (i.e. emergency funds from national budget, grant / credits from financial institution or donors, bi- or multilateral funds, etc.), in addition to type of beneficiaries assisted (i.e. gender groups), with possible identification of financial shortfalls required to provide the entire appealed support.

4. The implication of disasters on the formal and informal sector

Commercial agriculture, or the formal agricultural sector, is the main contributor to the agriculture GDP of a country; going from almost 100 percent in the industrialized nations, to 73 percent in Botswana, 46 percent in Sri Lanka, 20 percent in Iran and none in Burkina Faso (UN, 2004). This sector mainly consists of large scale farms or plantations, with a high level of mechanization, having access to credit and insurance schemes, often in line with and / or supported by agriculture policies of the country. Production is mainly directed to internal markets or to export.
On the other hand, the informal agriculture sector consists mainly of smallholding farmers that include agriculture casual labourers or kind of multiple job holders in rural areas. Farmers are producing mainly for their own consumption, and surplus is sold on the local markets. There are an estimated 500 million smallholder farmers in the world, supporting almost 2 billion people (IFAD, 2013). Even when smallholding

farmers represent a significant share – even the majority – of the rural population, they are still considered part of the informal sector, since they are not fully included into the national accounts system through paying taxes. As a result they are not comprised into the GDP calculations.
For example, in Mali the entire agriculture sector is considered informal, whereas in Kazakhstan, Belarus and Chile, informal agriculture represents 75, 56 and 37 percent of the agricultural sector respectively. On the other hand, the informal sector is almost absent in the industrialized countries (UN, 2004).
Disasters have negative implications in both the formal and informal sectors. In the formal sector, and to less extent in the informal one, disasters decrease national revenues to the GDP, leading to reduced internal food production levels and increased prices of food commodities, in addition to lowering countries' capacity of exporting agriculture products. Whilst in the informal sector, the effects of a disaster on the livelihoods of subsistence or smallholding farmers are usually devastating. In fact, they contribute to loss of and damage to agricultural production, in addition to losses of animals and stocks or damages to assets and infrastructures. Aside from the material losses, disasters increase the level of food insecurity and malnutrition, and diminish the casual and wage labour opportunities to generate income.
Indeed, the capacity to recover from disasters differs in the two sectors. The high level of mechanization, and the possibility to access savings and credits, makes the formal sector more resilient and enables a quicker recovery. In contrast, in the informal sector, the situation is completely the opposite since the people affected, mainly smallholders, are less resilient to disasters and usually require more time and efforts to reconstitute their livelihoods.
In addition, after a disaster, governments are generally more keen to assist in a rapid recovery of the formal agriculture sector in order to restore production and re-establish the contribution to the GDP and national food security, leaving the recovery of the informal sector in the hands of international humanitarian actors (NGOs and UN agencies) as well as faith-based or civil organizations, especially during the relief phase.
Despite this, the type of support provided by international donors or funding institutions depends mainly on their institutional mandate or political interest towards the affected countries. For example, the WB usually focuses in funding the rehabilitation of infrastructures and assets of the commercial agriculture sector (NDRRMC, 2015), whereas the EU plays a major role as a donor when the countries affected are in Europe or where the EU is supporting the implementation of large programmes such as the African Caribbean Pacific – European Union Disaster Risk Reduction Program (ACP *et al.*, 2016).
Overall, in the formal sector, the labour force is mostly provided by casual labourers, which are also largely constituting the informal sector (ILO, 1994; ILO *et al.*, 2007), with the share of female casual labourers ranging from 20 – 30 percent and child labour up to 30 percent (ILO, 1996). In contrast, in the informal economy, women play a much bigger role, together with the working poor and most low-income households (ILO, 2002). In general, rural women are the main producers of the world's staple crops - maize, rice, and wheat - which provide up to 90 percent of the rural poor's food intake. Studies have shown that rural women in particular are responsible for half of the world's food production and produce between 60 and 80 percent of the food in most developing countries (FAO-WB-IFAD, 2009).
Nonetheless, both men and women in the informal agriculture sector suffer increased vulnerability to disasters because they typically lack legal, land or labour rights. However, women suffer more from this deficiency, mainly due to cultural, social, religious or political / economic reasons. For example, women rarely have the same land tenure rights as men or access to the same resources. Animal ownership and use of animal products also differ, alongside cultural gender differences between women and men, including roles, capacities, responsibilities and freedom of speech (FAO, 2010).
Due to this situation, a main focus should be given to the integration of gender equality aspects in the formal and informal sector during the implementation of needs assessments and the response framework process after a disaster. For example, the Philippines' government under the Republic Act 10121 Section 9, item (m) emphases the need of institutionalizing gender analysis during the processes of post-disaster needs assessment and early recovery (NDRRMC, 2015).

5. Intended Beneficiaries and affected population.

The intended beneficiaries of the post-disaster recovery processes in the agricultural sector are usually the people relying on the sub-sectors of crops, livestock, fishery and aquaculture, as their main source of livelihood. They are generally included in the needs assessments through Household Surveys and Focus Group Discussions although not uniformly in different assessment methods. Livelihood-focused assessments engage beneficiaries more effectively both in the implementation and recovery processes compared to more macro-economic level assessment conducted through PDNA. Table 1 illustrates some typical groups of intended beneficiaries and the kinds of support that is usually required for each group.

Table 1: *Type of support and intended beneficiaries in livelihood-based needs assessment*

Beneficiaries	Immediate Relief	Early Recovery Support	Sustainable Livelihood Interventions
Crop farmers	- Provide seeds, fertilizers, pesticides, as well as tools and temporary storage facilities (in-kind or cash or voucher). - Construct temporary wells also using cash for work initiative.	- Rehabilitate storage and processing facilities. - Support farmers and agro-suppliers with credit facilities to improve access to inputs. - Repair equipment and machineries. - Rehabilitate irrigation infrastructure.	- Introduce crop insurance schemes. - Promote alternative crops and more diversified cropping systems and soil conservation practices. - Improve extension services. - Review relevant agricultural policies. - Expand advanced irrigation systems and introduce fees for water usage. - Improve/diversify market access.
Livestock Producers	- Support animal restocking and destocking. - Provide feed and vaccine. - Establish temporary shelters. - Provide emergency vet services.	- Rehabilitate animal shelters by distributing building materials or using cash or voucher schemes. - Provide subsidized feeds or feed-mills. - Expansion of vet services.	- Introduce livestock insurance. - Expand artificial insemination to increase productivity. - Regularize vet services. – Provide credit facilities. - Improve/diversify market access. - Improve extension services. - Revise relevant livestock policies.
Fishery/Aquaculture producers	- Support for restocking existing ponds. - Provide fish feed and meds. - Establish cash for work initiatives to rehabilitate ponds/hatcheries.	- Rehabilitation of ponds/hatcheries through voucher schemes and cash for work. - Provide subsidized animals.	- Provide credit facilities for aquaculture expansion. - Introduce effective extension services. - Improve/diversify market access.

The beneficiaries in livelihood assessments typically report needs for immediate relief or early recovery, while development agencies tend to introduce ideas for longer term planning, and sustainable development. In each of the groups of beneficiaries listed in Table 1 above, particular attention is usually given to gender balance to ensure women get the kind of support they need (UNDP, 2010). Nonetheless, there are few efforts to disaggregate male and female needs during post-disaster assessments and recovery process.

Other vulnerable groups such as youth, the aged, people with disabilities, and the landless will hopefully get special attention especially with the increased human impact focus (EU-GFDRR-UN, 2013).
The targeted numbers of intended beneficiaries (people affected) of course depends on the scale and intensity of the hazard and the vulnerability of the people affected.
Some people affected by disasters are able to recover on their own through existing insurance coverage, as members of church groups or other benevolent organizations, or through kinships and family networks. Others not directly affected might also benefit from post-disaster recovery efforts especially through Disaster Risk Reduction (DRR) and resilience building initiatives also called Building Back Better (BBB). In fact, these result in new and better infrastructures, economic investments, as well as livelihoods and job opportunities for communities at large.
The literature on actual people who benefited as a result of the conduct of a PDNA which led to a recovery plan is scarce. A statistical analysis of those who have actually benefited from related PDNAs in the agriculture sector is therefore not possible at this time, but it is strongly recommended that pertinent assessments which could provide such data are carried out. Nevertheless some beneficiary relevant lessons can be extracted from recovery programs as presented below.

5.1. Lessons learned from Case Studies

The revival of household and local economy has an important multiplier impact, which strengthens recovery and puts it on an upward trajectory. In many recovery programmes, the allocation of resources is largely for infrastructure reconstruction, and it tends to ignore the economic needs at the household and community levels. An emphasis on a more balanced recovery programme, which also empowers the affected households and communities through direct transfer of resources for restoration of livelihoods and other assets, would result in a more sustainable and equitable recovery.
A report published 3 years after the Pakistan 2005 earthquake noted that the agencies helping with recovery – the Pakistan Government, the Army, the international Financial Institutions and relief agencies – were not familiar with livelihood restoration and so major challenges were still present (Ahmad and Suleri, 2008). The report emphasised the need for a multidimensional livelihood assessment, a greater focus on assets recovery (livestock, crops, soil, etc.) as most attention was put on income regeneration, and for the livelihood strategies to be gendered. In addition, it stressed the need for strengthening capabilities to allow people to better utilise their assets.
In the PDNA of the Kenya drought (2008-2011) the inclusion of the Human Development Recovery Needs Assessment (HRNA) allowed a detailed assessment of the impact of the disaster on the livelihoods of the poor and showed the greater impact on those with lower Human Development Index (HDI). Nonetheless, this assessment did not lead to integrated livelihood recovery recommendations which remained largely macro-economic and sectorial in nature (Government of Kenya et al., 2012).

6. Conclusion and recommendations

Despite the existence of globally recognized methodologies such as PDNA, additional efforts are required to ensure a more transparent and well-coordinated recovery process in the aftermath of a disaster.
Post-Disaster Needs Assessments, should be constituted by follow-up mechanisms to verify the amount of funds pledged and disbursed to support the recovery process, possibly disaggregated by sector and sub-sectors, and indicating the source of funds (i.e. donors, government, etc.). In addition, a clear indication on the type of beneficiaries assisted or requiring assistance (divided by gender groups), should be also available, with potential identification of financial shortfalls required to provide the entire appealed support. The establishment and enforcement of these mechanisms should be discussed among the WB, EU and UN, which constitute the tripartite agreement of the PDNA methodology. All actors providing assistance during the recovery process, including the government of the country affected, should be informed in advance about the necessity of gathering specific information so that they can share whatever is required as part of their support efforts.

Due to the existing differences in the vulnerability and exposure to the disasters occurred in the formal and informal agriculture sector, it is generally recognized that this latter sector is usually considered the most affected. Nonetheless, there is no reliable information on the extent of support which is usually received by the two sectors. As a result more studies need to be conducted in these areas in order to ensure that both sectors are equally supported in the aftermath of a disaster, with particular attention on the informal sector where millions of smallholder farmers make their living and where most of the vulnerable people are recognized.
Finally, the PDNA methodology needs to be much more inclusive and accountable to the affected population by becoming more faithful to a people-centred approach. In this line, affected communities should be engaged more often during the assessment process in order to better understand how they were affected by the disaster and what they need most to recover and enhance their resilience capacities. This could be done through the use of more systematic primary data collection techniques such as surveys, to be included as part of the assessment methodology.

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A methodology to assess damage and losses from natural hazard-induced disasters in agriculture

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ABSTRACT

Over the last decades, there has been an increase in the occurrence of disasters worldwide, which is especially noteworthy in relation to climatological events (e.g. droughts), hydrological events (e.g. floods), and meteorological events (e.g. storms). For the agriculture sector, the increase of weather-related events is a significant concern given the high dependence of agriculture on climate. Yet, the impact of disasters on the sector is not well enough understood, given the limited statistics available and the lack of systematic reporting in countries.

The objective of this paper is to propose a methodology for monitoring the impact of disasters on agriculture and its sub-sectors (crops, livestock, fisheries, aquaculture and forestry). This would form the basis for setting up a monitoring system that can provide policy-makers and stakeholders at large with standardized data and metadata for evidence-based decision-making towards sustainable agricultural development and enhanced resilience.

Several approaches and methodologies exist to assess the impact of disasters. The basic methodological frameworks come from the Post-Disaster Needs Assessments (PDNA) conducted jointly by the World Bank, EU and United Nations with the leadership role of national Governments. A main conclusion from the literature discussing applications of these methodologies is the need to distinguish damage, i.e. total or partial destruction of physical assets existing in the affected area, from losses, i.e. changes in economic flows arising from the disaster.

Based on the analysis of 78 post-disaster needs assessments, the FAO's study on "The impact of disasters on agriculture and food security" found that agriculture absorbed 22 percent of all damage and losses caused by disasters in developing countries between 2003 and 2013. Furthermore, by analysing secondary data from FAOSTAT and other relevant sources, the FAO study found that significant drops in agricultural production, changes in agricultural trade flows and

declines in agriculture value added occurred after disasters in developing countries over the same period.

FAO aims at taking a broader perspective towards improving the amount and quality of the information available on disaster impacts in agriculture. The methodology proposed in this paper shall be designed also to support the monitoring of progress towards the achievement of global and national goals and targets on disaster risk reduction and resilience, including under the Sustainable Development Goals and the Sendai Framework for Disaster Risk Reduction.

Keywords: Natural hazards; Disaster impact assessment; Agricultural damage and losses.

1. Introduction

Over the last decades there has been an increase in the occurrence of natural hazard-induced disasters worldwide. Evidences show that extreme events such as droughts, floods and storms have occurred with high frequency and magnitude (CRED & UNISDR, 2015). These trends are particularly worrying for agriculture, considering the high dependence of the sector on climate and natural resources.

According to the Post Disaster Needs Assessment (PDNA) guidelines, the economic impact of disasters is measured as the sum of damage, i.e. monetary value of physical assets totally or partially destroyed, and losses, i.e. changes in economic flows arising from the disaster. Based on information obtained from PDNAs, the FAO study on The Impact of Disasters on Agriculture and Food Security showed that, between 2003 and 2013, 22 percent of the total economic impact of natural hazard induced disasters in developing countries was absorbed by agriculture, a figure much higher than previously reported. Yield trend analysis revealed that crop and livestock production losses after medium to large-scale disasters in developing countries averaged more than USD 7 billion per year over the same period (FAO, 2015). The study represented a first step towards filling the information and knowledge gap about the nature and magnitude of disaster impacts on agriculture, and highlighted the need for systematic monitoring and standardized assessment of damage and losses in crops, livestock, fisheries/aquaculture and forestry.

This paper describes a logical structure for linking the magnitude of the natural hazard to the corresponding damage and losses values, and proposes a standardized approach to measure damage and losses from natural hazard-induced disasters in agriculture. Overall, this paper fits in the FAO initiative for the development of an information system on damage and losses caused by disasters on the sector and its subsectors (crops, livestock, fisheries, aquaculture and forestry). As part of its commitment to enhancing the resilience of agriculture and rural livelihoods, FAO aims to support member countries to collect and report relevant data on the immediate physical damage caused by disasters on agricultural assets, as well as on the cascading negative effects of disasters on agricultural production, and value chains.

2. Logical steps for measuring disaster impact on agriculture

The logical structure behind a methodology for measuring the impact of disasters in agriculture involves three main steps:

1. The identification of the natural hazard and its magnitude.

2. The identification of the causal linkage between the hazard and damage and losses in agriculture.
3. The assessment of damage and losses caused by the hazard on agriculture, which constitute a measure of the disaster, i.e. the natural hazard impact on the primary sector.

The first step relies on the analysis of key indicators (e.g. climatic, environmental, geophysical, hydro-meteorological, biological indicators) in order to identify key characteristics of hazards, such as their location, area affected, intensity, speed of onset, duration and frequency. The second is the most delicate step: establishing a robust causal relation between the hazard and the impact on agriculture may be complex, as the effects should be isolated from idiosyncratic shocks such as civil conflicts, political instability or global macroeconomic shocks, which may play an important role in changing production dynamics. The third step involves the assessment of disaster impacts and the computation of the monetary value of damage and losses.

The definition of a standardized methodological framework is meant to support the process that goes from the collection and sharing of relevant data at global, national and sub-national level to the calculation of disaster's damage and losses in agriculture (Figure 1). The collection of relevant data includes the selection and use of multiple sources at different levels, including country-level observation data (e.g. agricultural surveys), earth observation data (e.g. satellite, drone-based imagery), and stressors data (e.g. climatic and environmental indicators), among others. The primary data gathered should be organized in order to develop relevant information on post-disaster situation, and a reliable baseline for robust counterfactual analysis. Finally, the assessment stage implies the application of methods for the attribution of monetary values to damage and losses in each agricultural sub-sector.

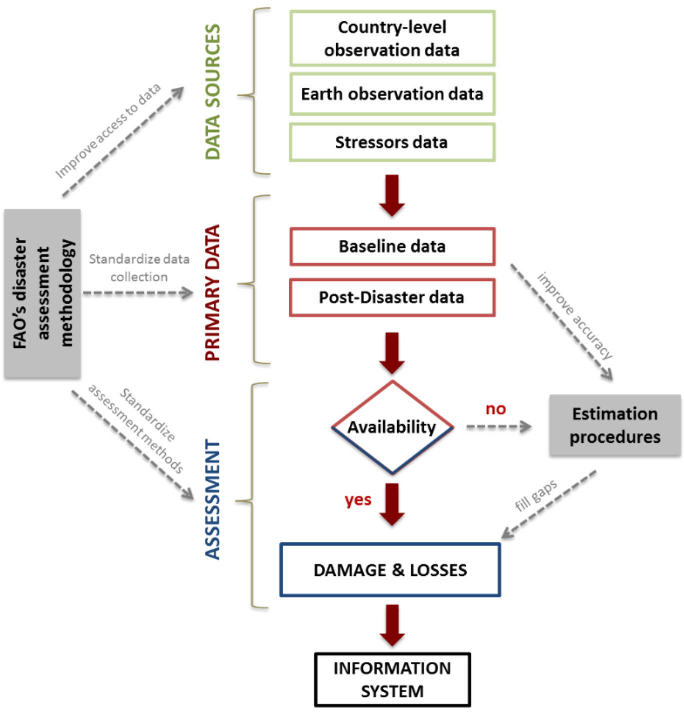

Figure 1: *Damage and Losses System Diagram: from data to D&L indicators*

In cases when vital baseline or post-disaster data are only partially available, estimation and imputation procedures can be implemented through a procedural cascading structure in order to provide approximate figures on disaster impact. The use of a set of statistical tools allows to (1) fill data gaps and provide robust numbers for both the baseline and disaster impact values; and (2) forecast the impact of natural hazard-induced disasters based on country-specific characteristics. The forecasting capacity is strictly linked to the availability of historical primary data on disaster impact collected through a standardized methodology, such as the one proposed in this paper.

Damage and losses data are expected to support research on disaster impact trends in agriculture, as well as to enhance the resilience of rural livelihoods by informing evidence-based policies, strategies and action plans in disaster risk reduction and management.

Starting from the above considerations, this paper builds on the PDNA guidelines in order to propose a standardized methodology for calculating damage and losses caused by disasters in each agricultural sub-sector. In particular, the paper seeks to define uniform computation methods for translating primary data on disaster physical impact into monetary values of damage and losses. The adoption of standardized and systematic reporting mechanisms on damage and losses data at country level are meant to provide policy-makers, and stakeholders at large, with a sound information base for decision-making. Ideally, the information should allow implementing ex-ante cost-benefit analysis of disaster risk reduction (DRR) as well as post-disaster resource allocation.

The analysis of damage and losses data on historical events, combined with information from early warning systems (e.g. GIEWS, EMPRES, IPC tool) could improve anticipation of disaster impact, and support actions to be taken before, during and in the immediate aftermath of an event. Accurate, up-to-date data on disaster impacts at the sector level would eventually inform the monitoring of progress towards sectoral resilience goals and targets set under key international agendas, including the Sustainable Development Goals (SDGs) and the Sendai Framework for Disaster Risk Reduction (SFDRR).

3. Damage and losses computation methods

Disaster impact assessment methods largely vary depending on the sectors addressed, the goals of the assessment, and the organizations, governments and research institutes involved. For the purpose of the FAO information system on damage and losses in agriculture, the key reference methodology is the Post Disaster Needs Assessments (PDNAs), developed jointly by the World Bank, the United Nations and the European Commission (EC, UN, World Bank, 2013). A key element of the PDNA methodology is the distinction between damage, i.e. total or partial destruction of physical assets existing in the affected area, from losses, i.e. changes in economic flows arising from the disaster.

Following the logical structure of the PDNA methodology, Table 1 provides a standardized definition of damage and losses in the crops, livestock, fisheries, aquaculture, and forestry sub-sectors, including an indication of the items and economic flows that should be considered in the assessments, as well as the proposed calculation methods for assigning a monetary value to damage and losses. Each sub-sector has been sub-divided into two main sub-components, namely production and assets.

The production sub-component measures disaster impact on production inputs and outputs. Damages include, for instance, the value of stored inputs (e.g. seeds) and outputs (e.g. crops) that were fully or partially destroyed by the disaster. On the other hand, production losses refer to declines in the value of agricultural production resulting from the disaster. In the case of perennial crops, for example, production losses correspond to the sum of the monetary values of (1) fully destroyed standing crops; (2) decline in production in partially affected areas, as compared to pre-disaster expectations; and (3) the discounted value of lost production in fully damaged areas, until perennial crops become fully productive again.

The assets sub-component measures disaster impact on facilities, machinery, tools, and key infrastructure related to agricultural production. Crop-related assets include, among others, irrigation systems, machinery, equipment; livestock-related assets include sheds, storage buildings; fisheries assets include ponds, hatcheries, freezers and storage buildings, engines and boats, fisheries equipment; forestry assets include, among others, standing timber, firebreaks and watch towers, forestry equipment and machinery, fire management equipment. The monetary value of (fully or partially) damaged assets is calculated using the replacement or repair/rehabilitation cost, and accounted under damage (EC, UN, World Bank, 2013). The assumptions and formulas proposed for the computation of damage and losses are listed and described in the Technical Annexes 1 and 2, respectively.

A central component of the proposed methodology is resilience, intended as the ability to prevent and mitigate disasters and crises as well as to anticipate, absorb, accommodate or recover and adapt from them in a timely, efficient and sustainable manner (FAO, 2013). The prevention and response components of resilience are embedded in the computation methods. A set of resilience parameters are linked to the 'Vulnerability' and 'Lack of coping capacity' dimensions of the Index for Risk Management- INFORM, an open-source methodology for quantitatively assessing crisis and disaster risk (De Groeve, Poljansek, & Vernaccini, 2015). The higher is the risk defined by INFORM at national level, ceteris paribus, the higher is the cost attached to the disaster in a specific area. In other words, given the same intensity of the natural hazard, the estimation of damage and losses will be higher in those areas where the level of risk defined by INFORM is higher.

The proposed methodology is based on a set of assumptions and exogenous knowledge-based parameters; hence, results might be biased for a variety of reasons. First, the lack of data and the impossibility to relax the assumptions implies the utilisation of estimation procedures according to a cascading structure defined within the methodology. Second, errors may occur due to noise for externalities or lack of sensitivity in the measurement. Third, the knowledge-based features of the methodology may modify the final output depending on the source of knowledge.

The damage and losses computation methods proposed in this paper focus uniquely on the impact of disasters on agricultural assets and production flows. Nevertheless, it is acknowledged that disasters have negative effects beyond agricultural production and along the entire food and non-food value chain. In medium- and large-scale disasters, high production losses can lead to increases in imports of food and agricultural commodities to compensate for lost production and meet domestic demand. They can also reduce exports and revenues, with negative consequences for the balance of payment. When post-disaster production losses are significant and in countries where the sector makes an important contribution to economic growth, agriculture value-added or sector growth falls, as does national GDP (FAO, 2015). At the community level, disasters may undermine rural livelihoods and challenge food security. While further research is needed to develop and standardize the assessment of the cascading effects of disasters on the agriculture sectors, these elements fall outside the scope of this paper.

Table 1: *Damage and losses assessment methodology*

Sub-sector	Component	Damage		Losses	
		Item(s)	**Measurement**	**Economic flow(s)**	**Measurement**
Crop	**Production**	Stored crops (annual and perennial); perennial trees; inputs stored (seeds, fertilizer, pesticide etc.); additional inputs bought for replanting (seeds, fertilizer, pesticide, labor etc.).	Annual crops: (1) Pre-disaster value of destroyed stored annual crops and inputs (e.g. stored seeds). (2) Cost of additional inputs (including labor costs) bought for replanting in fully damaged hectares, when replanting is possible within the same season.	Value of crop production (excluding stored crops).	Annual crops: (1) Pre-disaster value of fully destroyed standing crops minus pre-disaster value of replanted crops, when replanting is possible within the same season (2) Difference between expected and actual value of crop production in non-fully damaged harvested area in disaster year.
			Perennial crops: (1) Replacement value of fully damaged perennial trees. (2) Pre-disaster value of destroyed stored perennial crops (e.g. fruits), and inputs (e.g. seedlings). (3) Cost of additional inputs (including labor costs and cost of nursery trees) bought for replanting fully destroyed trees.		Perennial crops: (1) Pre-disaster value of fully destroyed standing crops (e.g. fruits). (2) Difference between expected and actual value of crop production in non-fully damaged harvested area in disaster year. (3) Discounted expected value of crop production in fully damaged harvested area until full recovery.
	Assets	Machinery, siloes, irrigation systems, equipment, tools.	Total destruction: replacement cost of fully destroyed assets at pre-disaster price.		
			Partial destruction: repair/rehabilitation cost of partially destroyed assets at pre-disaster price.		
Livestock	**Production**	Livestock units and livestock products (primary and secondary) stored or ready for sale.	Animals: Pre-disaster value of dead animals minus value of dead animals sold.		
			Livestock products: Pre-disaster value of destroyed stored livestock products (primary and secondary).	Production value of livestock products (primary and secondary)	Livestock products: (1) Difference between expected and actual value of livestock products (primary and secondary) from survived animals in disaster year. (2) Discounted expected value of livestock products (primary and secondary) from dead animals until full recovery of livestock.
	Assets	Machinery, siloes, equipment, tools, and other buildings e.g., cattle fattening and rearing pens,	Total destruction: replacement cost of fully destroyed assets at pre-disaster price.		
			Partial destruction: repair/rehabilitation cost of partially destroyed assets at pre-		

Sub-sector	Component	Damage		Losses	
		Item(s)	Measurement	Economic flow(s)	Measurement
		milking stalls, sheds, stables, pigsties etc.	disaster price.		
Fisheries	**Production**	Fish catch stored or ready for sale.	Pre-disaster market value of destroyed fish stored or ready for sale.	Value of fish catch.	(1) Difference between expected and actual value of annual fish cacth in affected area in disaster year.
	Assets	Boats, ice and fish storage facilities, fishing gear.	Total destruction: replacement cost of fully destroyed assets at pre-disaster prices. Partial destruction: repair/rehabilitation cost of partially destroyed assets at pre-disaster prices.		
Aquaculture	**Production**	Fish stock; fish stored or ready for sale	(1) Pre-disaster value of dead fish minus value of dead fish sold. (2) Pre-disaster value of destroyed fish stored or ready for sale.	Value of aquaculture production	(1) Difference between expected and actual value of aquaculture production in affected area in disaster year.
	Assets	Fishponds, ice and fish storage facilities, tools, machinery.	Total destruction: replacement cost of fully destroyed assets at pre-disaster prices. Partial destruction: repair/rehabilitation cost of partially destroyed assets at pre-disaster prices.		
Forestry	**Production**	Log stored or ready for sale.	(1) Pre-disaster value of destroyed log stored or ready for sale.	Value of log production.	(1) Pre-disaster value of log from destroyed production forests. (2) Difference between expected and actual value of log production in non-fully damaged harvested area in disaster year. (3) Discounted expected value of log production in fully damaged forest area until full recovery.
	Assets	Machinery, siloes, equipment, tools etc.	Total destruction: replacement cost of fully destroyed assets at pre-disaster prices. Partial destruction: repair/rehabilitation cost of partially destroyed assets at pre-disaster prices.		

4. Conclusions and way forward

This paper proposes a standardized methodological approach to assess damage and losses from natural hazard-induced disasters in agriculture, building on existing methodologies that are already implemented in several countries, such as Post Disaster Needs Assessment (PDNA). The systematic implementation of the methodology at national level would help refining and standardizing national methodologies for data collection, eventually leading to the establishment of an FAO global information system that supports resilient and sustainable sectoral development planning, implementation and funding.

The adoption of the methodology for regular damage and losses monitoring and reporting at national level will require strengthening the capacity of relevant national authorities involved in disaster impact assessment in agriculture. Furthermore, the development and use of mobile data collection tools would be an essential step to improve the efficacy and reduce costs of post-disaster impact assessments. The methodology will be tested through the development of a series of case studies on previous disasters, in order to further refine and fine-tune the logical steps, calculation methods and estimation procedures. The results of case studies, together with the data regularly collected at national level, will be analysed and disseminated in the FAO's periodic reports on The Impact of Disasters on Agriculture and Food Security.

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TECHNICAL ANNEXES

Annex 1. Assumptions

The overall assumptions of the methodology for damage and losses assessment from natural disaster in agriculture, fisheries, aquaculture and forestry are:

1. Single disaster assessment. It is assumed that shocks to the agricultural sector are independent and their effects are not cumulative. Way forward: note that the complexity of linkages between different disasters must be further explored.
2. Prices used in the damage and losses assessment are always farm gate prices.
3. Annual crop are not affect the years that follow the disaster.
4. Changes in yields and changes in the size of the area harvested are assumed to be independent.
5. For perennial crops, yields are assumed to have a constant linear behaviour through time in the years before the disaster (e.g. 5 years' time series).
6. For perennial crop losses, all fully damaged hectares are replanted the same year of the disaster and no production is available until full recovery.
7. Replanting of the annual crops is feasible in the same season only if the natural hazard strikes before or during the sowing season. If replanting is still possible, the productivity is considered a linear function of the time available for replanting (e.g. if the planting is possible 5 months per year and the natural hazard strikes at the 4th of the 5 months, then 20% of the of total expected production for the same year can be retrieved. A more flexible functional form would allow to relax the linearity assumption and to have room for more accurate calibration.
8. It is assumed there is no mixed use of assets (infrastructure, machinery, tools) in order to avoid double counting. A relaxed version of this hypothesis is also proposed in the methodology.
9. The repair and rehabilitation cost of assets is linearly correlated with the level of damage.
10. Changes of area harvested are calculated as the difference of the first data available for hectares before the disaster and the first available after the disaster, in order to avoid accounting for changes in area harvested not strictly related to the shock(s) of the same year. Multiple shocks in the same year are still a source of bias in the methodology.
11. The area harvested after the disaster is assumed to be remain constant at pre-disaster levels in the counterfactual scenario of no disaster.
12. If the immediate substitution of assets destroyed or the repair of the damaged assets is not possible, an average rental cost of the assets is taken into account as a (linear) function of a specific resilience indicator (e.g. INFORM). The fit of the functional form deserves to be further explored.
13. It is assumed that no additional investments in assets are done except for investments needed to restore pre-disaster production.
14. The physical weight of each type of livestock is assumed to be constant across time but livestock-specific.

15. It is assumed that restoring the size of the livestock happens in bulk after a livestock-specific amount of time, if immediate intervention is not possible.
16. Following existing disaster assessment approaches, this methodology focuses on damage and losses. Potential benefits from natural disasters are not considered.
17. All projections are based on pre-disaster information.

Annex 2. Mathematics behind the methodology

Consider the following sets and subsets:

$$\forall\, i \in I = \{ I_{AC}, I_{PC}, I_L, I_{FI}, I_{AQ}, I_{FO} \}$$

where i is the agricultural output considered and subscripts flag the sub-sectors (AC=Annual Crops; PC=Perennial Crops; L=Livestock; FI=fisheries; AQ=Aquaculture; FO=Forestry). Hence I_{AC} is the list of agricultural outputs of sub-sector. Note that $I_C = I_{AC} \cup I_{PC}$, where C= Crop

$$\forall\, j \in J = \{\text{set of most granular geographical units available}\}$$

where the granularity of the geographical unit depends on data availability. For instance it can be regions, provinces, villages, households);

$$\forall\, k \in K = \{ K_{AC}, K_{PC}, K_L, K_{FI}, K_{AQ}, K_{FO} \}$$

where k is the is the asset (infrastructure, machinery, tool) used in order to produce an agricultural output. The subsets structure is depending on the agricultural output i category. If the asset characterization is strictly dependent on i, then it is represented as K_i. Note that $K_C = K_{AC} \cup K_{PC}$, where C= Crop. If asset k can not be exclusively associate to one item i, then the share of value of the asset attached to item i is proportionate to the share of the value production of item i over the total production value of all items that use that precise asset k;

$$x \in X = \{X_{AC}, X_{PC}, X_L, X_{FI}, X_{AQ}, X_{FO}\}$$

where x is the input of agricultural output production. Note that x can be item specific (X_{ij}), as the asset k_{ij}. Note that $X_C = X_{AC} \cup X_{PC}$, where C= Crop.

Also, consider t as the first time unit when post-disaster data are available; and $t-1$ as the first time unit when pre-disaster data are available. For instance, if data of year 2013, when typhoon Haiyan stroke the Philippines, have been collected after the natural hazard stroke, then we consider $t = 2014$ and $t-1 = 2013$. If data for that year have been collected before the disaster then $t = 2013$ and $t-1 = 2012$. Note that pre-disaster prices and labour force cost are used. Integrating price volatility is out of the scope of the methodological effort done so far. In order to discount values through time it is used

$\rho = \frac{1}{1+r}$ *is the time discount factor and r is the interest rate* (*e.g.* 10%)

Finally, $y_{ij,t}$ is defined as the yield of item i in zone j at time t per spatial unit (i.e. hectare) and $1(s < m_{iN}) = \begin{cases} 1 \text{ if } s < m_{iN} \\ 0 \text{ otherwise} \end{cases}$ is an indicator function in which s corresponds to the moment when the disaster hits and m_{iN} is the moment when the sowing season of item i ends.

The methodology is presented by sub-sector, distinguishing damage from losses per component (production and assets) and considering further decompositions, for example in the case of crops sub-sector where annual and perennial crops are treated separately (sub-components).

The methodology also takes into account both prevention and response components of resilience. Note that resilience is both endogenously defined (e.g. variation in yields due to disasters) and exogenously parametrized (e.g. the capacity to sell the meat of animals dead because of the disaster).

Consider the following definitions, which rely on different subsets of the afore-mentioned sets according to the sub-sector:

$q_{x,ij}$ *is the quantity of input x in zone j needed for producing i in one hectare;*

$\bar{q}_{ij,k,t}$ *is the stored average quantity of item i in zone j per unit of infrastructure k;*

$\bar{q}_{x,ij,t}$ *is the stored average quantity of input x for item i in zone j per unit of infrastructure k;*

$\Delta q_{kj,t} = E_{t-1}[q_{kj,t} \,|\{q_{kj,t-1}, \dots, q_{kj,t-n}\}] - q_{kj,t}$

is the unexpected change of the number of assets fully damaged at time t in zone j;

$\Delta q_{ij,k,t}$ *is the unexpected change in quantity stored of item i in zone j in each asset k;*

$\Delta q_{x,ij,t}$ *is the unexpected change in quantity stored of input x in zone j for item i in each asset k;*

$q_{kj,t}$ *is the number of assets k in zone j at time t;*

$\Delta q_{zj,t} = E_{t-1}[q_{zj,t} \,|\, \{q_{zj,t-1}, \dots, q_{zj,t-n}\}] - q_{ij,k,t}$

is the unexpected change in quantity of stored product z in zone j at time t;

$p_{x,ij,t-1}$ *is the price of input x for item i in zone j at time* $t-1$;

$\bar{c}_{kj,t-1}$ *is the repair (rental) average cost in zone j per unit of capital k that has been only partially(fully)destroyed; that has been only partially (fully destroyed) destroyed;*

$p_{zj,t-1}$ *is the price of one unit of product z (primary or secondary)in zone j at time* $t-1$;

$p_{zj,t-1}$ *is the price of one unit of weight of stored product z in sone j at time* $t-1$;

$p_{ij,t}$ *is the price of of one unit of weight of item i in zone j at time t;*

$l_{ij,t-1}$ *is the labour force cost per unit of time for one hectar of item i production in zone j;*

$T_i = T_{i,l} + T_{i,\$}$

is the number of time units needed for the production of item i in one hectare to be restored, decomposable in the effective working time needed $(T_{i,l})$ *and the waiting time due to credit constraints* $(T_{i,\$})$;

$\bar{w}_i$ *is the average weight of item i;*

T_k *is the time needed to asset k to be reconstructed, expressing the response component of resilience;*

$ha_{ij,t}$ *is the number of hectares devoted at item i in zone j at time t;*

$\Delta ha_{ij,t} = E_{t-1}[ha_{ij,t}] - ha_{ij,t}$ *is the unexpected change in the quantity of hactares where i is produced;*

$k_{ij} \in K_{PC}$ *is the number of trees per hectare of item i in zone j;*

$\Delta y_{ij,t} = E_{t-1}[y_{ij,t} \,|\, \{y_{ij,t-1}, \dots, y_{ij,t-n}\}] - y_{ij,t}$

is the unexpected change in yields per unit (e.g. km or ha) of geographical extention;

$\Delta y_{zj,t} = E_{t-1}[y_{zj,t} \,|\, \{y_{zj,t-1}, \dots, y_{zj,t-n}\}] - y_{zj,t}$ *and*

$y_{zj,t}$ *is the yield of product z (primary or secondary) per item i (i.e. animal) in zone j at time t;*

$\mathcal{I}(\Delta q_{kj,t} > 0)$ *implies that only assets k partially or fully destroyed are taken into account;*

s is the month when the disaster hits;

m_{i0} *is the month when the sowing season of item i begins;*

m_{iN} *is the month when the sowing season of item i ends;*

$\beta = f(R)$ *is a function of a specific resilience index R (e.g. INFORM) s.t.* $\beta \in [0;1]$.

α *is the share of the value dead animal that can be sold.*

CROP DAMAGE

1. CROP PRODUCTION DAMAGE

1.1. **ANNUAL CROP PRODUCTION INPUT DAMAGE.** $\forall\, i \in I_{AC} \wedge \forall\, j \in J$, given $x \in X = \{set\ of\ inputs\ for\ crop\ production\}$, the Damage to all Input x of Annual Crop i in zone j is

$$DIAC_{ij} = \beta \cdot \left(\sum_{x \in X} \left[p_{x,ij,t-1} \cdot q_{x,ij} \right] + l_{ij,t-1} \cdot T_i \right) \cdot \Delta ha_{ij,t} \cdot 1(s \in [m_{i0}; m_{iN}])$$

1.2. **PERENNIAL CROP PRODUCTION INPUT DAMAGE.** $\forall\, i \in I_{PC} \wedge \forall\, j \in J$, given $x \in X = \{set\ of\ inputs\ for\ crop\ production\}$, the Damage to Inputs x of Perennial Crop i in zone j is

$$DIPC_{ij} = \left(\sum_{x \in X} \left[p_{x,ij,t-1} \cdot q_{x,ij} \right] + l_{ij,t-1} \cdot T_i + p_{ij,t-1} \cdot k_{ij} \right) \cdot \Delta ha_{ij,t}$$

1.3. **STORED CROP DAMAGE (PRODUCTION AND INPUT).** $\forall\, i \in I_{PC} \wedge \forall\, j \in J$, given $x \in X_C$ and $k \in K_C$, the Damage to Stored Crops (inputs and production) is

$$DSC_{ij} = p_{ij,t-1} \cdot \sum_{k \in K_C} \Delta q_{ij,k,t} + p_{x,ij,t-1} \cdot \sum_{k \in K_C} \sum_{x \in X_C} \Delta q_{x,ij,t}$$

Note that $\Delta q_{ij,k,t} = E_{t-1}[q_{ij,k,t}] - q_{ij,k,t}$ and $\Delta q_{x,ij,t} = E_{t-1}[q_{x,ij,t}] - q_{x,ij,t}$ where $E_{t-1}[\cdot]$ is the expectation function of $[\cdot]$ at time $t-1$. Because of a systematic lack of these type of data, this methodology proposes the following estimation procedures:

$\Delta q_{ij,k,t} = \sum_{k \in K_C} \bar{q}_{ij,k,t} \cdot \Delta q_{ij,t}$ and $\Delta q_{x,ij,t} = \sum_{k \in K_C} \bar{q}_{x,ij,t} \cdot \Delta k_{ij,t}$

2. ***CROP ASSETS DAMAGE***

2.1. **CROP ASSETS TOTALLY DAMAGED.** $\forall\, i \in I_{PC} \wedge \forall\, j \in J$, given $k \in K_i \subset K_C$, the Damage of Assets Totally destroyed for Crops production is

$$DATC_{ij} = \sum_{k \in K_i} p_{kj,t-1} \cdot \Delta q_{kj,t}$$

Note that the estimation function $E_{t-1}[\cdot]$ is conditional on the time series of quantities of q_{kj} in the pre-disaster period for n units of time. This implies a direct relation with the size of investments in assets, which are assumed to be null except for investments needed to restore pre-disaster production.

2.2. **CROP ASSETS PARTIALLY DAMAGED.** $\forall\, i \in I_{PC} \wedge \forall\, j \in J$, given $k \in K_i \subset K_C$, Damage of Assets only Partially destroyed for Crops production is

$$DAPC_{ij} = \sum_{k \in K_i} \bar{c}_{kj,t-1} \cdot \Delta q_{kj,t}$$

CROP LOSSES

1. ***CROP PRODUCTION LOSSES***

1.1. **ANNUAL CROP PRODUCTION LOSSES.** $\forall\, i \in I_{AC} \wedge \forall\, j \in J$, given $y_{ij,t}$, the Losses of Annual Crops Production component are

$$LACP_{ij} = p_{ij,t-1} \cdot \Delta y_{ij,t} \cdot ha_{ij,t} \cdot 1(\Delta y_{ij,t} > 0) + \\ + \left(1 - \frac{m_{iN} - s}{m_{iN} - m_{i0}} \cdot 1(s \in [m_{i0}; m_{iN}]) \right) \cdot p_{ij,t-1} \cdot y_{ij,t-1} \cdot \Delta ha_{ij,t}$$

1.2. **PERENNIAL CROP PRODUCTION LOSSES.** $\forall\, i \in I_{PC} \wedge \forall\, j \in J$, given $y_{ij,t}$, the Losses of Perennial Crops Production component are

$$LPCP_{ij} = \sum_{g=0}^{T_i} \rho^g \cdot E_{t-1}[p_{ij,t-1} \cdot y_{ij,t-1}] \cdot \Delta ha_{ij,t} + p_{ij,t-1} \cdot \Delta y_{ij,t} \cdot ha_{ij,t}$$

2. ***CROP ASSETS LOSSES.*** $\forall\, i \in I_C \wedge \forall\, j \in J$, given $k \in K_i \subset K_C$, the Losses of Assets partially or fully destroyed used for Crops production are

$$LAC_{ij}=\sum_{g=0}^{T_k}\rho^g\cdot\left\{\sum_{k\in K_i}\bar{c}_{kj,t-1}\cdot\Delta q_{kj,t}\cdot 1(\Delta q_{kj,t}>0)\right\}$$

LIVESTOCK DAMAGE

1. ***LIVESTOCK PRODUCTION DAMAGE.*** $\forall i\in I_L\wedge\forall j\in J$, given $z\in Z_{stored}=$ *{set of livestock primary and secondary stored products}* $\subset Z_L=\{set\ of\ livestock\ primary\ and\ secondary\ products\}$, the Damage to the Production component of Livestock is

$$DPL_{ij}=\sum_{z\in Z_{stored}}\{\Delta q_{zj,t}\cdot p_{zj,t-1}\}+(\Delta q_{ij,t}\cdot\bar{w}_i)\cdot(p_{ij,t-1}-\alpha\cdot p_{ij,t})$$

2. ***LIVESTOCK ASSETS DAMAGE***
   2.1. **LIVESTOCK ASSETS TOTALLY DAMAGED.** $\forall i\in I_L\wedge\forall j\in J$, given $k\in K_i\subset K_L$, the Damage of Assets Totally destroyed for Livestock production is

$$DATL_{ij}=\sum_{k\in K_i}p_{kj,t-1}\cdot\Delta q_{kj,t}$$

   2.2. **LIVESTOCK ASSETS PARTIALLY DAMAGED.** $\forall i\in I_L\wedge\forall j\in J$, given $k\in K_i\subset K_L$, Damage of Assets only Partially destroyed for Livestock production is

$$DAPL_{ij}=\sum_{k\in K_i}\bar{c}_{kj,t-1}\cdot\Delta q_{kj,t}$$

LIVESTOCK LOSSES

1. ***LIVESTOCK PRODUCTION LOSSES.*** $\forall i\in I_L\wedge\forall j\in J$, given $z\in Z=$ *{set of livestock primary and secondary products}*, the Losses of Livestock production (primary and secondary) are

$$\sum_{g=0}^{T_i}\rho^g\cdot\left\{\sum_{z\in Z}(\Delta q_{ij,t}\cdot p_{zj,t-1}\cdot y_{zj,t-1})\right\}+\sum_{z\in Z}(q_{ij,t}\cdot p_{zj,t-1}\cdot\Delta y_{zj,t})$$

2. **LIVESTOCK ASSETS LOSSES.** $\forall i\in I_L\wedge\forall j\in J$, given $k\in K_i\subset K_L$, the Losses of Assets partially or fully destroyed used for Livestock production are

$$LAL_{ij}=\sum_{g=0}^{T_k}\rho^g\cdot\left\{\sum_{k\in K_i}\bar{c}_{kj,t-1}\cdot\Delta q_{kj,t}\cdot 1(\Delta q_{kj,t}>0)\right\}$$

FISHERIES

Consider the following additional definitions:

$$y_{ij,t}=\frac{\bar{w}_{ij}\cdot q_{ij,t}}{area_{ij,t}}\ where\ \bar{w}_{ij}\cdot q_{ij,t}$$

$is\ quantity\ of\ fish\ i\ catch\ (e.g.in\ tons)(average\ weight\ times\ the\ number\ of\ fishes);$

$area_{ij,t}\ is\ the\ number\ of\ unit\ of\ area\ where\ item\ i\ (i.e.type\ of\ fish)\ in\ zone\ j\ at\ time\ t\ is\ catched;$

FISHERIES DAMAGE

1. ***FISHERIES PRODUCTION DAMAGE.*** $\forall i\in I_L\wedge\forall j\in J$, given $k\in K_i\subset K_{FI}$, the Damage of Fisheries Production component is

$$DFiP_{ij}=p_{ij,t-1}\cdot\Delta q_{ij,k,t}\cdot\bar{w}_i$$

Note that the estimation procedure is equivalent to the one proposed for stored crops.

2. ***FISHERIES ASSETS DAMAGE***
   2.1. **FISHERIES ASSETS TOTALLY DAMAGED.** $\forall i\in I_{FI}\wedge\forall j\in J$, given $k\in K_i\subset K_{FI}$, the Damage of Assets Totally destroyed for Fisheries production is

$$DATFi_{ij}=\sum_{k\in K_i}p_{kj,t-1}\cdot\Delta q_{kj,t}$$

2.2. **FISHERIES ASSETS PARTIALLY DAMAGED.** $\forall\, i \in I_{FI} \wedge \forall\, j \in J$, given $k \in K_i \subset K_{FI}$, Damage of Assets only Partially destroyed for Fisheries production is

$$DAPFi_{ij} = \sum_{k \in K_i} \bar{c}_{kj,t-1} \cdot \Delta q_{kj,t}$$

FISHERIES LOSSES

1. ***FISHERIES PRODUCTION LOSSES.*** $\forall\, i \in I_{FI} \wedge \forall\, j \in J$, the Losses of Fisheries production are

$$LFP_{ij} = area_{ij,t} \cdot p_{ij,t-1} \cdot \Delta y_{ij,t}$$

2. ***FISHERIES ASSETS LOSSES.*** $\forall\, i \in I_{FI} \wedge \forall\, j \in J$, given $k \in K_i \subset K_{FI}$, the Losses of Assets partially or fully destroyed used for Fisheries production are

$$LAF_{ij} = \sum_{g=0}^{T_k} \rho^g \cdot \left\{ \sum_{k \in K_i} \bar{c}_{kj,t-1} \cdot \Delta q_{kj,t} \cdot 1\left(\Delta q_{kj,t} > 0\right) \right\}$$

AQUACULTURE

Consider the following additional definitions:

$$\Delta area_{ij,t} = E_{t-1}\left[\Delta area_{ij,t}\right] - \Delta area_{ij,t}$$

is the unexpected change in spatial unit quantity (e.g. cube metres) where item i is produced;

AQUACULTURE DAMAGE

1. ***AQUACULTURE PRODUCTION DAMAGE.*** $\forall\, i \in I_{AQ} \wedge \forall\, j \in J$, given $k \in K_i \subset K_{AQ}$, the Damage of Aquaculture Production component is

$$DAQP_{ij} = \left(p_{ij,t-1} - \alpha \cdot p_{ij,t}\right) \cdot \bar{w}_i \cdot \left(\Delta q_{ij,t} + \Delta q_{ij,k,t}\right)$$

Note that the estimation procedure of $\Delta(\cdot)$ is equivalent to the one proposed for stored crops.

2. ***AQUACULTURE ASSETS DAMAGED***

2.1. **AQUACULTURE ASSETS TOTALLY DAMAGED.** $\forall\, i \in I_{AQ} \wedge \forall\, j \in J$, given $k \in K_i \subset K_{AQ}$, the Damage of Assets Totally destroyed for Aquaculture production is

$$DATAQ_{ij} = \sum_{k \in K_i} p_{kj,t-1} \cdot \Delta q_{kj,t}$$

2.2. **AQUACULTURE ASSETS PARTIALLY DAMAGED.** $\forall\, i \in I_{AQ} \wedge \forall\, j \in J$, given $k \in K_i \subset K_{AQ}$, Damage of Assets only Partially destroyed for Aquaculture production is

$$DAPAQ_{ij} = \sum_{k \in K_i} \bar{c}_{kj,t-1} \cdot \Delta q_{kj,t}$$

AQUACULTURE LOSSES

1. ***AQUACULTURE PRODUCTION LOSSES.*** $\forall\, i \in I_{AQ} \wedge \forall\, j \in J$, the Losses of Aquaculture production are

$$LAQP_{ij} = \Delta area_{ij,t} \cdot p_{ij,t-1} \cdot y_{ij,t-1} + area_{ij,t} \cdot p_{ij,t-1} \cdot \Delta y_{ij,t-1}$$

2. ***AQUACULTURE ASSETS LOSSES.*** $\forall\, i \in I_{AQ} \wedge \forall\, j \in J$, given $k \in K_i \subset K_{AQ}$, the Losses of Assets partially or fully destroyed used for Aquaculture production are

$$LAAQ_{ij} = \sum_{g=0}^{T_k} \rho^g \cdot \left\{ \sum_{k \in K_i} \bar{c}_{kj,t-1} \cdot \Delta q_{kj,t} \cdot 1\left(\Delta q_{kj,t} > 0\right) \right\}$$

FORESTRY DAMAGE

1. ***FORESTRY PRODUCTION DAMAGE***

$\forall\, i \in I_{FO} \wedge \forall\, j \in J$, given $k \in K_i \subset K_{FO}$ and $z \in Z_{stored}$ = {set of forestry primary and secondary stored products} $\subset Z_{FO}$ = {set of forestry primary and secondary products} ,the Damage of Forestry Production component is

$$DFoP_{ij} = \Delta ha_{ij,t} \cdot \bar{y}_{ij,t-1} \cdot p_{ij,t-1} + \sum_{z \in Z_{stored}} \left\{ \Delta q_{zj,t} \cdot p_{zj,t-1} \right\}$$

2. **FORESTRY ASSET DAMAGE**

   2.1. FORESTRY ASSETS TOTALLY DAMAGED. $\forall\, i \in I_{FI} \wedge \forall\, j \in J$, given $k \in K_i \subset K_{FI}$, the Damage of Assets Totally destroyed for Forestry production is

$$DATFi_{ij} = \sum_{k \in K_i} p_{kj,t-1} \cdot \Delta q_{kj,t}$$

   2.2. FORESTRY ASSETS PARTIALLY DAMAGED. $\forall\, i \in I_{FI} \wedge \forall\, j \in J$, given $k \in K_i \subset K_{FI}$, Damage of Assets only Partially destroyed for Forestry production is

$$DAPFi_{ij} = \sum_{k \in K_i} \bar{c}_{kj,t-1} \cdot \Delta q_{kj,t}$$

FORESTRY LOSSES

1. ***FORESTRY PRODUCTION LOSSES.*** $\forall\, i \in I_{FO} \wedge \forall\, j \in J$, given $z \in Z_{FO} = \{set\ of\ forestry\ primary\ and\ secondary\ products\}$, the Losses of Forestry production (primary and secondary) are

$$\sum_{g=0}^{T_i} \rho^g \cdot \left\{ \sum_{z \in Z} \Delta ha_{ij,t} \cdot p_{zj,t-1} \cdot y_{zj,t-1} \right\} + \sum_{z \in Z} \left(ha_{ij,t} \cdot p_{zj,t-1} \cdot \Delta y_{zj,t} \right)$$

2. ***FORESTRY ASSETS LOSSES.*** $i \in I_{FO} \wedge \forall\, j \in J$, given $k \in K_i \subset K_{FO}$, the Losses of Assets partially or fully destroyed used for Forestry production are

$$LAAQ_{ij} = \sum_{g=0}^{T_k} \rho^g \cdot \left\{ \sum_{k \in K_i} \bar{c}_{kj,t-1} \cdot \Delta q_{kj,t} \cdot 1\left(\Delta q_{kj,t} > 0\right) \right\}$$

Annex 3. Error analysis: calculation of error intervals in measurement

In order to represent at least part of this variability in the outcome measurements, the following error interval procedure is proposed.

1. **Min-Max Interval.** The methodology presents a set of exogenous parameters per sub-component, distinctly for damage and for losses.

   1.1. For each parameter, it is defined an *average* value, a *minimum* and a *maximum*. All three values are primarily based on the existing concerned literature and on experts' judgment.

   1.2. The outcome values for damage and for losses are calculated three times for each sub-component, using the *average* values of the exogenous parameters, the values that *minimize* the outcome, and the values that *maximize* the outcome.

Outcomes can also be aggregated per component, sub-sector, or totally as all sub-components are mutually exclusive and additive.

2. **90% Confidence Interval per level of geophysical stressor.**

In order to identify the magnitude of a natural hazard, climatic and geophysical stressors information is collected at the most cost-efficient level of granularity.

2.1. Categories of intensity of the stressors are defined. For instance, in the case of Typhoons, wind speed (in accordance with the topography of the area) is a strong determinant of the magnitude of the natural hazard, and four categories are identified.
2.2. For each cluster (i.e. category of stressor's intensity), the mean of damage and mean of losses in zones j falling under that precise cluster are calculated.
2.3. Each mean of step 2.2. is provided with a 90% confidence interval.
2.4. Hypothesis test of difference between means is calculated. The T test tests the internal validity of step 2.

THEMATIC SET

F39

NEW SOFTWARE, APPS AND TOOLS FOR DATA COLLECTION IN AGRICULTURE STATISTICS

Session Organizer
J. Parsons | USDA National Agricultural Statistics Service | Washington, DC | USA

ABSTRACT

Technology continues to change at a rapid rate and has become increasingly consumerized. The internal and external stakeholders of government statistical agencies have come to expect statistical agencies to provide products, tools and services at a comparable level to multinational information technology firms. Statistical organizations operate in complicated environments and often use customized, unique tools that employ sophisticated statistical techniques for both internal external use cases. This session will be focus on new, innovative data collection and processing tools with a focus on services that meet the needs of an increasingly mobile and consumer oriented set of stakeholders. We would like to focus on innovative data collection tools that are being used to manage data collection, leverage automated data reporting opportunities, improve data collection in the field, increase the speed of data delivery, improve the quality of data collected, increase response rates, and provide a quality response with minimal data discrepancies. Our goal is to acquire a high quality responses using new technologies that are responsive, usable and reduce burden. Examples of concrete projects, plans or ideas on how to harness the new technology and methods that are being developed to create better statistics are highly welcomed.

LIST OF PAPERS

Data Collection Methods and Information Technologies in Russian Agricultural Statistics
A. Surinov | Federal State Statistics Service (Rosstat) | Moscow | Russian Federation
DOI: 10.1481/icasVII.2016.f39

The use of satellite images to forecast agricultural production
A. Laczynski | Central Statistical Office of Poland | Warsaw | Poland
DOI: 10.1481/icasVII.2016.f39b

Making the best selection and utilization of new IT tools for data warehouse systems
L. Bowling | USDA National Agricultural Statistics Service | Washington, DC | USA
T. Zhou | USDA National Agricultural Statistics Service | Washington, DC | USA
DOI: 10.1481/icasVII.2016.f39c

Leveraging technology to streamline the collection and visualization of agricultural and socio-economic data of vulnerable communities
J. Ardila | United Nations Office on Drugs and Crime | Bogotà | Colombia
J. Rojas | United Nations Office on Drugs and Crime | Bogotà | Colombia
F. Ramírez | United Nations Office on Drugs and Crime | Bogotà | Colombia
R. Vargas | United Nations Office on Drugs and Crime | Bogotà | Colombia
DOI: 10.1481/icasVII.2016.f39d

F39

Are CAPI based surveys a cost-effective and viable alternative to PAPI surveys? Evidence from agricultural surveys in Tanzania and Uganda

M. Rahija | FAO | Rome | Italy
T. Mwisomba | National Bureau of Statistics | Dar es Salaam | Tanzania
M. A. Kamwe | National Bureau of Statistics | Dar es Salaam | Tanzania
J. Muwonge | Uganda Bureau of Statistics | Kampala | Uganda
U. Pica-Ciamarra | FAO | Rome | Italy
DOI: 10.1481/icasVII.2016.f39e

Seventh International
Conference on
Agricultural Statistics

Modernization of
Agricultural Statistics
in Support
of the Sustainable
Development
Agenda

Rome
26·27·28
OCTOBER
2016

THEMATIC SET F
Data sources / Data collection / Use of IT tools / Data quality

New software, apps and tools for data collection in agriculture statistics

Data Collection Methods and Information Technologies in Russian Agricultural Statistics

Federal State
Statistics Service

ICASVII

Alexander SURINOV

DOI: 10.1481/icasVII.2016.f39

Head of Federal State Statistics
Service, Russian Federation

Categories of agricultural producers

Agricultural enterprises (large &medium) include business partnerships, limited liability or additional liability companies, private (closed) joint-stock companies, public (open) joint-stock companies, production cooperatives, agricultural communities, unitary state enterprises and subsidiaries of non-agricultural business entities

Small agricultural enterprises (including micro enterprises) include legal entities – commercial organizations listed in the Unified State Register of Legal Entities

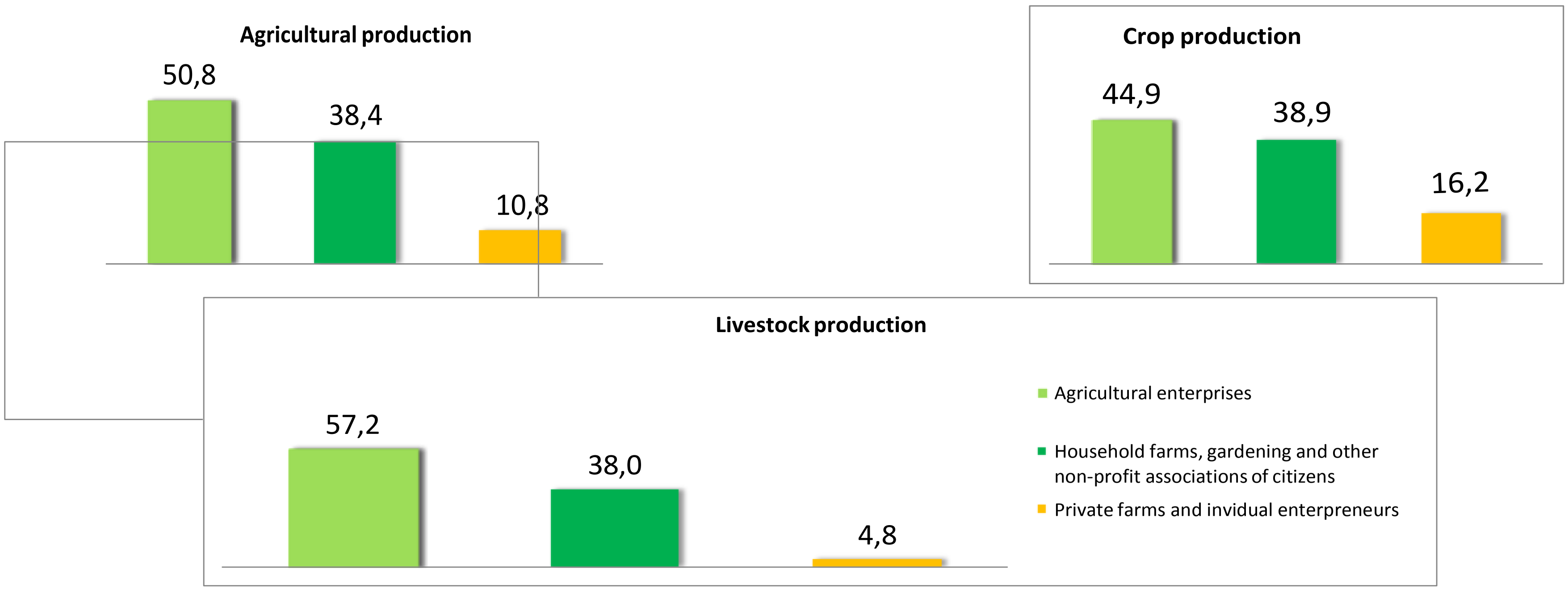
Private (peasant) farm –is the property jointly owned by immediate family or legal relatives, who collectively and personally conduct entrepreneurial activities, production or other business operations (production, processing, storage, transportation or sales of agricultural products)

Individual entrepreneur - a citizen (physical person), who conducts entrepreneurial activities without legal entity registration, who is registered in accordance with the Civil Code of the Russian Federation; and has a Certificate of state registration of individual entrepreneur with the listed types of activities

Household farm – is a noncommercial entity for the production or processing of agricultural products for on-farm consumption by individuals or immediate family members on the land plot, which is provided or purchased for private household farming **Gardening, vegetable-growing and dacha type non-profit association of citizens** - a noncommercial organization of volunteers created for the purposes of addressing their common social and operational issues related to their activities in horticulture, vegetable growing and dacha maintenance

Agricultural economy by categories of agricultural producers in 2015

(in current prices, in percent)



COMBINED METHOD OF SURVEY BY TYPE OF AGRICULTURAL ACTIVITIES:

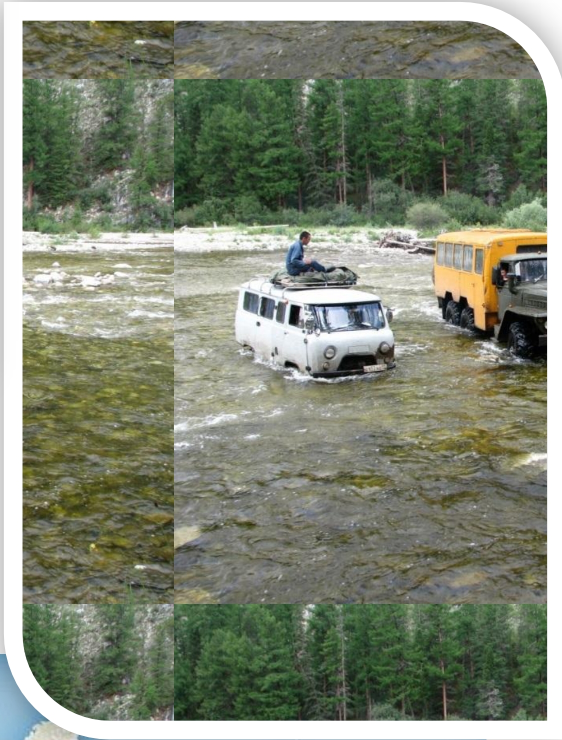
- at least once in 10 years - the Russian agricultural census
- no later than 5 years after regular agricultural census – agricultural micro census
- during the intercensal period:
  - complete enumeration - in large and medium agricultural enterprises;
  - sample surveys - of small agricultural enterprises and individual entrepreneurs

2016 Russian agricultural census

July 1 - August 15, 2016

in remote regions

September 15 - November 15, 2016



Remote regions

The number of agricultural producers, covered by the Russian agricultural census

Category of census subjects	Census-2016
Agricultural enterprises, in total, thsd., including:	40,4
Agricultural enterprises (without micro enterprises)	17,4
Micro enterprises	18,7
Subsidiary enterprises of non-agricultural entities	4,3
Private farms and individual entrepreneurs, thsd.	206,8
Household farms, in total, mln.	23,3
including those:	
in rural areas in	14,9
urban areas	8,4
Gardening, vegetable-growing and dacha-type non-profit associations of citizens, thsd.,	76,3
Number of land plots in them, mln.	12,7


Information sources
Statistical Business Register
Lists of houses in urban settlements, formed for the Russian Population Census 2010
The Unified State Register of Rights in Immovable Property and Transactions Involving Such Property
Information, provided by the regional bodies of state supervision over the technical condition of self-propelled vehicles and other equipment
Information about state technical inventory of the facilities, related to the town-planning activity in Russia
The Unified State Land Register, The Federal Service for State Registration, Cadastre and Cartography
Information from regional bodies of the Federal Service for Veterinary and Phytosanitary Surveillance

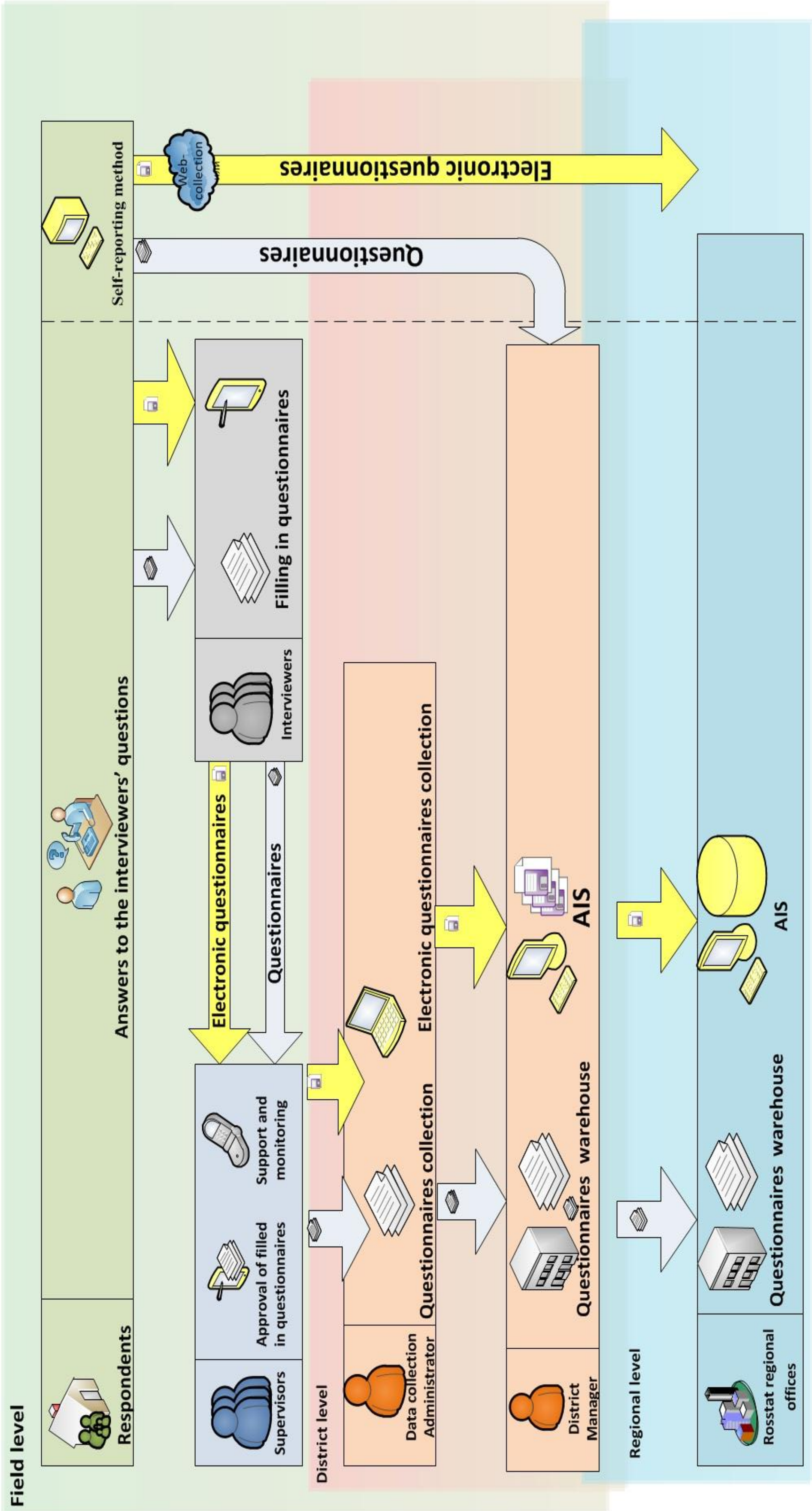
Data collection methods of the Russian agricultural census' objects

- **Complete enumeration**:
  - Agricultural enterprises ,
  - Private farms and individual entrepreneurs,
  - Gardening, vegetable-growing and dacha-type non-profit associations of citizens,
  - Household farms in rural areas
- **Sample survey:**
  - Owners of the land plots, comprising gardening and non-profit citizen groups - (10% sample),
  - Household farms in towns and urban settlements - (20 % sample)

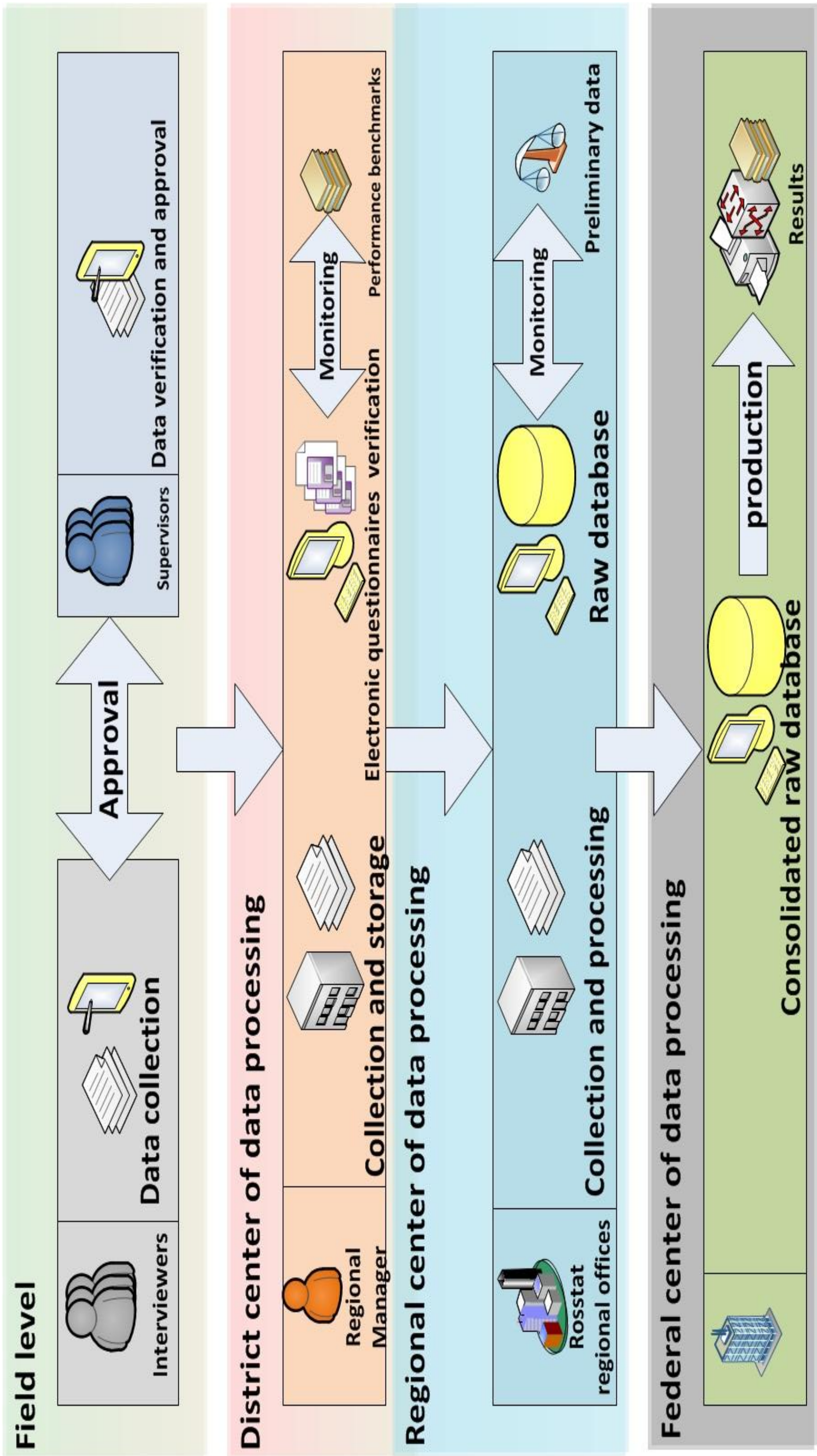
Data collection methods of the Russian agricultural census

- **filling** of questionnaires by respondents, using machine-readable forms of documents
  - Agricultural enterprises ;
- **electronically via the Rosstat internet site**
  - Agricultural enterprises;
  - Private farmers and individual entrepreneurs;
- **questioning respondents using questionnaires for further scanning**
  - Private farmers and individual entrepreneurs;
  - Household farms and other personal farms;
  - Gardening, vegetable-growing and dacha-type non-profit associations of citizens;
  - Owners of the land plots, comprising non-profit citizen groups;
- **questioning respondents by enumerators, using tablets**
  - Household farms and other personal farms.

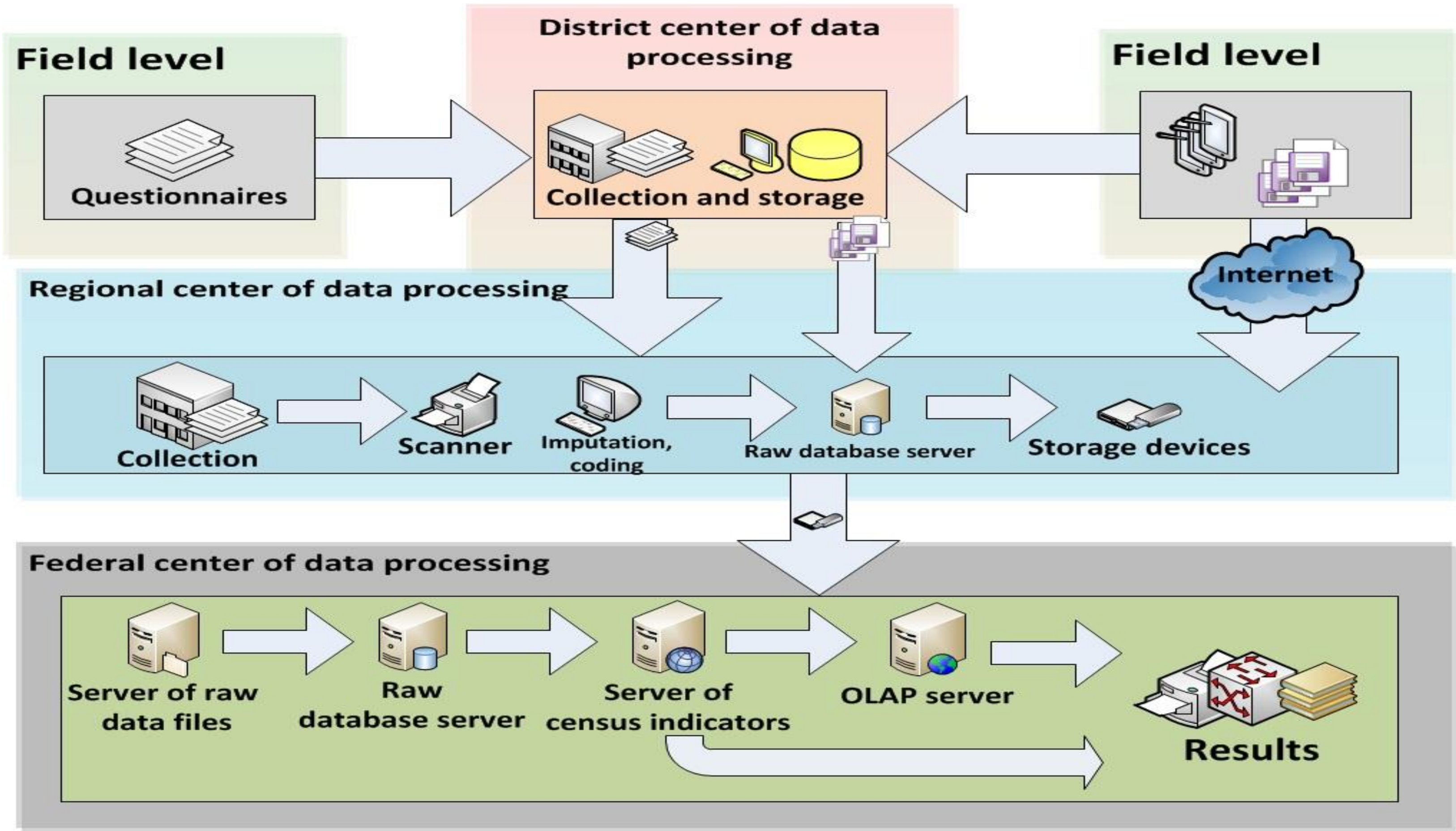
2016 Data Collection



Data processing centers



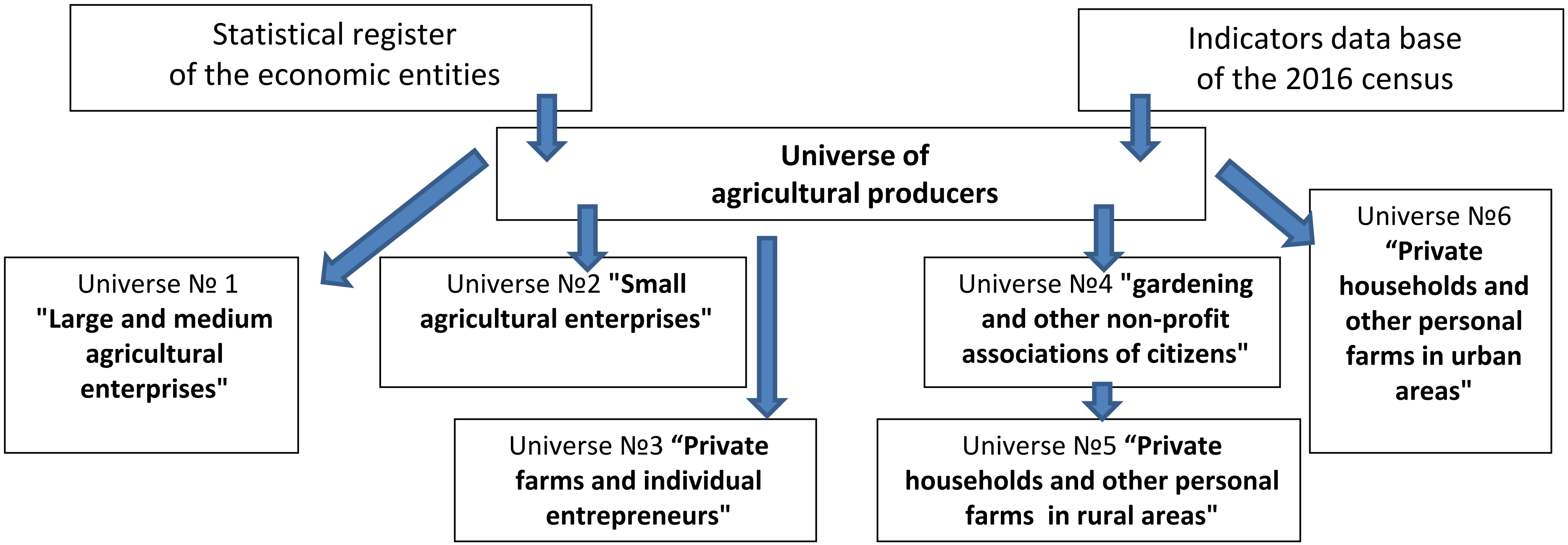
Census technological cycle



Intercensal period

Agricultural enterprises	**Combining complete enumeration with sample survey** (depending on type of business)
Large and medium	***Crop production and livestock*** monthly complete enumeration reports (including indicators - acreage, livestock farm animals, production and sale of agricultural products) - on short program; annual accounts - on broader program.
Small **small enterprises (except micro enterprises)** **micro enterprises**	**Sample survey** *Crop (acreage and crop production) – twice a year* *Livestock (livestock farm animals and livestock production) - monthly* *Crop and livestock production - annually*
Private farms and individual entrepreneurs	**Sample survey** – annually *Sown areas and crop production; livestock farm animals and livestock production;* *Sale of agricultural products.*
Household farms	**Multi-purpose sample survey** - monthly *Crop, livestock, sale of agricultural products, the cost of purchasing industrial goods, payment of production services.*

Agricultural producers



Thank you for your attention!

The use of satellite images to forecast agricultural production

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ABSTRACT

In the first part of the speech, the results of cooperation between the Department of Agriculture in the Central Statistical Office and the Institute of Geodesy and Cartography in Warsaw will be presented. The presentation will be focused on the possibility of satellite image use to forecast agricultural production. A short description of NOAA AVHRR satellite images will be presented. Furthermore, a satellite imagery receiving system, which consists of a parabolic antenna with the diameter of 1.2 m, a signal receiver and specialised software enabling data recording, will be described. The software provides automatic operation of the station, namely, recording of images as soon as the NOAA satellite comes within the range sufficient for receiving signals, designated by the minimum "view" angle of the satellite. It also provides up-to-date information on the position of the satellite in relation to the area of Poland, as well as the time of the nearest recording. During recording, it allows for "viewing" the image in 2 radiation ranges - near-infrared and thermal infrared. While speech, a system of crops condition estimation using comparative maps will also be discussed. The final products in the Crop Yield Assessment System are comparative maps of the NDVI value as compared to an average year and the previous year. In order to generate these products, a specialised module has been developed as part of the ArcMap software. This module, using software functions, enables execution of creation of ten-day compositions from the corrected images of the NDVI and creation of comparative maps of the NDVI distribution in comparison to an average year and the previous year. These maps are generated on a 1 km2 grid and averaged to voivodships (NTS 2) and in selected voivodships to poviats (NTS 4).

In the second part of the paper, it will be presented a comparison of yield estimation for a few crops, carried out by experts for field crop production with the data obtained from maps of NDVI indicator distribution. It will be presented comparing the imaging index NDVI with data obtained from estimates developed in the Central Statistical Office, Agriculture Department for 2015, as a model to represent optimal weather conditions for crop production from wheat and all cereals. The map of agricultural drought in Poland in 2015 will also be presented.

Keywords: satellite imagery, yield estimation, harvest statistics

1. Introduction

The role of the official statistics is delivering high quality data concerning broad variety of topics. The very important domain of the official statistics is agriculture as a part of wider classification of land cover or use. Because of its characteristics such as large area or huge spatial and temporal variability, agriculture is predestined to survey techniques that can globally survey areas of whole countries or regions delivering data in short time intervals during a year.

Therefore, the satellite imagery can be successfully used for agriculture and different land cover/use classifications. In agriculture, the most common applications of satellite images can be attributed to crop area estimation, plant production estimation / prediction as well as measuring plant growth conditions or effects of extreme weather conditions (e.g. droughts, floods, frost damages). The above mentioned examples do not exhaust possibilities of using satellite images. However, for the needs of this publication only application in estimation of agricultural production would be described.

The satellite images are usually classified as Big Data. In many projects launched by EUROSTAT, use of Big Data sources in combination with existing official statistical data is studied to improve current statistics and create new statistics in various statistical domains, namely, agriculture. The more important running projects belonging to multisource statistics, where the satellite data are investigated, are following:

ESS ADMIN VIP - use of administrative data in statistics including issues related to multisource statistics

ESSNET ADMIN - quality of multisource statistics

ESSNET BIG DATA - matching administrative data i.e. LPIS with big data i.e. satellite imagery in agriculture statistics

The Central Statistical Office cooperates closely with the Institute of Geodesy and Cartography in Warsaw, which provides results of NDVI for poviats (NTS 4) as well as production forecasts for cereal crops for voivodships (NTS 2). This multiannual cooperation yielded with the systematically updated data base and the sustainable model of vegetation assessment.

2. Materials and methods

<u>Yield estimates of Central Statistical Office</u>

The Central statistical Office collects information concerning areas, yield and harvest from different sources. The basic information about crop areas comes from farm surveys (e.g. Farm Structure Survey) or administrative data like IACS (Integrated Administration and Control System). Information about plant production is obtained from field experts in each gmina (NTS 5). The estimated yields are representative for voivodships (NTS 2). Furthermore, the voivodship and country yield and harvest estimates are reviewed by regional and country experts. In estimation of harvest also market data are taken into account. The estimates are published three times a year starting from the end of July.

<u>Method of satellite imagery processing in the Institute of Geodesy and Cartography</u>

One of the first systems for monitoring of agricultural areas CCAP (Crop Condition Assessment Program) was created by the Canadian Centre for Remote Sensing CCRS. This programme was based on the use of satellite images taken every ten days by the NOAA AVHRR (Advanced Very High Resolution Radiometer) for determination of the development state of crops. The technology developed by the CCRS was implemented in 1996 in the Institute of Geodesy and Cartography in Warsaw, see fig. 1.. This technology consists of the following stages:

- recording of satellite images acquired by AVHRR scanners installed on the NOAA series satellites for the area of the entire country within the vegetation period of the cultivated plants,
- geometric and radiometric processing of the recorded images taken by the NOAA AVHRR,
- determination of the vegetation index - NDVI, on the basis of the radiation value recorded by the NOAA AVHRR scanner,
- creation of ten-day compositions for agricultural areas on the basis of daily images of the NDVI distribution,
- preparation of comparative maps of the NDVI distribution in comparison with an average year and with the previous year for particular ten-day periods of the vegetation season,
- determination of the process of changes in the value of the NDVI describing the development of cultivated plants within the vegetation season.

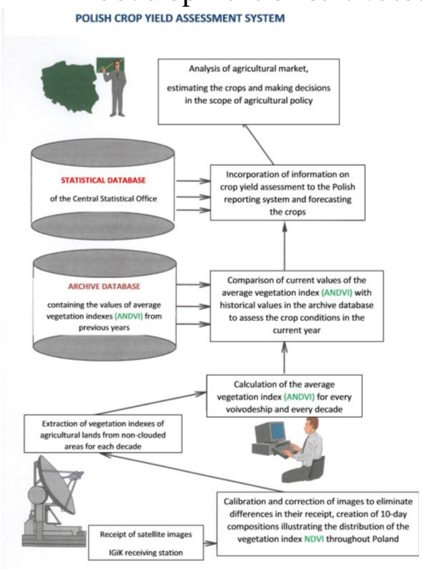

Figure 1: *The diagram of the crop yield assessment system operation.*

Satellites launched by the American agency NOAA are equipped with several instruments for environment research. An instrument used for acquiring information about reflection of radiation from land and about surface temperature is the AVHHR scanner (Advanced Very High Resolution Radiometer). The latest version of this instrument (AVHRR3) can register radiation in 6 scanning ranges:

channel 1 - 0.58 - 0.68 μm
channel 2 - 0.72 - 1.0 μm
channel 3A - 1.58 - 1.64 μm
channel 3B - 3.55 - 3.93 μm
channel 4 - 10.3 - 11.3 μm
channel 5 - 11.5 - 12.5 μm

The first two channels provide information about reflection of radiation in the full-visible and near-infrared range. Channels 3A and 3B cover medium infrared range, and channels 4 and 5 (thermal infrared) provide information about land temperature.

Images recorded by the NOAA AVHRR scanner cover an area of ca. 2400 x 2400 km. Depending on the location of the orbit in relation to the receiving station, they may be received 2 - 4 times per day. For the purpose of monitoring of the area surface, images recorded in early afternoon (12:30 a.m. - 3:00 p.m.) are most often used. Field resolution of images in the nadir point is 1.1 x 1.1 km. The images are transmitted to the data receiving station in the HRPT format (High Resolution Picture Transmission) - it is the basic transmission format; they can also be received in the LAC format (Local Area Coverage). "Raw" images recorded by the receiving station require specialised software in order to process them to a state enabling environment condition analysis.

The receipt system consists of a parabolic antenna with the diameter of 1.2 m, a signal receiver and specialised software enabling data recording. The software provides automatic operation of the station, namely recording of images as soon as the NOAA satellite comes within the range sufficient for receiving signals, designated by the minimum "view" angle of the satellite. It also provides up-to-date information on the position of the satellite in relation to the area of Poland, as well as the time of the nearest recording, and during recording it allows for "viewing" the image in 2 radiation ranges - near-infrared and thermal infrared. The images recorded in the HRPT format are saved in the relevant system folder connected to the data receiving software, and then transmitted to the image processing system for the satellite images taken by the NOAA AVHRR.

Currently, for processing of satellite images taken by the NOAA AVHRR, the Institute of Geodesy and Cartography uses specialized module developed as part of the Chips software for Windows. This module covers full processing of data in 5 stages:

- import of the image in the HRPT format to the format of the software, along with analysis of image quality and extraction of information about orbit parameters, used in the subsequent data geometrisation,
- interactive geometric adjustment of the "raw" satellite image taken by the NOAA AVHRR to the reference picture,
- rectification of the image to a specified map projection (Albers projection), as well as to defined dimensions (700 x 700 km),
- radiometric calibration of the image in order to obtain pictures of albedo distribution in channels 1 and 2 and radiation temperature in channels 4 and 5,
- establishment of derivative products - a picture of distribution of the Normalised Difference Vegetation Index (NDVI) and a picture of temperature distribution of the area surface.

The final product of the module of the NOAA AVHRR Chips software for Windows is a set of geometrically adjusted and radio-metrically calibrated images in channels 1 - 5 of the AVHRR scanner, as well as derivative products. The data are prepared in the export format for use in the final stage of the Crop Yield Assessment System operation.

The final products in the Crop Yield Assessment System are comparative maps of the NDVI value as compared to an average year and the previous year. In order to generate these products, a specialised module has been prepared as part of the ArcMap software. This module, using software functions, enables execution of the following stages of works:

- atmospheric correction of daily images taken by the NOAA AVHRR in channels 1 and 2,
- creation of ten-day compositions from the corrected images of the NDVI,
- determination of agricultural areas of Poland by means of a mask created on the basis of the land cover map, drawn up under the CORINE Land Cover Programme,
- determination of threshold values of cloud cover and determination of ten-day composition unaffected by cloud cover for agricultural areas of the country,

- creation of comparative maps of the NDVI distribution in comparison, to an average year (designated on the basis of the NDVI value from 1992 - 2008) and to the previous year

These maps are generated on a 1 km2 grid and averaged to provinces. Information on the condition of crops is expressed by the relation of the NDVI in the current ten-day period to the value of this index in the same ten-day period of an average year or the previous year.

Comparative maps are supplied in ten-day intervals throughout the crops vegetation period (1st April - 30th September) to the Central Statistical Office, Department of Agriculture. On the basis of information from subsequent ten-day periods, charts are also created presenting changes in the NDVI within the vegetation season, as well as comparisons of comparative maps for the whole vegetation season. These products are supplied to the Department of Agriculture of the Central Statistical Office as part of the annual reports on the consecutive stages of the works.

3. Results and discussion

The monitoring of vegetation is expressed by indicator NDVI, which can be observed during the season. The seasonal differences are attributed to plant growth cycle as it can be presented in fig. 2. The interregional differences can be also noticed because of different cropping schemes and agricultural specialisation as well as climatic conditions.

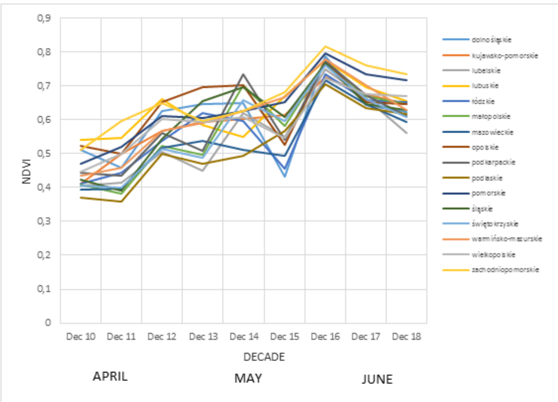

Figure 2: *NDVI changes during the first half of the vegetation period in 2015 for the different NTS2 regions (voivodships) of Poland.*

The NDVI values can compared with the same period of the previous year or an average year for a chosen region. In fig. 3, the regional differences (for NTS 4 – poviats) for June 2016 in comparison with June 2015 have been presented. Weaker vegetation (pink colour) is visible for the south eastern, central and north western Poland, which can be attributed to effects of drought in the second half of 2015 and majority of the first half of 2016.

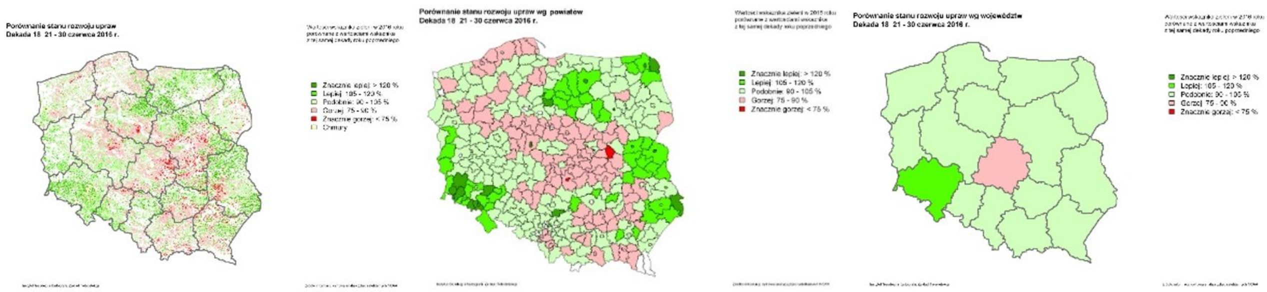

Figure 3: *Comparison of NDVI values of June 2016 with NDVI values in 2015. Data are presented for 1 square km grids, for NTS 4 regions and generalised for NTS 2 regions.*

Nevertheless, in the very south western region the vegetation is much better developed that a year ago. The analysis of the generalised and grid images shows huge decrease of details. However, the selection of agricultural areas helps to separate them from the other land cover classes.

The additional information from satellite imagery interpretation can be detection and determination of dangerous weather conditions or disasters. In agriculture, such disastrous situation can happened due to droughts, floods, hurricanes, freezing. Fig. 4 presents assessment of droughts prepared by Institute of Geodesy and Cartography in 2015. The intensity of red colour indicates drought in August 2015. The drought maps are very important for yield and harvest estimates as well as for farmers, agricultural advisors, administration or can be used by insurance companies.

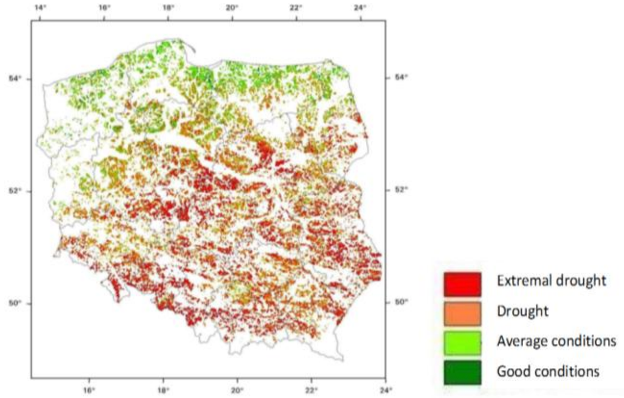

Figure 4: *The drought in August 2015 in Poland.*

The analysis of NDVI is a very helpful tool to assess the development of crop plants, which is ancillary to yield and harvest estimates. However, this indicator cannot be directly referred to yield estimates because the other factors such as start of vegetation period in a given year have to be considered. This issue is very important in terms of climate changes, when the vegetation period can start earlier resulting in earlier harvest and shifting NDVI values in a given year.

In the Central Statistical Office, the basis for the yields and harvest estimates are estimates of regional experts working on areas of gminas (NTS 5). Thus, about 2500 estimates are prepared and compiled for whole Poland each year. Simultaneously, data from modelling based on satellite imagery are delivered by the Institute of Geodesy and Cartography. The Fig. 6 presents the yield estimated for wheat in 2016. The yields are generalised for NTS 2, which is the standard grouping for official statistics. Data from satellite imagery interpretation are ancillary to yield and harvests estimates prepared by Central Statistical Office. In 2016, the modelling based on satellite images was applied for whole Poland for the first time. Thus, assessment of this data is still ongoing.

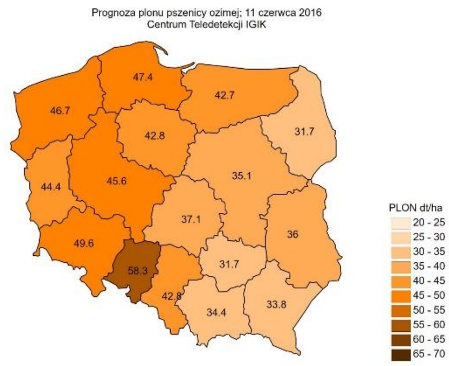

Figure 5: *The wheat yield estimates (dt/ha) for NTS2 regions in Poland in 2016.*

In 2015, the yield and harvests estimates based on modelling were studied in four NTS 2 regions (voivoships: dolnośląskie, warmińsko-mazurskie, wielkopolskie, zachodniopomorskie). The results were compared with the official data based i.e. on expert estimates, what was illustrated in Tab. 1.. The similar data were obtained also for all cereals.

Table 1: *Title of the table* (above the table, 12 pt italics, left-justified)

Voivodship (NTS 2)	Estimated yields (dt/ha)		Yield difference	
	Satellite	Statistical	dt/ha	%
DOLNOŚLĄSKIE	48,7	53,0	4,3	108,8
WARMIŃSKO-MAZURSKIE	43,3	50,9	7,6	117,6
WIELKOPOLSKIE	44,1	48,9	4,8	110,9
ZACHODNIOPOMORSKIE	46,1	59,2	13,1	128,4

The comparison shows that the yields and in consequence harvests are underestimated by the models based on satellite data. The above mentioned results cover only a few regions. The explanation of the differences could be attributed to use of long time series with yield low estimates. In recent years, the yield increase is being noticed due to development of highly specialised agricultural holdings and farm modernisation. The further validation of the results from interpretation of satellite imagery would be continued in 2016 for the whole territory of Poland. In coming years it is planned to switch to the satellite technics and modelling of harvest estimates as the basic source of information in this domain.

The experiences with satellite imagery interpretation show a huge potential for use in agricultural statistics. The vegetation monitoring and yield estimation are good examples of practical applications. Furthermore, the extremely important issue for agriculture statistics is assessment of crop area. The need for pilot studies and thematic project appears especially in recent years, when access to high resolution images has increased due to COPERNICUS or LANDSAT programmes. The official statistics is tapping in these new data sources but appropriate validations and methodological as well as quality review has to be carried out. The new initiatives of EUROSTAT concerning big and administrative data projects are good examples of such trend.

Making the Best Selection and Utilization of New IT Tools for Data Warehouse Systems

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ABSTRACT

There are many types of databases. For this topic the focus will be on the data warehouse. While a data warehouse can be defined in a wide variety of ways, for this discussion the focus will be around a data warehouse based on the Inmon concept of having one enterprise data warehouse which serves as the source for all other data based systems in an organization. On line analytical processing, or OLAP, will also be the targeted type of system for the purpose of this discussion. In short, the data system is optimized for rapid data retrieval and analysis.

Most entities recognize the utility of data and its retention. As these data stores grow, more and more resources are needed to hold the data, make backup copies of it, create new copies for reporting, and many other uses. Planning for the best methods of accessing and coordinating data have always been of paramount importance. Many organizations are still working on making maximum use of their data for adding value to all business processes. In many places even with efficient planning for how to use data, however, a point has been reached where the amount of data preserved can be problematic for retrieval with the IT tools which have been available in the past.

The National Agricultural Statistics Service has used the same data warehouse system for more than 17 years. There have been upgrades to hardware and software, along with needed structure changes, but no major shift in types of processors or software vendors. The system has served well, but recently the agency has seen more and more need to schedule certain analytical queries for 'off' hours when there would be few users on the system. One of the most basic reasons for having a data warehouse is the ability to analyze data and make use of it. Large queries accessing every known table and row could take up to five hours to run on the system as it was designed. It was also found that the software provider was not planning to make more substantive upgrades to the system, but would instead put resources into other products they felt were more in keeping with current trends.

Any decision for changing the data warehouse would affect literally hundreds of in-house agency applications. Along with considerations of cost, support, and integration, there was recent research into new massive parallel processing systems which could yield dramatic increases in query speeds. This presentation will detail the planning, areas of consideration, and comparison of features available in newer systems which lead to the purchase of a new data warehouse appliance for the agency and potential decreases in query time from hours to minutes or even seconds.

Keywords: Data Warehouse, Massive Parallel Processing

1. Introduction

1.1 An agency within the United States Department of Agriculture (USDA), the National Agricultural Statistics Service (NASS) conducts hundreds of surveys every year and prepares reports covering virtually every aspect of agriculture in the United States. Our mission is to provide timely, accurate, and useful statistics in service to U.S. agriculture. The surveys and related work are conducted mainly in twelve Regional Field Offices and five call centers across the United States.

1.2 NASS has used the same data warehouse system for more than 17 years. There have been upgrades to hardware and software, along with needed structure changes, but no major shift in types of database or software vendors. The system has served well, but recently the agency has seen more and more need to schedule certain analytical queries for 'off' hours when there would be few users on the system.

1.3 One of the most basic reasons for having a data warehouse is the ability to analyze data and make use of it. The largest queries, accessing every known table and row, began taking more time to process, taking up to five hours to run on the system as it was designed. The software behind the database engine had been purchased over time by a number of vendors. It was announced that the most recent software provider was not planning to make more substantive upgrades to the system, but would instead put resources into other products they felt were more in keeping with current trends. This was a concern with a steady progression of the hosting hardware and operating systems possibly leading to more errors or speed problems with the warehouse system which would not be upgrading.

1.4 Any decision for changing the data warehouse would affect literally hundreds of in-house agency applications. Along with considerations of cost, support, and integration, there was recent research into new Massive Parallel Processing (MPP) systems which could yield dramatic increases in query speeds. This presentation will detail the planning, areas of consideration, and comparison of features available in newer systems which led to the purchase of a new data warehouse appliance for the agency and potential decreases in query time from hours to minutes or even seconds.

2. Background

2.1 There are many types of databases. For this topic the focus will be on the data warehouse. While a data warehouse can be defined in a wide variety of ways, for this discussion the focus will be around a data warehouse based on the Inmon concept of having one enterprise data warehouse which serves as the source for all other data based systems in an organization (Inmon, 1993). On line analytical processing, or OLAP, will also be the targeted type of system for the purpose of this discussion. In short, the data system is optimized for rapid data retrieval and analysis.

2.2 Most entities recognize the utility of data and its retention. As these data stores grow, more and more resources are needed to hold the data, make backup copies of it, create new copies for reporting, and many other uses. Planning for the best methods of accessing and coordinating data have always been of paramount importance. Many organizations are still working on making maximum use of their data for adding value to all business processes. In many places even with efficient planning for how to use data, however, a point has been reached where the amount of data preserved can be problematic for retrieval with the IT tools which have been available in the past.

2.3 The variety of data available has also increased. The internet has virtually exploded with new and varied data and data sources. While there are still differences in internet access across the globe, the coverage and availability is growing at an increasing pace, with over 1000 percent growth in some areas of the world since the beginning of the century (Bell, 2011). Multi-media data and Big Data concepts are available if one has a suitable system, with enough speed potential and analytical tools, to take advantage of them (Beyer & Edjlali, 2015).

2.4 NASS was a comparatively early adopter of data warehouse concepts and has gathered a great deal of historic data over time. Most of the agency data is structured and uses detailed metadata. These characteristics affected the field of choices in warehouse products, making those with more open formats or ‘no sql’ choices more problematic in our case. There were early concerns about any cloud offerings, as well. Most of this was regarding either real or perceived security concerns. The selection team was open to possibilities but concerned that the timing might not yet be right for a cloud product.

2.5 More and more vendors are offering data warehouse appliances. Instead of purchasing a variety of hardware and software separately and then doing the integration within your own organization, there are now viable choices for systems which have already been designed and tested for optimum performance from a combination of hardware and software. Queries that might have taken hours on self-assembled systems can potentially take only seconds on pre-configured appliances (Beyer & Edjlali, 2015).

3. Steps Taken

3.1 With the current system in place for nearly two decades, there was some expectation at NASS that whatever new system was selected should be something that could grow with the agency and with the changing needs. The current system had over 11 billion rows of data, grew from over 250 surveys’ data annually, and was accessed by several hundred in-house software application systems and two primary Commercial Off The Shelf (COTS) software packages for business analytics and statistical analysis. The agency staff were particularly familiar with one COTS business intelligence analytical tool considered the standard tool for its purpose.

3.2 Investigation and planning were needed, but also some degree of speed in the decision. In our case ‘speed’ meant the investigation/selection project should take less than one fiscal year in order to take advantage of funding that could not be guaranteed in subsequent years. Even with time concerns, however, the agency would follow the three historic ‘pillars of progress’ which had been observed in the past NASS data warehouse implementation: 1) Focused Direction; 2) Sound Evaluation and Development; 3) Solid Implementation (Yost, 1999).

3.3 A seven person team was formed for the purpose of investigating options for replacement of the data warehouse system. Members were drawn from among the database administrators, metadata specialists, contract database support, the application software architect, and data analysts from outside of the IT division. The IT Division Head was the executive sponsor and the IT Division Senior Project Manager provided support for budgetary and procurement concerns.

3.4 From the literature available and based on the original cost of the current solution, a very broad estimate of purchase cost was put forward. This was needed at the beginning to plan and help in discussions with senior management. If the upper managers were put off by the cost or the upcoming degree of effort then any project could be considered defeated before it began. By setting the general expectations early in the project senior manager support was fully behind the process. This helped in a wide variety of ways, including recruiting team members and building favorable support.

3.5 The general timeline for the project was:

Dec. 2014:	Establish initial project plan
	Collect market information
	Reach out to business users
	Determine criteria for further investigation and selection
Jan. -Feb. 2015:	Request contract specialist from procurement staff on team
	Selection of pool of vendors based on criteria for products
	Prepare Proof Of Value (POV) trial criteria for vendors
Feb – Apr. 2015:	POV with vendors (four total)
May - June, 2015:	Report of findings to Data Services Branch staff
	Report of findings to NASS Enterprise Architecture Council
	Report to Senior Executive Service
June – Sept. 2015:	Work with contract specialist to procure recommended product

3.6 Communication was key. The project team included statisticians from the business community, who were also heavy/frequent users of the data warehouse. These same people helped to spread information and interest for the project. Other business side users were invited to help in developing the POV tests to be used with the various vendors. Evaluation results and periodic status messages were communicated directly among the team, with the entire Data Services Branch staff, the NASS Enterprise Architecture Council and the Senior Executive Team. All of this helped in planning and to promote acceptance and a favorable climate of acceptance for the general direction and product choices of the team.

3.7 A separate project team was also formed to review choices for a new analytical software tool. That effort was conducted in much the same way as the analytical database team's project, with both teams communicating with each other.

3.8 Instead of creating all of the selection criteria from scratch, the team chose to use a third party authoritative source to describe the features desired. In our case the publicly available Gartner ***Magic Quadrant for Data Warehouse and Data Management Solutions for Analytics*** report was an excellent resource. An abridged version was advertised and available via the web and we received the entire report via a subscription service (Beyer & Edjlali, 2015). This had several benefits. The research was current, in-depth, and forward looking. In this case it helped narrow the field considerably when it was found that only four of the vendors in the 'Leaders' quadrant also produced appliances. And a major benefit in our situation was the ability to provide a third party list of characteristics and rating to our procurement office in support of the team's methods and ultimate recommended selection.

3.9 A special comparison was made with a leading vendor cloud offering. This was in anticipation of trends in the industry and potential questions from stakeholders. NASS is a statistical agency dealing in confidential data protected by law. Even the appearance of a compromise in data security can lead to lower response rates to agency surveys. The Agricultural Advisory Committee (composed of public and private stakeholders in statistical reporting) had even made previous recommendations against some cloud systems housing our data. In addition to any concerns about public opinion, there is also an official accreditation process for federal government systems. There are several federal programs underway specifically for the purpose of certifying cloud based offerings for various purposes. The Department of Agriculture also has some internal initiatives with the goal of providing cloud services. Ultimately it was decided that cloud offerings were not yet at a stage of acceptance either internally or externally in terms of confidential data security or the perception needed for our data security. As government certification programs advance, this may change and cloud offerings may be a more viable option in the future.

3.10 Market research consisted of internet sources and searches (including the previously mentioned magic quadrant report), vendor meetings, demonstrations, attendance in public conferences on the topic, and internal stake holder meetings. The team compiled a list of other government agencies doing similar work to our own. Calls and meetings were organized to enquire about these agencies' own data warehouse solutions, planning direction, and general satisfaction with their current systems and vendors. General comparison criteria during the market research included:

- Architecture.
- Scalability
- Reliability
- Performance
- Compatibility (with existing environment and code in place)
- Administration tools (availability, and ease of use)
- Price (a formal decision was based on best overall value, not simply lowest purchase price)

3.11 Our investigations led to a special focus on two characteristics. The systems using both preconfigured appliances and described as using massive parallel processing (MPP) presented the potential for the greatest speed increases. Simply put, MPP means dividing the work for different parts of an application or data retrieval among multiple processors. In the majority of the vendors we reviewed, the solutions included specialized processors and a set number of specific disc drives associated with any one processor. It was difficult to get a precise estimate ahead of time of what the speed increase would be without testing with a specific data structure and volume. Estimates ranged from 10 to 100 times faster (Lopes, 2015). All of the vendor systems reviewed showed significant speed increases over the current NASS data warehouse. The system ultimately selected returned the longest running known queries roughly 100 times faster. Queries that would typically take over five hours, returned results in roughly three minutes.

3.12 Once the field of potential vendors that excelled in our initial criteria was established at four, the Proof Of Value (POV) trials were begun. Vendors were allowed to conduct the tests off site from our own facility. All were given a group of representative queries for benchmarking times. All were given the same test data which had been approved by our agency Security Staff and statistical staff to ensure there was no release of confidential data and to prevent any confusion leading to any appearance of releasing confidential data. The team visited each vendor and took along specific queries and use cases for testing. Each vendor was asked to specifically demonstrate the ability of their system to be accessed by one COTS statistical software package and one COTS analytical software package. Both of these are considered standards and are in wide use in the agency. The broad criteria used in the evaluations included:

- Benchmark and test case performance.

- Workload of database migration
- Post migration work on in-house applications and programs.
- Backup and restoration
- DBA technical requirements
- Administration tools (availability, and ease of use)
- Price (a formal decision was based on best overall value, not simply lowest purchase price)

3.13 The project team created a project plan and documented the steps taken. The team also created a slide presentation which could be used to communicate the process and give a comparison of the vendors involved showing all of the criteria in side-by-side comparisons. The same groups which were consulted at the project initiation were again presented with results and recommendations. The presentation and approval sessions included a dry run within the team to ensure there was consensus and record notes and details for items that generated discussion. The findings were then presented to the IT Division Head, the Data Services Branch staff, the NASS Enterprise Architecture Council, and to the Senior Executive Team. All of this sought to ensure alignment within our agency planning and with the USDA capital planning and investment direction. Once any lingering questions were answered we sought final approval from the IT Division Head.

3.14 Working through the federal government procurement process was the final step. The team had worked diligently to be sure a contract specialist was engaged months before sending the final recommendation. The contract specialist worked with the team to ensure that all the required forms and steps were followed and completed. Because this person’s expertise was in federal contracting and not in IT or data warehousing, there were many opportunities to help in their understanding of terms and clarification of concepts and requirements.

3.15 The size of the procurement in terms of monetary value was also a consideration. In our purchasing system the higher the value, the longer the time period is for notice of the potential contract to vendors, and the more demanding the process for documentation of the salient characteristics of the intended system. Purchasing something costing over one million dollars requires more rigor in documenting the selection process and can also increase the potential for vendor protests. The artifacts developed by the team proved to be invaluable as documentation in the actual contracting process. It was used to demonstrate thoroughness, objectivity, and as a rationale for the recommended purchase.

4. Current State and Next Steps

4.1 NASS procured two appliance systems to be placed in physically separate USDA data centers; one for production and one for disaster recovery (DR). We also procured two development blade servers for testing purposes that will reside in our headquarters location. The purchase was made in September, 2015. The equipment was delivered in early calendar 2016. USDA has been undergoing continuing consolidation of data center resources and deployment of the NASS data warehouse system had to be scheduled between many of these activities. The primary appliance was put in place in March 2016 and the DR appliance was put in place in April 2016. The selection team has turned the project over to the Data Services Branch Staff for setup, population and integration of the units.

4.2 The fundamental plan is to parallel test the new system through the next year’s survey cycle, incorporating all of the same data and inputs, leading to creating the same outputs. Where differences are found, further work will be needed to document and change either the new or old system if needed. This is no small task due to the release of over 400 statistical reports and the existence of hundreds of systems/applications involved in the annual process.

4.3 One large challenge is the integration of all of the feeder systems through the Extract, Transform, & Load (ETL) process. There are discussions under way about the best ways to adapt the current procedures to the new products and potential paradigm shifts to an Extract, Load, and Transform (ELT) process. With the speed potential of the new system, it may often make sense to do data transformations within the appliance rather than at the feeder system or within the ETL programming currently in place. This potential speed increase also points toward the efficiency of doing other analytical operations within the database system rather than extracting data with another tool and pulling that over the network to the analyst's workstation. While this may seem like an obvious improvement to systems integrators it has proven to be a persistent problem with agency employees.

4.4 The agency has a public facing web system based in the same data warehouse technology. This 'Quick Stats' system provides the public with the latest estimates. The new data warehouse platform must also be integrated into Quick Stats with little or no interruption to public service.

5. Lessons Learned

5.1 Lessons learned include:

- Do preliminary research on technical possibilities and price ranges
- Think strategically and look to the future
- Secure senior management buy-in early
    - Include budget considerations
- Communicate, communicate, communicate
    - Include entities outside of IT
    - Include your procurement staff early in the process
- Where ever possible use third party and objective sources in your market research
- Plan the work and document as you go
    - Keep the documentation of comparisons as objective as possible
- Test the options as much as possible before committing to any particular solution
    - Document the testing
    - Document why a particular direction was chosen
        - In-house vs. cloud
        - Structured vs. unstructured data
- Consider all of the other systems and data interactions
    - Can they work with any new solution
    - What changes will be needed?
    - Will there be any required paradigm shifts (ETL vs. ELT)

6. Conclusion

6.1 NASS and other statistical organizations are 'data factories'. Our agency mission is to provide timely, accurate, and useful statistics in service to U.S. agriculture. It can be difficult at times to remember that we are *not* IT systems integrators. Everything we do should be put in place to support the business mission. Our data warehouse replacement team had to consistently remind ourselves of that as we went through the process. That reminder promoted some of the decisions to move toward a pre-engineered appliance. There were advantages in not only speed of queries and results but in ease of maintenance and reduction of workload in areas where we did not need to focus. When one buys a refrigerator, you do not have to assemble the compressor and charge the Freon unit. It is delivered, plugged in to power, and generally works.

6.2 Communication takes time but proved to be an overall time saver in the end. By including both our business partners and our procurement staff, we promoted understanding, minimized 're-telling' of the story, and negotiated a good business deal for the product and services. We also found that some advance favorable opinion of what was being done had preceded the team to a variety of meetings. When the time came for final approvals, stakeholders reached a consensus fairly quickly because of their involvement in the process.

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Leveraging technology to streamline the collection and visualization of agricultural and socio-economic data of vulnerable communities.

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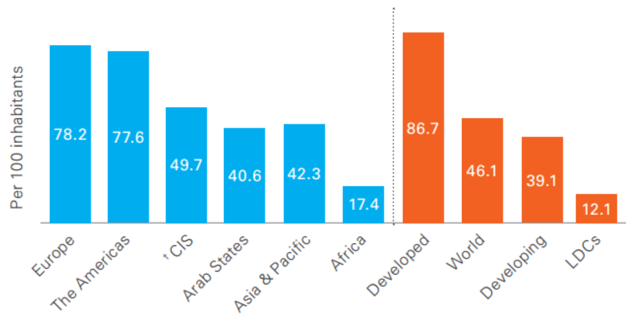
ABSTRACT

This paper presents the use modern technologies implemented by UNODC in the monitoring of Alternative Development projects established in social and economically vulnerable agricultural areas in Colombia. The system supports data capture applications implemented via smartphones with the ODK and GeoODK arquitecture. Collected data include georeferenced field boundaries, field areas, geotagged photos, and socio-economic questionnaires. Offline collected data is stored in a relational database which is directly queried by several web applications that publishes and visualizes data reports and indicators in almost real time. A key feature of the designed infrastructure is the tight integration between data collection, processing, storing and visualization that ensures straight access to the raw data and derived indicators. The system is a low-tech solution and has been automated in order to secure data collection and minimize data loss or input errors. We present the system as an example of efficient information systems implemented by institutions working in developing countries with limited infrastructure.

Keywords: data collection, survey, monitoring, information, ODK.

1. Introduction

Currently more than 3.2 million people have access to the Internet and almost half of the world population has access to mobile broadband subscriptions (International Telecommunication Union, 2015). A large share of the adoption of communication technologies is happening in developing and least developed nations, which provide thriving conditions in places where physical infrastructure still limits the exchange of goods and until recently, ideas. As shown in Figure 1, as of 2015, the percentage of mobile broadband subscriptions reached 86.7% in developed countries and about 40% in developing countries (Dutta, 2009). There is, however, an increasing technology divide between developing countries and the rest of the world as shown also in the figure (left) (International Telecommunication Union, 2015).



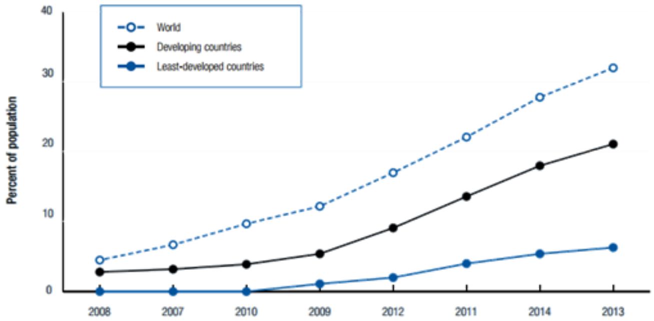


Figure 1. Left: percentage of mobile broadband subscriptions in 2015. Right: Mobile broadband penetration over the last years by region

As expressed by ITU, societies that transitioned to information technologies are experiencing a positive impact on economics, government, businesses and education, moving faster to the achievement of United Nations Sustainable Development Goals. The steady growing penetration rates of mobile broadband subscriptions in developing countries over the last years indicates that there are excellent business opportunities for the private sector but also enabling conditions for government and institutions to improve the knowledge of territorial and socioeconomic indicators of its populations.

Developing nations still face the legacy of paper loaded processes, red tape and slow data collection rates, which ultimately compromise the possibilities of data analysis and data dissemination to the final users. In this environment, data collection is so difficult, that often, completed questionnaires are dumped into boxes awaiting the availability of human and financial resources to interpret and make sense of their information. Publication of collected data often comes late, when decisions have been made, attention has already shifted to another project, and funds are depleted.

Recent ICAS conferences have reported efforts on the use of ICT systems to collect data and implement agricultural censuses. Those undertakings reflect specially the state of the art in developed countries or in national statistical agencies that have the infrastructure to invest on these endeavours. However, as exemplified by this paper, the development of infrastructure, communication networks, user communities, global positioning systems, software and hardware facilitates today reliable data collection, processing and dissemination at a low cost and a fast rate.

This paper reflects on the implementation of the information cycle of data collection, data processing and data visualization for the collection of agricultural and socio economic data. These processes have been implemented by UNODC in Colombia to document rural development transformations in areas affected by illicit crops. The experience is implemented in vulnerable remote rural areas, which largely match the conditions of least developing countries. As presented in this report, the developed system has resulted in timely data collection in areas monitored by UNODC in Colombia and an advanced organizational know-how of information systems.

2. The information cycle

UNODC supports the Colombian Government in the monitoring of the implementation of rural development programmes aimed at ensuring food security and socio economic integration of vulnerable communities immersed in areas affected by illicit crop cultivation (**insert note**). UNODC has been providing this support for more than a decade under several government administrations and policy implementations. The solution presented in this paper is the result of the evolution of a process that started in the early 2000's and has been improved and adjusted to honour the conditions of the policy implementation and the situation on the ground.

Under the Alternative Development monitoring programme, UNODC verifies: 1) the physical transformation of the territories being supported by the Government, and 2) the socio economic transformation of the communities targeted by the Alternative Development programme. This requires the collection of the following data in the field:

1) Measurement and georreferencing of parcels supported by the Alternative Development Programme. This includes the registration of the parcel boundaries, and capture of photographs of the area. Enumerators also collect data on land characteristics such as land ownership, land suitability and planted crops.

2) Administration of interviewing questionnaires inquiring about social, economic, environmental and institutional indicators related to the rural district of the participating household.

In the interventions of 2012, 2013 and 2014 a total of 34,000 households were registered in the Programme. Each household parcel was measured while questionnaires were administered randomly to selected households based on a stratified sample. Parcels were measured and identified at the beginning of the intervention, while interviewing questionnaires were administered during field visits at the beginning, mid-term and final stage of the project. This temporality permitted to monitor territorial performance of the communities involved in the program.

The information cycle of the implemented agricultural survey includes all the necesary steps to ensure: a) efficient data collection, b) data processing, c) analisis of derived information and d) publication and visualization of results. The transition from one stage to the next is an interrelated process, tightly integrated with coupled by technology, software, users and infrastructure (Figure 2).

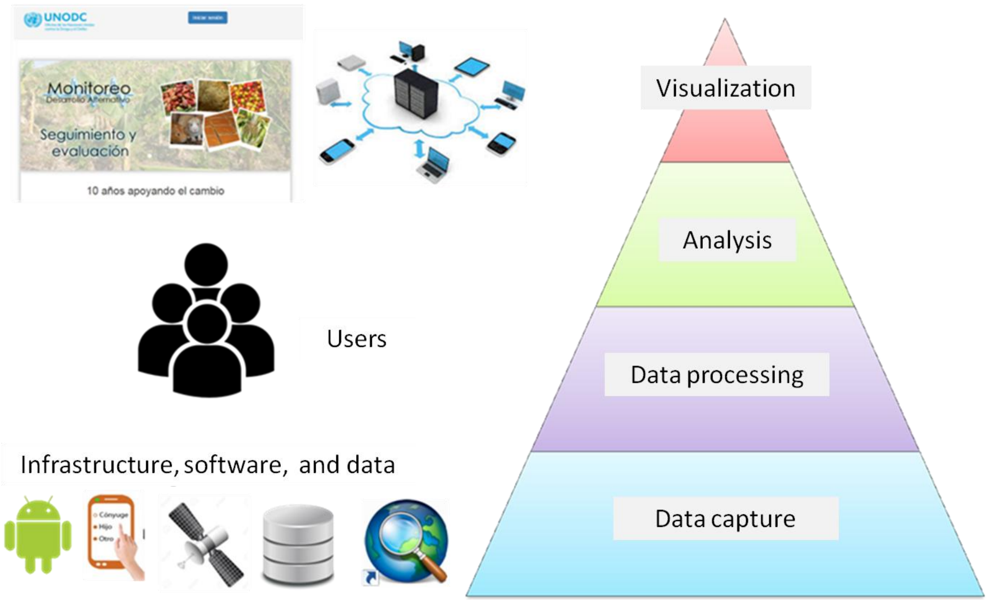


Figure 2. Stages of the information cycle: from data collection to visualization and dissemination

3. Data collection

We based data collection on the Open Data Kit project developed at the University of Washington (Hartung et al., 2010). This project includes several applications that assist during data collection:

ODK design: language and interface to design survey questionnaires. Questionnaires are implemented in the XLM/Xform standard which allows interoperability and readability by various systems. To facilitate multiuser form design, we used Google spreadsheets. Questions and logical flow of the questionnaire were validated and translated into an XLM file using the XLSform conversion tool.

ODK collect: ODK collect is the client application deployed to Android systems (currently supporting Android versions > 4.1). This application provides the ability to log into a specified server to download blank forms using defined user credentials. The server hosts the blank forms as well as completed submissions sent by collectors as explained below.

With the blank forms downloaded to the Android device, the enumerator can initiate data collection. Several forms can be stored in the same device, and with forms having a size of a few kilobytes, there is no practical restriction to the volume of collected data that can be stored in a device. The application interprets the questions, the flow and the logic conditions implemented in the form. For instance, the application prevents enumerators from leaving unanswered mandatory questions, or moving to the next question if some logical rule is violated with the current answer. Similarly, the application skips irrelevant questions depending on the answers of the interviewed household.

Collection of Geographic data: to enable spatial data collection we used GeoODK, a modified version of ODK Collect (Nordling, 2015). GeoODK facilitates the collection of polygons using the Geotrace geometry, where polygon vertices are recorded in continuous mode every few seconds or, alternatively, when requested by the user. Point data is also collected to register the location of the interview.

Location accuracy depends on the GPS chipset of the recording device being used. With the implemented system, any Smartphone device equipped with a built-in GPS can be used to collect the alphanumeric and spatial data. To streamline technical support, two devices were selected, based on their robust construction, GPS reliability, battery duration and cost (Figure 3).

Figure 3. View of the Monterra Garming GPS and Moto G Android smarthphone used for data collection

4. Data processing

Storage of collected spatial and alphanumeric data was centralized via the ODK Aggregate application. ODK Aggregate provides a ready-to-deploy server and data repository to: 1) retrieve blank questionnaire forms to be used in ODK Collect; 2) Accept finalized forms (submissions) from ODK Collect and manage collected data; 3) Visualize the collected data using maps and simple graphs; 4) export data (e.g., to a CSV files for spreadsheets, SQL database or as KML files for Google Earth).

ODK Aggregate can be deployed in several configurations, such as Google's App Engine, Amazon web servers or the organization server. Given the ease of configuration and server reliability needed for intensive and continuous data collection, we set up a hybrid system that stores collected data by mobile devices into an SQL database hosted by Google's App Engine and continuously synchronizes to a local repository.

We developed an R routine to process the data, normalize it and reshape it to the required format and structure of the local SQL database system. The script reads the CSV data, checks for new information and reshapes the data accordingly. The R system communicates directly with the database management system and stores the new records into the relational tables of the UNODC database (Figure 4).

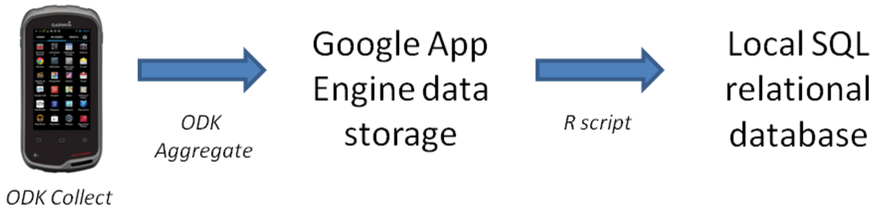


Figure 4. Flow of data from collection to storage into an SQL database

The spatial data collected in ODK undergoes the same transformation as the rest of the data described previously, but required a different treatment during the transformation in the R script. Spatial data is registered in the XLM form as an alphanumeric data type noted by a sequence of vertex coordinates in WGS84 system. The R script implements the following operations:

- Verifies and fixes topological errors: this involves removing signal overshoots and spiky vertices affected by the quality of the GPS signal during data capture.
- Verifies and closes open rings to transform them into polygons.
- Verifies spatial data consistency. i.e polygons should be located in a given municipality.

5. Data visualization

The automation of all previous steps needed to transfer data into a relational spatial database facilitates almost real time visualization of collected data. For instance, Figure 5 illustrates a digital interactive web map showing the locations of Alternative Development projects. Data visualization and reporting of collected data is supported by modern open web technologies like PhP, JavaScript and the Leaflet mapping library. Applications like interactive maps or data collection dashboards have been designed at UNODC to retrieve information directly from the relational Database and publish to the web.

An important development for the project was the possibility to serve spatial data directly from the database stored in UNODC servers to dynamic web maps. The common approach of serving shapefiles or text files is popular, but when data is dynamically and continuously updated the automation of a synced database becomes relevant.

6. Users

A fundamental step in the implementation of a successful survey is user training. In UNODC enumerators have extensive experience in collecting data. However, not all of them were equally savvy in the use of Android systems, applications and digital content management. Several thematic trainings were held to explain the basics of the operation in the field and how to verify the correct configuration of the device as well as data transferring. Data analyst and survey coordinators were also trained on the use of the web visualization tools and dashboard of data collection campaign.

7. Discussion

This document presented the configuration of a tightly integrated system between data capture, data processing and visualization with an system suitable for the type of infrastructure present in developing countries. The system has been successfully deployed at UNODC for the monitoring and georreferencing of rural households participating in the Alternative Development program. The system relies on the ODK architecture for spatial data collection in disconnected mode and information technologies like scripting languages for data processing and web applications for visualization.

Data collection is, perhaps, the most crucial stage of the information cycle process. The opportunity to measure a field or interview a farmer is an irreplaceable event as the conditions enabling data collection are unique considering weather, financial resources, staff availability, field security and objects being measured. Teams long accustomed to conventional analogue data collection will initially be reluctant to the idea of a digital collection system, given the intangible nature of digital data as compared to conventional paper forms. To facilitate adoption of the system and reassure field enumerators at UNODC, we develop a dashboard on the website where they can login to trace the submitted data. The system provides them general indicators of their work such as the number and type of questionnaires effectively received, and a point map of the visited locations.

The deployed infrastructure is economic in terms of hardware and software resources. Most importantly, it is flexible and can be adapted to available budget. If for instance, a server is not locally available, data can be hosted permanently on third party servers for a low cost (e.g. Amazon, Google). Several GPS enabled Smarthphone devices can also selected depending on the local market availability. What is more crucial for the implementation of a full-fledged project as described here is to count with expert knowledge on information technologies. This is needed for database design and maintenance, server configuration for data collection, data scripting for data processing, and programming of web applications for visualization and data reports.

Fortunately local knowledge is growing rapidly in developing countries. Furthermore, there are generous developer communities in the Web around open technologies as the ones presented here. For instance, the ODK user community is moderated at the University of Washington and daily support is provided to ODK users, with a large volume of knowledge accumulated in the history of its forums. The same happens with the communities of R, PhP, Javascript and Leaflet. This shared knowledge adds a vital level of support that accelerates local knowledge and ensures sustainability.

8. Results

The impact of the implementation of the described system has enabled timely and accurate data collection and dissemination under a low cost implementation, using open source technologies. Firstly, data has been captured in an efficient way, with minimal data errors, minimal data loss and a more fresh transition between collected data to indicators and data visualization. Field enumerators have been relieved from carrying paper forms to the field and from memorizing questionnaires guidelines as the application guides the enumerators through the questionnaire restrictions and the logic flow.

Secondly, the information technology capacities of UNODC has grown rapidly with a group of information technology professionals that before spent most of their time scanning, editing and digitizing collected data, to a more rewarding and exciting environment where they develop skills in data manipulation, database management and data visualization tools. We consider this highly relevant, to close the digital divide between developed and developing nations, and ultimately, to promote a higher impact of information technologies in developing countries.

Figure 5. Digital interactive map showing field collected data directly stored in a database

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Are CAPI based surveys a cost-effective and viable alternative to PAPI surveys? Evidence from agricultural surveys in Tanzania and Uganda.

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ABSTRACT

As the world embarks in a major effort to achieve the Sustainable Development Goals, there is a high demand for high quality and timely agricultural statistics in order to design and implement effective policies, allocate investments, monitor and evaluate progress. Most of the Governments in developing countries are thus searching for cost-effective methods of collecting high quality data on agriculture. Literature from small surveys conducted by research institutes suggest that using Computer Assisted Personal Interview (CAPI) technologies could be a cost effective alternative to the traditional Paper and Pen Interview (PAPI) method. Additionally, there is preliminary evidence that CAPI can improve data quality, shorten interview duration, and that enumerators prefer CAPI to PAPI. As National Statistical Systems (NSSs) operate in a very different context from research institutes and the applicability of these findings are limited. This paper analyses paradata on cost, interview duration, data quality, and enumerator feedback on various surveys conducted by National Statistical Systems (NSSs) in Uganda and Tanzania. The results confirm that CAPI is cost-effective across multiple surveys. Statisticians in Uganda also indicated there were an increase in data quality after using CAPI. Additionally, data from a questionnaire administered to enumerators in both countries showed that they indeed prefer CAPI over PAPI. The analysis of interview duration did not indicate that CAPI interviews are shorter, but this is likely due to factors other than the survey instrument.

Keywords: CAPI, National Statistical Systems, Data collection, Surveys

1. Background and Introduction

January 1st, 2016 marked the official beginning of the 2030 Sustainable Development Agenda agreed upon by leaders from all over the world in September 2015. The Sustainable Development Agenda (SDA) defines 17 Sustainable Development Goals (SDGs) that promote sustainable economic growth, elimination of poverty and inequality, and address a host of social needs. Under these goals there are 169 individual targets. The SDGs will be monitored by indicators developed by the Inter Agency and Expert Group on SDG Indicators (IAEA-SDGs) and then agreed upon by the UN Statistical Commission. It is anticipated that 2 indicators will be assigned to each target creating approximately 338 indicators (United Nations 2016).

The National Statistical Systems (NSSs) are the natural sources of information for producing the data needed for the SDG indicators. With such a large suite of indicators, it is apparent that there will be a substantial cost of collecting this data and ensuring that it is timely and reliable. The burden is particularly high on NSSs in developing countries that face resource constraints. Accordingly, any cost-savings tools for data collection would be advantageous to the SDG process.

A large share of the cost of data collection traditionally carried out using Pen and Paper Interivewing (PAPI) relates to theprinting of the questionnaire itself, transporting them to and from the field, as well as transferring the data into a digital format so it can be analysed, and storing the completed questionnaires. Computer Assisted Personal Interviewing (CAPI) tools which collect data using electronic devices completely eliminate some of these costs. However, the adoption of CAPI has been slow, due to concerns about the fixed cost of equipment, reorganization of statistical processes, and training, quality of technology, lack of Internet connectivity, human capacity and resistance to change. Indeed, there is so far little systematic evidence on the advantages of using CAPI over PAPI to collect data for official statistics.

By using paradata provided by the Ugandan Bureau of Statistics (UBOS), the National Bureau of Statistics of Tanzania (NBS), and the Ministry of Agriculture, Livestock and Fisheries (MALF) of Tanzania on various surveys conducted using CAPI and PAPI, this paper analyses the differences in implementing CAPI and PAPI based surveys across four dimensions: cost, interview duration, data quality, and enumerator opinion. The paper aims at assisting survey managers in developing countries to take a decision on whether to invest in CAPI. Results, however, should be taken with caution as equipment and training cost have been constantly declining in recent years and an ever-growing number of devices and user-friendly software are being marketed and, in some cases, are freely available.

2. Literature review and previous findings

The literature comparing CAPI and PAPI survey methods in developing countries is restricted mostly to small sample surveys carried out by research institutes. As NSSs face very different contexts than research institutes, the findings may be of limited use. However, an overview of the main results relating to costs, interview duration, data quality, and enumerator opinion is informative.

2.1 Cost

It is well established that, there is a high fixed cost of switching to CAPI due to the purchase of equipment such as tablets or smartphones, servers for data storage, etc. However, there are also savings generated from the reduction or elimination of some variable costs including double data entry, paper storage costs, less data cleaning resulting from higher quality data, and elimination of printing costs (Zhang, et al 2012; King, et. al 2013, Leisher 2014).Caeyers, et. al (2010)found that the break-even number of interviews where the reduction of variable costs associated with PAPI by using CAPI equals the fixed costs of purchasing equipment was 4,000 interviews. Accordingly, surveys with sample sizes below 4,000 respondents would be more expensive using CAPI, but it would be cost-effective for larger samples. Note that this assumes the equipment is only used for one survey. If the fixed cost of the equipment were to be spread over more surveys, this break-even point would certainly decline. Also, the prices of electronic devices that can be used for CAPI have declined greatly in recent years, which would cause this number to decline further. This suggests that CAPI becomes cost-effective after some threshold, and surveys conducted on large sample sizes will benefit more from CAPI. That said, an issue is whether this trend holds for even larger census size samples as substantially more equipment is needed.

2.2 Interview duration

Shorter interviews result in lower respondent fatigue and improve data quality. Caeyers, et. al (2010) found a positive correlation between the number of errors recorded during an interview and interview duration. More studies than not which examine the relationship between the method of data collection and interview duration show that CAPI interviews tend to be shorter. The idea being that selecting options from a list on a smart phone or tablet is generally quicker than hand writing answers on paper (CSO 2016; Zhang, et al 2012**)**. One study involving sample surveys in Kenya and Tanzania found that on average CAPI interviews were 16 minutes shorter than interviews conducted using PAPI. Notably this same study indicated that this time saving was not realized until after 3 days of data collection (Leisher 2014). Another study specifically designed to compare CAPI and PAPI using a Randomized Control Trial (RCT) showed that interviews conducted using CAPI were 10 percent shorter than PAPI (Caeyers, et. al 2010**)**. On the other hand, a few studies have found longer interview durations by using CAPI or no statistically significant relationship at all (King, et. al 2013**)**.

2.3. Data quality

In terms of data quality, most if not all CAPI products allow survey designers to program validation conditions that detect erroneous data and display a warning message to the enumerator. Furthermore, routing errors are eliminated because skip patterns are programmed into the structure of the questionnaire and automatically enforced. Finally, since the data is immediately digitized during the interview, potential data entry errors during the transcription from the paper into a database are eliminated. Indeed, studies have found that data entry errors wereeliminated using CAPI (Zhang, et. al., 2012, King, et. al 2013). Furthermore, the literature comparing results from the same questionnaire using both PAPI and CAPI found that the percentage of interviews containing erroneous data was much less for interviews conducted using CAPI (Caeyers, et. al 2010).

2.4 Enumerator opinion

The individuals affected the most by the choice of using CAPI or PAPI are the interviewers themselves. If all enumerators strongly prefer the traditional PAPI method, that may be enough justification to keep using it. The available literature suggests that enumerators prefer using electronic devices over paper questionnaires, for reasons such as less weight to carry around, reduced worry about correctly following skip patterns, easier organization and less risk of damaging completed surveys because of weather conditions. The only worry cited was the possibility of technical failure during an interview (Zhang, et al 2012; King, et. al 2013).

In summary, the literature indicates that CAPI shows promise as a cost-effective alternative to the traditional PAPI methods with the potential to improve data quality, reduce respondent through shorter interviews, and indeed when asked, enumerators seem to prefer CAPI tools. However, this evidence comes from on small sample surveys conducted by research institutes and, therefore, the conclusions are not necessarily applicable for NSOs that operate in a very context.

3. Methodology and data sources

The UBOS, NBS, and MALF assembled available data on costs, start and end time of interviews, and data quality for a number of surveys. A questionnaire was also distributed to a random sample of enumerators to assess their overall opinion of using CAPI to collect data in both countries.

3.1. Ugandan Bureau of Statistics

UBOS provided data for the first four waves of the National Panel Survey (NPS) from 2009 to 2014, a nationally representative multi-topic householdsurvey.The first wave was performed using PAPI, while waves 2-4 were administered using a combination of Ultra-mobile PCs (UMPCs) and Lenovo tablets. The software used was Capture with Enhanced Survey Technology (CWEST). The number of questions in the four surveys varied between 1,090 and 1,152 and targetedinformation on education, health, labor, housing conditions, non-agricultural enterprises, vulnerable groups, agriculture (crops, livestock, and fisheries), water and sanitation. Each wave collected data from about 3,000 households.

Comparing the 4 waves of the NPS offers the opportunity to assess the cost and quality differences between CAPI and PAPI, as well as how the costs of adopting CAPI changes over time.

Furthermore, UBOS has a rich pool of enumerators with vast experience and knowledge of both PAPI and CAPI making them ideal respondents for comparing PAPI and CAPI. The start time, end time, and dates were provided for Waves 1 and 4 so that the duration of interviews could be compared.

3.2. National Bureau of Statistics (NBS) and the Ministry of Agriculture, Livestock and Fisheries (MALF) of Tanzania

NBS provided cost data for the 4th wave of the National Panel Survey and for the Tanzania Demographic and Health Survey (DHS). Both of these surveys were conducted using PAPI, so for comparison,MALFprovided datafor the 2015 Livestock Field Officer Survey (LOS) conductedentirely using CAPI. Data regarding the start time, end time, and date of each interview was available for theLOS survey. Many of the enumerators mobilized for the LOS had been employed by NBS meaning that they had experience conducting surveys on CAPI and PAPI. Accordingly, they were an ideal pool of respondents.

4. Analysis and Results

4.1. Cost comparison

Tables 1 and 2 below show a cost comparision per interview of each survey by cost category in 2005 Purchasing Power Parity (PPP[1]) dollars. Enumerator, and supervisor costs are the product of the number of enumerators and supervisors, daily remuneration, and number of days worked. Cost for data cleaning for surveys in Tanzania were computed the same way using the human resources for data cleaning. Data cleaning costs could not be estimated for Uganda.

The paper questionnaire costs include printing, transportation to/from field, and the product of the cost of yearly storage and required number of years. Even when a survey is implemented using CAPI, there are minor paper questionnaire costs because enumerators are given back-up questionnaires incase of equipment failure. The electronic equipment costs include the purchase price of the electronic devices used for data collection, accessories (e.g. extra batteries, anti-glare covers; etc.), data transfer, generators for recharging, and consulting fees if required. The costs of the electronic devices and accessories were divided by 5 as experience at UBOS showed that this type of equipment usually lasts for 5 rounds of data collection, after which it needs replacement.

It is notable that for the DHS and NPS-Wave 4 surveys conducted in Tanzania, double data entry was conducted: once in the field, and once in the office. The field data entry was conducted using tablets for the DHS and laptop computers for the NPS, which contributed to the equipments costs. It should also be noted that computers used for cleaning are not included in these figures. This is based on the assumption that an institution would likely use the same number of computers for CAPI and PAPI surveys.

In both countries, the cost per interview of surveys implemented with CAPI is lower than PAPI. Consistently, these savings can be attributed to lower paper questionnaire costs, and the elimination of data entry by CAPI. In Tanzania, the cost of data cleaning are also lower for the CAPI survey due to the higher data quality and the precoding of variables programmed into the questionnaire. In Uganda, the expenses of paper questionnaires decreased with subsequent years using CAPI. This is because UBOS gained confidence with the technology and printed fewer back-up paper questionnaires.

Furthermore, a minor contributing factor of the lower costs of CAPI is the fact that these values are given in PPPs. In Uganda, the enumerator and supervisor salaries were constant across

[1]Purchasing Price Parity were used because they provide a standard unit of measure to compare expenditures across multiple countries. More information can be found at www.worldbank.org.

all waves. So when the values were converted into PPPs, they appear lower because inflation is taken into account. In current local currency units, the enumerator and supervisor were the same across all four waves of the NPS.

Table 1: *Cost per interview in Tanzania in 2005 PPP values*

Description	**NPS – Wave 4**	**DHS**	**LOS**
Year	2014-2015	2015-16	2015
Sample Size	5,010	13,376	415
Number of questions	782	879	239
Method of data collection	PAPI	PAPI	CAPI
Costs			
Enumerators salaries	124.63	67.95	62.06
Supervisor salaries	32.40	14.84	32.85
Data Entry	24.09	14.10	-
Cleaning costs	10.80	2.72	0.21
Paper questionnaire cost	11.60	8.45	0.07
Electronic equipment cost	7.66	2.24	11.21
Cost per interview	211.18	110.29	106.40

Note: Values converted from Tanzanian Shillings to 2005 PPP values using the World Development Indicators (2016).

Table 2:*Cost per interview in Uganda in 2005 PPP values*

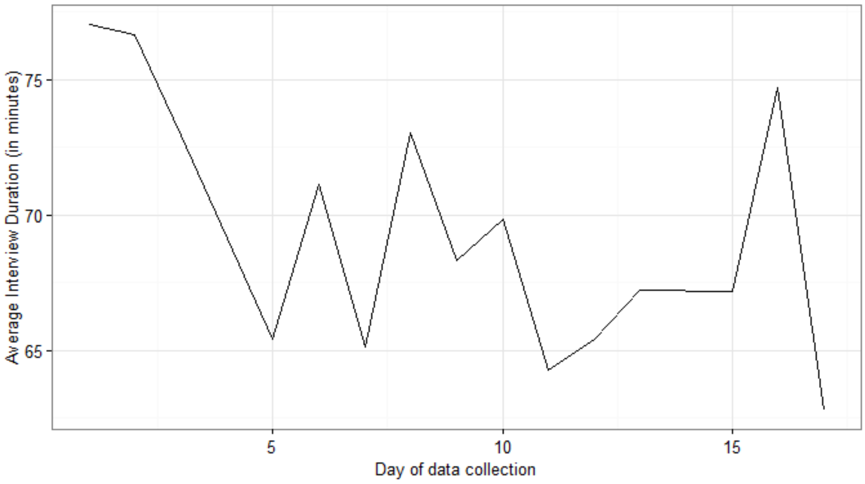
Description	**Wave 1**	**Wave 2**	**Wave 3**	**Wave 4**
Year	2009-2010	2010-2011	2012-2013	2013-2014
Sample Size	3000	3000	3000	3000
Number of questions	1090	1097	1152	1148
Method of data collection	PAPI	CAPI	CAPI	CAPI
Costs				
Enumerators salaries	91.46	81.05	63.96	61.42
Supervisor salaries	45.27	40.12	31.66	30.40
Data Entry	28.38	-	-	-
Cleaning costs	NA	NA	NA	NA
Paper questionnaire cost	35.04	6.21	4.44	3.68
Electronic equipment cost	-	8.14	7.26	7.07
Cost per interview	200.16	135.52	107.33	102.56

Note: Values converted from Ugandan Shillings to 2005 PPP values using the World Development Indicators (2016).

4.2. Interview Duration

As mentioned in Section 2, Leisher (2014) found that the interview duration of CAPI surveys decreased after the first 3 days of data collection. Figure 1 below reflects this same experience in the Tanzania LOS. The average interview duration by day drops from 77 minutes on the first day of data collection to 66 minutes by day 5. Thereafter the average duration of interviews fluctuated, but never reached more than 75 minutes. Notably, the LOS involved a long and complex game as well as very challenging questions involving scenario building and behavioural projections. Thus, the data from this survey does not provide a good comparison with the other surveys from Tanzania, whichare based on straightforward questionnaires.

Figure 1:*Average duration of interviews for the LOS survey in Tanzania*



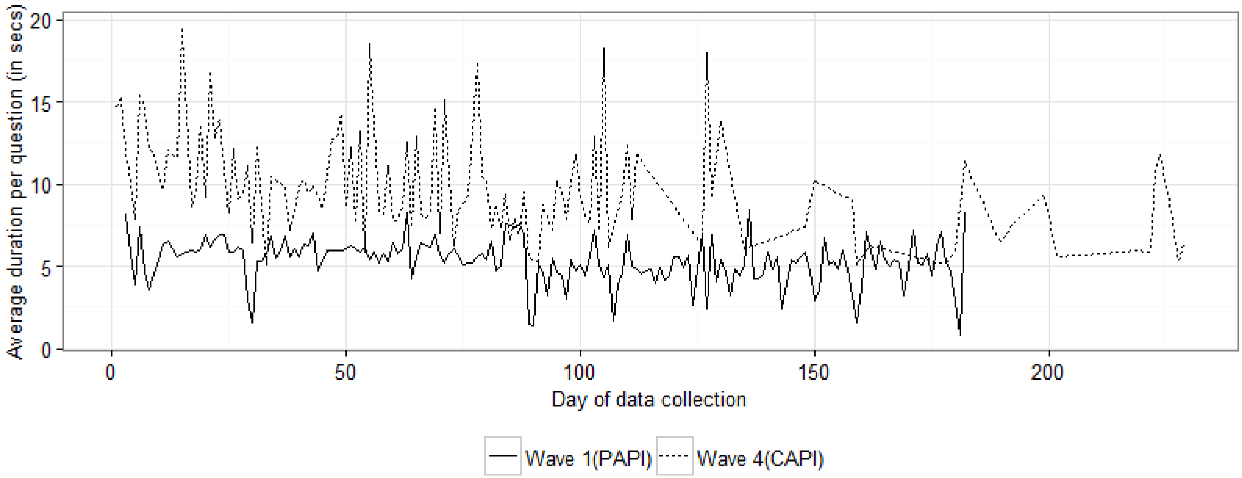
The start times and end times for Waves 1 and 4 of the NPS in Uganda were provided, and the duration of each interview was computed. Wave 4 had more questions than Wave 1, so the duration of each interview was divided by the number of questions. The duration of interviews across the two surveys were independent, ordinal, and did not follow a normal distribution.As a result, a Wilcoxon Sum Rank test was performed check if the difference was statistically signficant.

Table 3:*Comparison of interview durations across Waves 1 and 4 of the Uganda NPS*

Item	Wave 1	Wave 4
Number of questions	1090	1148
Median duration per question (in seconds)	5.83	7.67
Mean duration per question (in seconds) **	5.57	8.48

Note: ** Indicates p-value <.05 as measured using the Wilcoxon Rank Sum test.

Figure 2:*Average per question in seconds for Waves 1 and 4 of the Uganda National Panel Survey*



Note: Missing values were imputed using linear interpolation.

Figure 2 shows the time series of average interview duration by day of data collection for both waves. Almost the entire series of Wave 4 conducted using CAPI lies above Wave 1 signaling that the CAPI interviews took longer. The Wilcoxon Sum Rank test indicates that the results are statistically significant confirming that interviews conducted with CAPI were longer in duration. This finding is at odds with previous literature that finds CAPI interviews are frequently shorter in duration.This can perhaps be explained by the fact that this survey is a panel, and in later waves, there is more information to cooberate from previous waves resulting in longer interviews. Furthermore, problems were reported with the tablets during Wave 4 including “black outs” and “freezing”. These issues may have resulted in longer interview durations during the 4th Wave. Notably, these types of problems were not reported in other survey using CAPI.

4.3. Data Quality

As the PAPI and CAPI surveys were implemented in Tanzania by different institutions, no one was available to provide a comparision on the quality of data collected across the two methods. However, since the same staff at UBOS implemented all waves of the NPS, UBOS was in a excellent position to provide comparision.

According to senior statisticians inside UBOS, there was gradual improvement in the quality of data following the introduction of CAPI. First, most of the inconsistences previously found in data collected using PAPI were eliminated because they were addressed at the design stage in the programming of consistency checks. However some inconsistencies were still found, but were addressed through the regular updates to the application during data collection. Thiswould not have been possible using PAPI.

Furthermore, CAPI facilitates the linking of the different modules due to prior programming and fixing of ID codes making data from different modules collected at the same household easier to merge. For Wave 4 for example, there was no need to re-enter names of household members from the household roster and it was easier to add new members of the households. In the case of PAPI, entire household rosters had to be rewritten for different modules which resulted in mistakes, and lower quality data.

In all cases, an analysis of the raw data – before being cleaned – would be needed to assess any significant difference in data quality between CAPI and PAPI. Unfortunately, this raw data was not available.

4.4. Enumerators'opinion

A questionnaire asking the enumerators sex, age, number of surveys implemented using electronic questionnares, number of surveys implemented using PAPI, and the rating of their experience using both tools was completed by 11and 21 randomly selected enumerators in Tanzania and Uganda respectively.

Figure 3:*Enumerator experience rating of CAPI and PAPI surveys*

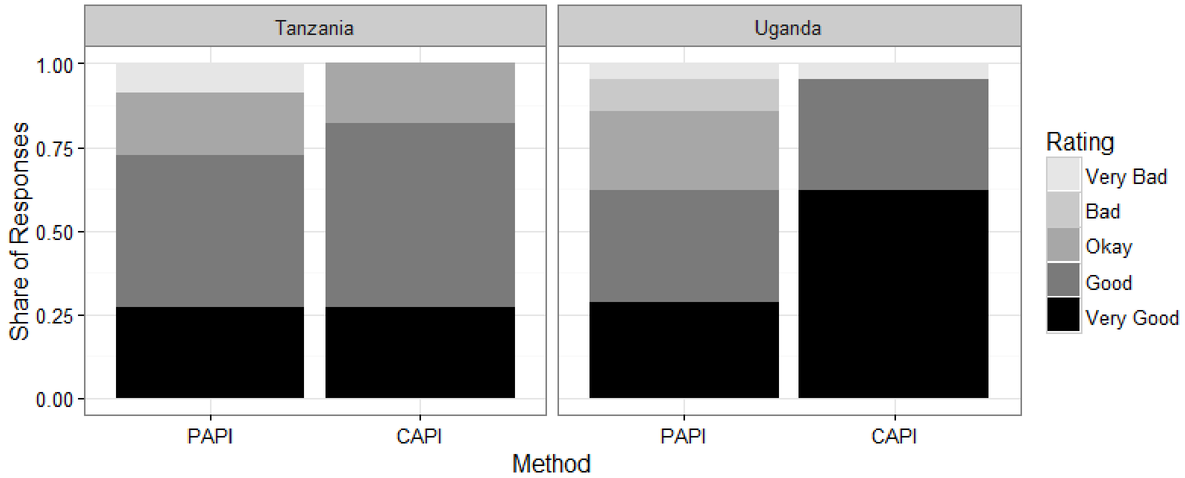


Figure 3 shows that more than 75 percent of enumerators rated their experience as "Good" or "Very Good" in both Tanzania and Uganda. Only one enumerator in Uganda described his/her experience as "Very Bad". Notably, this same respondent indicated that his/her experience with PAPI was also "Very Bad". The overwhelming positive experience with CAPI reveals an enumerator preference for electronic surveys.

4. Conclusions and Recommendations

As countries begin developing a strategy for collecting the data demanded by the SDG framework, additional pressure will be placed on NSSs with already signficant resource contraints. Accordingly, institutions must look for tools which reduce the cost of data collection without jeopardizing data quality. Experiences from small surveys conducted by research institutes indicate that CAPI could be a cost-effective alternative to PAPI due to reduced cost of printing paper questionnaires, and data cleaning costs resulting from higher quality data. Also, one study (Caeyers, et. al 2010) found that CAPI is more cost-effective for surveys with large sample sizes as the sample size increases, the fixed costs are offset by a reduction in variable costs. Some studies(CSO 2016; Zhang, et al 2012;Leisher 2014; Caeyers, et. al 2010**)**. also found a reduction in interview duration using CAPI reducing respondent burden, and that enumerators frequently prefer collecting data using electronic devices. Despite being informative, research institutes operate in a very different context than NSSs. As a result, the results form the currently available literature are of limited the applicability toNSSs.

This paper represents a first attempt to assess the advatanges and disadvantages of using CAPI vs PAPI by analyzing quantitative and qualitative information of cost, duration, data quality and enumerators' opinions from conducting large-scale surveys.Results indicate that the fixed costs of purchasing equipment for CAPI surveys is compensated by lower variable costs, andCAPI interviews are longer than PAPI interviews.The laterresult is highly questionnable and maybe due to equipment failure as well as the use of a longitudinal survey. Also, statisticians in Uganda report an increase in data quality from switching to CAPI, andenumerators in both Uganda and Tanzania show a strong perference for surveys using CAPI.

This paper, though building on quantiative and qualitative information from only two countries, confirms that CAPI could represent a low-cost effective option to collect high quality data in countries with financial and human resource constraints. The advantages of CAPI over PAPI are also expected to become larger in the coming years, because of improvements in equipment, softwareand availability of internet services in rural areas especial for developing countries. Additional evidence is however needed to substatiante these findings. It is recommended that NSSs start systematically collecting and analysing paradata on their PAPI and CAPI based surveys, in order to better assess when to allocate their scarce resources for data collection through PAPI or CAPI.

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THEMATIC SET

G40
G41

SPATIAL AND ECONOMETRIC ANALYSIS IN AGRICULTURE STATISTICS

Session Organizer
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ABSTRACT

The application of spatial models to agricultural data analyses is a novel and emerging field of applied research. Researchers in agricultural, food and environmental economics increasingly need to understand the extent of spatial variability of data and to construct models accordingly, accounting for the geographical aspects involved in economic phenomena as well as for the spatial interconnections between the units of observation, in order to increase the precision of the estimatesand of the related predictions.
Spatial statistical and econometric methods provide a toolbox for the geographical analysis of agriculturerelated topics and their potential can be already appreciated from the application to a variety or highly relevant themes such as a) the analysis of environment in relation to farmland values and the spatial extent of the environmental externalities; b) the relevance of urban-rural interactions in shaping structural change in agriculture and in modelling hierarchy and distance in the diffusion of urbanization; c) the spatial impact of soil heterogeneity and the development of precision agriculture.
The application of these methodological approaches to a growing number of topics, as well as the potential for empirical applications that follows the increasing integration of geographical information into several databases, is marking the progresses made by the discipline. Modern spatial methods allow for a variety of empirical applications including spatial models analysing the geographical scope of agro-economic and environmental spillovers and models that address several aspects of spatial heterogeneity: the spatiallyvarying behaviours of agents, the presence of multipleequilibria in space and the spatially-related nonlinearities in the predictors.
Although the natural field for the empirical application of these methods is the cross-sectional or longitudinal analysis of agricultural data across territorial administrative units, for which data are normally available in national statistics, new ways of integrating geographical information into agricultural statistics arealso emerging. In particular it is worth recalling the integration into individual level survey of the geographical coordinates related to the location of the farm or household, and the use of territorial statistics produced by the aggregation of data taken from farm-level surveys such as the Farm Accounting Data Network (FADN) of the European Union (EU).
The session will host both methodological and empirical contributions, preferably covering issues in line with the conference Agenda, thus related to the relationship between agriculture, sustainable development and the environment. Case studies related to developing countries will be especially welcome.

LIST OF PAPERS

Spatial convergence and growth in Indian agriculture: 1967-2010
T. Chatterjee | Indira Gandhi Institute of Development Research | Mumbai | India
DOI: 10.1481/icasVII.2016.g40

Inference and diagnostic in spatial linear models: an application to wheat productivity
F. De Bastiani | Universidade Federal de Pernambuco | Recife | Brazil
DOI: 10.1481/icasVII.2016.g40b

THEMATIC SET

G40 G41

Inferring the big picture from data: combining different data sources to understand the operation of the dairy sector in Malawi

C. Revoredo-Giha | Scotland's Rural College (SRUC) | Edinburgh | United Kingdom
L. Toma | Scotland's Rural College (SRUC) | Edinburgh | United Kingdom
F. Akaichi | Scotland's Rural College (SRUC) | Edinburgh | United Kingdom
DOI: 10.1481/icasVII.2016.g40c

A dynamic spatial modeling of agricultural price transmission: evidence from Niger millet market

A. Goundan | IFPRI | Dakar | Senegal
M. Tankari | IFPRI | Dakar | Senegal
DOI: 10.1481/icasVII.2016.g40d

Spatial convergence and growth in Indian agriculture: 1967-2010

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ABSTRACT

Inter-state diversity has been a perennial feature of Indian agriculture. The study probes if per capita income from agriculture has converged across states and finds evidence in favour of beta convergence. Spatial econometric techniques used indicate significant spatial dependence in agricultural growth. Infrastructure like roads, irrigation, and electricity, diversification in cropping pattern and quality of human capital are found to aid in growth. However, excessive rainfall tends to decrease growth rate in India. The spill-over across states are found to be primarily driven by roads, irrigation and rural literacy and we also find significant impact of spatial income growth providing evidence in favour of agglomeration effects. Hence, investments in human capital, physical infrastructure specially water management and incentives towards growing crops which yield higher returns will aid agriculture growth in India.

Keywords: *Agriculture, growth, regional convergence, spatial econometrics*

JEL Codes: *O13, O18, R12, R15*

1. Introduction

The level and growth of agricultural income plays an undisputed role on poverty reduction, food security and employment generation (Ravallion and Datt 1996; Warr 2003; Kumar, et al, 2011). On comparing the impacts of growth in agriculture, secondary and tertiary sector on rural poverty alleviation, Ravallion and Dutt, 1996 find the highest impact is from agricultural sector. This is not surprising given that 68 % of total population in India live in rural areas and out of the total rural working population 50 % are employed in agriculture as cultivators and agricultural labour (Source: Principal Census Abstract, 2011). Kumar, et al (2011) finds evidence of a significant negative relationship between farmer's poverty and agricultural NSDP per person through a log-linear regression model. The relationship between nutrition and agriculture has been explored in many past studies. Gulati, et al (2012) finds a significant negative relationship between agricultural performance and income measures and malnutrition index. Gillespie, et al (2012) direct us towards the direct and indirect pathways through which income from agriculture can act as a way out from the curse of malnutrition. For all these reasons, from a policy perspective it is desirable to achieve some degree of convergence in the level and growth of agricultural income across regions.

However, inter-state disparity has been an enduring feature of Indian agriculture. Over the years, states in India have shown variation among themselves across various dimensions like cropping pattern, income generated from agriculture, value of output produced and land and productivity. Studies like Bhalla and Singh (1997), Bhide et al (1998), Chand and Chauhan (1999), Mukherjee and Koruda(2003), Ghosh(2006), Somashekharan, et al (2011), Birthal, et al (2011) and Mukhopadhyay and Sarkar (2014) have documented the rise in inter-state disparity. However, they also found that along with high spatial variation, there has been temporal variation in performance as well. Growth rates of better performing states in the past like Punjab and Haryana have dropped while that of states which were poorer performers earlier like Madhya Pradesh, Gujarat have gone up.

The difference across states is potentially because of differentials in agro-ecological conditions, cropping pattern, input usage, infrastructural support etc. It is widely accepted that agricultural growth is hugely dependent on agro-climatic conditions of a region. A state with favourable agro-climatic condition might have an upper hand in agriculture production and hence have higher chance of generating more income from the same. However, advancement in technology, investments aiding growth in infrastructure and input use and other state level policies can help a state initially un-favourably endowed, to perform better than it would have been in their absence. Reducing inter-state disparity has been one of the primary developmental concerns of policy makers in India.

Inter-state disparities are typically studied using beta and sigma convergence measures in the empirical literature. Sigma convergence is said to occur if the dispersion of income or any other variable of interest across a group of economies or regions declines over time. The idea of beta convergence has been derived from the Solow growth model which predicts that because of diminishing returns to capital, growth will be strong when regions first begin to accumulate capital but will slow down as the process of capital accumulation continues and that regions will converge with one another over time as initially growing regions will slow down and regions growing later will catch up with them. Beta convergence is said to be occurring when a poor economy/region tends to grow faster than the rich one. Formally, this result is obtained if a regression of income growth on initial income level has a significant negative slope coefficient. There are two forms of beta convergence viz. unconditional or absolute wherein all regions are assumed to converge to the same steady state and conditional beta convergence wherein regions are assumed to converge to different steady states depending on the region specific characteristics.

Studies like Bhide et al (1998), Chand and Chauhan (1999), Mukherjee and Koruda (2003), Ghosh (2006), Somashekharan et al (2011) and Mukhopadhyay and Sarkar (2014) have explored convergence across Indian states on various agricultural outcomes for example on per capita agriculture net state domestic product (NSDP), per capita food grain production, land and labour productivity, and total factor productivity growth. Findings from all these studies point towards increasing divergence across states when tested through sigma convergence measure and unconditional beta convergence. Bhide et al (1998) find states converging in the shorter time interval of five years but in the longer time interval of ten years, they find that state level growth rates converge to different levels. They find that changes in rainfall and irrigation to be significant in driving growth although they do not explore factors driving convergence. Ghosh (2006) on controlling other factors driving growth finds evidence in favour of conditional beta convergence and found that human capital, physical capital and rural infrastructure drive convergence in Indian agriculture.

Internationally in the broader literature on convergence for aggregate economy, studies like Rey and Montourri (1999), Egger and Pfaffermayr (2006) among many others have documented evidence in favour of significant spatial dependence in convergence across regions. The underlying idea is that a region's growth performance is dependent on where it is located either because of its own geographical features for example topography, climatic condition etc. or because of the fact that a region shares its geographical neighbourhood with another region i.e. through spatial spill-over. These two pathways linking geography and growth have been discussed in detail in Abreu et al (2005). The first pathway wherein a region's performance is believed to be because of its own geographical features is called 'absolute geography' while the second pathway wherein a region performs in a certain way because of the fact that it is geographically located near another region is known as 'relative geography'.

The significance of role of relative spatial dependence in agriculture i.e. impact of geographical location of regions with respect to each other on land use, deforestation patterns, farming decisions and land price volatility is gaining popularity in recent years (Irwin and Bockstael, 2002, Nelson and Hellerstein, 1997 and Binkley, 1994, Florax et al, 2002 and Schmidtner, 2012).The underlying idea is that forces driving regional agricultural performance could exhibit significant geographical dependence because of agro-climatic zones being spread over multiple regions, spill-over of information and technology and trade and transportation infrastructure into neighbouring regions, institution of market, common river basins across regions etc. Because of the inter-play of these and other possible factors, regions act like interacting agents and not as isolated 'absolute' units..

Econometrically, controlling 'absolute' location in estimation implies that the impact of being located at a particular point in space is controlled by explicit region specific geographic factors and/or region dummies or through fixed effect estimation techniques. Incorporating 'relative' location in estimation technique implies that the effect of being located closer or farther away from specific regions is being controlled. This is done through spatial weight matrices which help in quantifying spatial dependence across regions by giving it a structure and the same are used in estimation techniques.[1]As will be seen later, the spatial econometric models and estimation techniques to assess the role of relative geography requires the use of panel data. Consequently, they do not permit incorporating multiple time-invariant absolute

[1]For details on absolute and relative location, refer Abreu, De Groot and Florax(2005).

geographic factors in the empirical model. Nevertheless, absolute geography is incorporated into the model as state fixed effects.

The impact of geographic factors, in particular relative geography, on convergence, to our best possible knowledge, has not been studied in the empirical literature on Indian agriculture. This study aims to fill this gap in the literature on Indian agriculture. It examines spatial convergence across states in per capita income from agriculture, through sigma and beta convergence measures, controlling for relative geography in our empirical models for beta convergence. We identify the drivers of convergence of per capita income and test if differences in the same across 17[2] major states of India have narrowed down over the period from 1967-68 to 2010-11. The methodology used for the study is drawn from Barro and Sala-I-Martin, 1992 and spatial econometrics literature (Anselin, 1988, Elhorst, 2003).The analysis has been done at the state level because of paucity of a rich data set for such a long time span at a lower level of geographical aggregation for example districts although spatial dependence is expected to be stronger at a lower level of geographical aggregation.

One of the contributions of this study is use of alternative spatial weight matrices. We try out four different spatial weight matrices viz. state-contiguity based, inverse distance based, common border based and district contiguity based in this study beyond the conventional matrices used in the literature. This helps us to compare and identify the spatial weight matrix which explains spatial dependence across states in the best possible manner. Further the use of alternative matrices adds robustness to our results.

Findings from the study give evidence in favour of significant spatial dependence across regions and highlight the importance of inputs and infrastructure in growth in agriculture. In particular, we are also able to identify the channels of spatial spill over on income convergence. Further, we find that spatial dependence is robust across different spatial weight matrix and that district based spatial weight matrix explains spatial dependence in the best possible manner among all other matrices.

The rest of the paper is organized as follows: The next section briefly describes the methodology adopted and data used in the study. The growth performance of the states from 1967-68 to 2010-11 have been compared and spatial patterns discussed in section 3. Section 4 reports the results of the analysis while section 5 provides some concluding remarks.

[2]These 17 states contribute more than 96% of the national Net Domestic Product (NDP) from agriculture. The states are Andhra Pradesh (AP), Assam, Bihar+Jharkhand, Gujarat, Haryana, Himachal Pradesh (HP), Jammu & Kashmir (JK), Karnataka, Kerala, Maharashtra, Madhya Pradesh +Chhattisgarh (MP), Orissa, Punjab, Rajasthan, Tamil Nadu (TN), Uttar Pradesh+ Uttarakhand (UP) and West Bengal (WB)

Methodology and data used

As discussed, the two commonly used approaches to test income convergence in literature are sigma and beta convergence. Sigma convergence refers to reduction in dispersion in the levels of income across regions over time. Beta convergence estimation is based on a log-linear approximation around the steady state of a Solow type growth model. In this approach, an empirical relationship between the initial income level in a region and the subsequent growth rate is estimated. A significant positive association shows high growth rate for richer economies and hence a divergent growth scenario while a significant negative relationship indicates convergence i.e. that poorer regions are growing faster than the richer ones and hence is evidence in favour of "catching up" by the poorer states. It is based on the Neoclassical growth model which predicts that regional incomes will overtime converge to their respective steady states, which depends on savings rate, population growth rate and rate of technological progress in a region, which are assumed exogenous in the model. Therefore, the exogenous rates at which all the factors of production in an economy grow, determine the long run steady rate of growth of the economy.

Studies like Quah, 1993, a, b; Barro and Sala-I-Martin, 1992Young, 2008 have acknowledged that beta convergence is not a sufficient condition for sigma convergence. Sala-I-Martin (1994) suggests that beta convergence measure is more interesting concept since it responds to questions, such as, whether poor economies (countries or regions) are predicted to grow faster than rich ones, how fast the convergence process is, whether the convergence process is conditional or unconditional and whether there is a different convergence process between groups of economies with different structures. However, Quah, 1993a suggests that sigma convergence is of greater interest since it speaks directly as to whether the distribution of income across economies is becoming more equitable. Additionally, Quah, 1993b shows that a negative relationship between growth rates and initial values do not indicate a reduction in cross-sectional variance and it is also possible to observe a diverging distribution (sigma dispersion) in presence of such negative relationship. Given that there is no general consensus on this issue, in this study, both approaches have been used to analyze convergence across states in Indian agriculture. Additionally, spatial dependence among states has also been controlled in the estimation of beta convergence.

Spatial dependence is said to occur when observations of a particular spatial unit is dependent on observations of its neighbours. It implies that there exists a relationship between what happens at different points in space. Econometrically, one of the first and most important steps towards quantifying relative spatial dependence is specifying the structure of spatial relationship among regions. Empirically, spatial dependence is quantified through spatial matrix (*W*)(Anselin, 1988, Elhorst, 2003, 2010a). '*W*' is a symmetric 'nxn' matrix where 'n' is the number of regions and the numerical values of the elements of the matrix are driven by the criteria of neighbourhood definition. *W* can be defined on the basis of context of the study. By convention, the diagonal elements are set to zero,$w_{ii}=0$. However, *W* must satisfy two basic rules of being finite and non-negative (Anselin, 1988). In the simplest case, the weights are defined on the basis of contiguity i.e. regions are assigned 'one' in the matrix if they share borders and 'zero' otherwise.

It is necessary that the relative spatial location is specified correctly in *W* so that the relation among states is appropriately controlled for in the estimation strategy. Eventually *W* will determine the extent and possibility of spatial spill over across regions which are later controlled through the spatial models. Stetzer (1982) shows that the specification of weight is important for parameter estimation, especially when sample sizes are small and the data is auto correlated. Griffith and Lagona (1998) show that incorrectly specified weight matrix can lead to a loss of efficiency of the estimators. Monte-Carlo study by Stakhovych and Bijmolt (2009) conclude that a weights matrix selection procedure that is based on 'goodness-of-fit' criteria increases the probability of finding the true specification. In case the spatial interaction model is estimated based on different spatial weights matrices and the log-likelihood function value of every model is estimated, one may select the spatial weights matrix with the highest log-likelihood function value (Elhorst, 2010b). This method of selecting spatial weight matrices has been criticized by Harris & Kravtsova (2009). They claim that it would only find the best among the competing spatial weight matrices and will not be able to identify the true spatial relationship unless one of the competing matrices is actually the true spatial relationship. However, Elhorst (2010B) argues that, 'the Monte Carlo results found by Stakhovych and Bijmolt (2009) partly refute this critique. Although there is a serious probability of selecting the wrong spatial weights matrix if spatial dependence is weak, the consequences of this poor choice are limited because the coefficient estimates are quite close to the true ones. Conversely, although the wrong choice of a spatial weights matrix can distort the coefficient estimates severely, the probability that this really happens is small if spatial dependence is strong.'(Pp: 17, Elhorst; 2010 b). Elhorst (2010b) additionally stress on the importance of correct specification of spatial weight matrices and suggests that researcher must correctly specify it and check for robustness.

In this study, we have used and compared four spatial weight matrices namely, state-contiguity based, inverse-distance based, shared border based and district-contiguity based matrices. In case of state-contiguity based matrices, weight 'one' implies that states are contiguous to one another and 'zero' implies that they are not. In case of inverse-distance based matrix, inverse of the Euclidean distance between the geographical centroid of two states is used as the weight. This weighing scheme ensures that higher weight is given to states which are closer to each other and vice-versa. In case of length of border based spatial weight scheme, weights are assigned according to the length of the border shared between two states. The idea behind using length of shared borders between states is that spatial spill-over is expected to be proportional to the possibility of connectivity between two states which is more for states with higher length of shared borders. For example if a state shares its borders with two other states, then through this spatial weight matrix, higher weight is given to the state with which it shares longer border compared to the second state with which it shares a smaller border length.

In case of contiguous-district based spatial scheme, weight is assigned according to the total number of contiguous districts between two states. The idea behind using districts based spatial weight matrix is again to control spatial effects in a manner that they are proportional to the possibility of spatial spill-over. States in India are spread across diverse agro-ecological zones and hence controlling state level contiguity does not guarantee that spatial dependence is completely incorporated. Quite often districts within a state are more homogeneous to contiguous districts in the neighbouring states than non-contiguous districts of the same state. For example eastern and western parts of the state of Uttar Pradesh fall under different agro-ecological zone, while eastern part is similar to eastern state of Bihar, western part is similar to northern state of Himachal Pradesh. Hence, giving a uniform weight of 'one' to both Bihar and Himachal Pradesh will not correctly quantify the spatial dependence. This district based matrix will give a higher weight to states with which Uttar Pradesh has more number of contiguous districts. Although this does not ensure that spatial dependence is completely controlled, it is expected to be an improvement over basic state level contiguity. All the matrices have been row standardized.[3]

[3]Lesage and Pace (2009)

Spatial dependence is typically detected using Global and local Moran's I-tests. If these tests reject the null of absence of spatial dependence, then spatial modelling should be used to explain the behaviour of the data. Global Moran's I-test statistics for the presence of global spatial dependence among the spatial units is given by:

$$I = \frac{n}{\sum_i \sum_j w_{ij}} \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij}(x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^{n}(x_i - \bar{x})^2} \quad (1)$$

Where n is the number of regions, w_{ij} is the element of the weight matrix W, x_i is the value of the variable at region i and $\bar{x}$ is the cross-sectional mean of x. A significant correlation statistic indicates presence of spatial dependence. However, these global tests overlook the local spatial dependence. It is possible that for a given year global spatial detection tests indicate no spatial relation while local spatial tests indicate strong dependence across some regions in the total set of regions. Hence, to have a better idea on local spatial dependence, local Moran's I-tests are used. For each location, these values compute its similarity with its neighbours and test whether the similarity is statistically significant.

For each location, local Moran's I-test statistic can be computed and this is given by

$$I_i = \frac{(x_i - \bar{x}) \sum_j w_{ij}(x_j - \bar{x})}{\sum_i (x_i - \bar{x})^2 / n} \quad (2)$$

Under the null hypothesis of no spatial dependence, both the global and Local Moran's I-test statistic asymptotically follow a standard normal distribution.

Once, spatial dependence is detected, relationships across spatial units are incorporated in the estimation strategy. There can be three types of spatial relation: (1) spatial dependence in dependent variable i.e. spatial lag model, (2) spatial dependence in error i.e. spatial error model and (3) spatial dependence in explanatory variables i.e. spatial Durbin model. A full model in a panel framework, once all types of spatial interactions are incorporated will be as follows:

$$Y_{i,t} = \eta_i + \rho Y^*_{i,t} + \alpha + X_{i,t}\beta + X^*_{i,t}\theta + u_{i,t}, \quad (3)$$

$$u_{i,t} = \lambda u^*_{i,t} + \varepsilon_{i,t}$$

where the variable $Y^* = WY$ captures the spatial dependence among the dependent variables, $X^* = WX$ the spatial effects among the independent variables, and $u^* = Wu$ the spatial effects among the disturbance terms of the different units, $\boldsymbol{\rho}$ is called the spatial autoregressive coefficient, $\boldsymbol{\lambda}$, the spatial autocorrelation coefficient, while $\boldsymbol{\theta}$, just as $\boldsymbol{\beta}$, represents a $K \times 1$

vector of fixed but unknown parameters. W is a nonnegative $N \times N$ spatial weights matrix of known constants representing the spatial arrangement of the units in the sample.

However, if all three forms of spatial interaction effects are estimated simultaneously, then it is not possible to distinguish and identify one from another (Lee and Yu, 2010). According to Lesage and Pace (2009), the cost of ignoring spatial dependence in the dependent variable and/or in the independent variables is relatively high because of omitted variable bias and the estimator of the coefficients for the remaining variables is biased and inconsistent. In contrast, ignoring significant spatial dependence in the disturbances will only cause a loss of efficiency. Elhorst (2012) suggests that the best option to estimate a spatial model is to exclude the spatially auto correlated error term and to consider a model with spatial interaction effects in dependent and explanatory variables (Spatial Durbin model). Both Anselin (1988) and Lesage (2009) show that least squares estimators, if used in case of models with spatially lagged dependent variables lead to biased and inconsistent estimates. They recommend the use of maximum likelihood estimation techniques to estimate the coefficients of the model. In panel data framework, Lee and Yu (2010) show that the maximum likelihood estimator of the spatial lag and of the spatial error model with spatial fixed effects, as set out in Elhorst (2003, 2010), will yield inconsistent estimates of all parameters of the spatial lag and of the spatial error model with spatial and time-period fixed effects. To correct this, they propose a simple bias correction procedure based on the parameter estimates of the uncorrected approach. Panel data suffers from initial values problem and this is controlled through dynamic panel models where the lagged value of the dependent variable is also used as an additional explanatory variable. This corrects the autocorrelation problem in panel data models (Wooldridge (2005), Pfaffermayr (2012)).

Hence, in this study, spatial dynamic conditional beta convergence and sigma convergence across states in income from agriculture has been explored for 17[4] states in India from 1967-68 to 2010-11. The only consistent state level data available on income from agriculture for states in India from 1967 onwards is net state domestic product (NSDP) from agriculture. Our primary variable of interest is annual growth in NSDP per rural population. Data on NSDP was collected from EPW Research Foundation and rural population from CENSUS. The

[4]The 17 states are Andhra Pradesh (AP), Assam, Bihar+Jharkhand, Gujarat, Haryana, Himachal Pradesh (HP), Jammu & Kashmir (JK), Karnataka, Kerala, Maharashtra, Madhya Pradesh +Chhattisgarh (MP), Orissa, Punjab, Rajasthan, Tamil Nadu (TN), Uttar Pradesh+ Uttarakhand (UP) and West Bengal (WB)

newly formed states of Jharkhand, Chhattisgarh and Uttaranchal have been clubbed together with their parent states of Bihar, Madhya Pradesh and Uttar Pradesh respectively to maintain uniformity in the panel data set.

For purpose of analysis, the time period from 1967-68 to 2010-11 has been divided into following three sub phases on the basis of changing policies in agriculture sector. This aids in better understanding of the changing pattern of growth of agricultural income in India.

- 1st sub-phase : 1967-1977: the period of green revolution
- 2nd sub-phase: 1978-1989: period of falling public investment in agriculture
- 3rd sub-phase: 1990-2010: period of economic reforms

Figure 1plots the shares of public investments i.e. share of gross fixed capital formation (agriculture) in GDP from agriculture (both at constant 2004-05 prices). Investments were higher in the latter half of 1960s (sub phase 1 in our study) compared to the beginning of 1980s. The 1980s and 1990s are characterized with low levels of public investment in agriculture. One can however see a rising trend in late 1990s and early 2000s[5].

[Figure 1]

Following other studies on Indian agriculture (like Fan et al, 2000, Binswanger, 1993), we have controlled for state level inputs, infrastructure, human capital, and rainfall, besides spatial variables while testing for conditional beta convergence .The conditional convergence equation using a spatial dynamic panel fixed effects model in a maximum likelihood framework used for the analysis can be written as:

$$\begin{aligned} growth_{it} &= ln(y_{i,t}) - ln(y_{i,t-1}) \\ &= \alpha_i + \beta\, ln(y_{i,t-1}) \\ &+ \delta growth_{i,t-1} + \gamma_1 inputs_{it} \\ &+ \gamma_2 infrastructure\ and\ other\ state\ level\ characteristics_{it} \\ &+ \gamma_3 human\ capital_{i,t} + \gamma_4 rainfall_{i,t} + \gamma_5 spatial\ variables_{i,t} + \epsilon_{i,t} \qquad (4) \end{aligned}$$

Here, coefficient of β gives evidence in favour or against convergence across states α_i is the state specific effects and the impact of the other factors on growth can be obtained from coefficients$\gamma_1 to\ \gamma_5$.

[5]The rise in share of gross fixed capital in the 3rd phase has been controlled in the study through year dummies as number of years post rise in investment was very low to accommodate a separate phase and perform a robust statistical analysis.

Among inputs we control for land, tractors, fertilizer and livestock as inputs in agriculture. The annual data on land use is available in "Land use statistics, Department of economics and statistics, ministry of agriculture". Data for number of tractors was obtained from quinquennial livestock Census which is conducted by Department of animal husbandry, dairying and fishing, Government of India. The data has been interpolated using compound growth rate to get a panel data set on tractors used from these quinquennial surveys. Fertilizer use has been defined as total fertilizer (Nitrogen+Phophate+Potassium) consumed in kilograms per unit total cropped area. The data for fertilizer consumed is available state-wise and annually from "Fertilizer Statistics". Livestock has been defined as number of livestock per unit total area of the state. Data for number of livestock in total and also number of cattle, buffaloes, goats and sheep was collected from quinquennial livestock census conducted by conducted by Department of animal husbandry, dairying and fishing, Government of India. The data from these quinquennial surveys has been interpolated using compound growth rate to get a panel data set on total livestock and its types.

Infrastructure and other state level characteristics have been controlled through road quality, irrigation, electricity, state expenditure on agriculture and cropping patterns. Road quality is defined as a ratio of total surfaced road length to total road length (both in kms.) in the state. The state-wise annual data on total road length and surfaced road length was collected from "Basic Road Statistics" and "Statistical abstracts of India". Electricity is defined as percentage of villages electrified. Annual state-wise data for the same was obtained from EPRWF database. A dummy variable with value equal to 'one' when less than 100 per cent villages have been electrified and 'zero' if 100 per cent villages are electrified. Irrigation is defined as share of gross area irrigated in total cropped area. State-wise annual data on gross area irrigated and total cropped area from "Land use statistics, Department of Economics and Statistics, Ministry of Agriculture". State expenditure on agriculture is defined as state expenditure in agriculture per unit sq. km. area.[6]. State-wise annual data on expenditure was collected from "Finances of state government" published by RBI. Cropping pattern is defined as share of area under different crops. State-wise annual data was collected from "Area, Yield, Production of Principle Crops" by Ministry of Agriculture. Share of area under

[6]Expenditure on agriculture and allied activities include expenditure on crop husbandry, soil and water conservation, animal husbandry, dairy development, fisheries, forestry and wild life, plantations, food storage and warehousing, agriculture research and development, food and nutrition, community development and other agricultural programmes. Both revenue and capital expenditure have been included. This data is available from 1972.

different groups of crops namely cereals, pulses, fibre, oilseeds, sugar and all other crops have been clubbed together as rest.

As in other studies on Indian agriculture (Fan et al, 2000), rural literacy rate has been used as a proxy for quality of human capital. This is defined as percentage of literate rural persons in total rural population. Data on rural literacy rate was collected from CENSUS (various years). The years between two consecutive censuses were interpolated using assuming constant growth rates.

Rainfall has been controlled in such a manner that the impact of different levels of deviation of actual rainfall from the normal levels can be differentiated. Three rain dummies have been defined on the basis of absolute percentage deviation of actual average annual rainfall from normal average annual rainfall. The dummies are based on rain dummy_1 =‘one’ if percentage absolute deviation of rainfall from normal is between 5 and 10 per cent otherwise zero. Rain dummy_2 =‘one’ if percentage absolute deviation of rainfall from normal is between 10 and 20 per cent otherwise zero and rain dummy_3 =‘one’ if percentage deviation of actual average annual rainfall is between 20 and 100 otherwise zero. Average annual data on rainfall was collected from various publications of Statistical abstract of India.

Spatially weighted variables have been constructed by weighing the neighbouring states using the different spatial weight matrices described earlier; i.e. these newly created variables are the weighted means of observations of neighbouring states where the weights are used according to the spatial weight criteria in the models.

Growth performance across states

As a prelude to examining convergence in agricultural income across states, we first look at the growth performance across states. Figure 2 and Table 1, which give the levels and growth of per capita NSDP at 2004-05 constant prices, brings out some interesting features on the regional pattern of agricultural growth in India. Taking the entire period, the all India annual compound growth rate of NSDP from agriculture at 2004-05 constant prices was 2.29 per cent. During this entire period, the highest growth rate was recorded by northern state of Punjab (4.78 per cent) while the lowest growing state was eastern state of Assam (0.50 per cent).The other states with high growth in the entire time period were Haryana in the north, Maharashtra and Gujarat in the west and West Bengal in the east. Apart for Assam, the states with low growth were Andhra Pradesh in the south and Uttar Pradesh in central India, JK and

HP in the north. The coefficient of variation of growth rates across states in the entire time period was 39.26 per cent.

There were important changes in the regional growth pattern in the sub-phases. In sub-phase 1 (green revolution phase), growth rate of income from agriculture in India was 5.42 per cent. This period recorded the highest growth rate among all the sub-phases. However, this phase also recorded a high coefficient of variation across states (51.75 per cent). Growth rate was highest for Punjab (13.77 per cent) in north while it was lowest for Andhra Pradesh (0.32 per cent) in south. The other states with a high growth rate in this phase were Haryana in the north-west, Gujarat in the west and Bihar and West Bengal in the east. And the states with low growth rates were Andhra Pradesh and Tamil Nadu in the south, Assam in the east, Uttar Pradesh and Madhya Pradesh in central India.

In the 2nd sub-phase, growth rate of agricultural income at the national level fell to 0.69 per cent. This was the phase with the lowest growth rates and highest disparity measured in terms of coefficient of variation (78 per cent). States like Bihar (-1.34 per cent), Jammu and Kashmir (-0.85 per cent) and Tamil Nadu (-0.83 per cent) recorded a negative growth rate in this sub-phase. Growth rate of Orissa (4.62 per cent) was the highest while Bihar grew at the lowest rate. The states which performed better compared to the rest of the states were Orissa and West Bengal in east, Madhya Pradesh in central India, Punjab and Himachal Pradesh in the north while the states which performed the worst during the 1980s were Bihar in the east, Jammu and Kashmir in north, Tamil Nadu in south, Rajasthan and Gujarat in west.

The all India growth rate in the third sub-phase was 1.46 per cent and the coefficient of variation fell to 49.87 per cent. Maharashtra, Gujarat, Kerala, Andhra and TN grew at the highest rates while the states like Madhya Pradesh, Uttar Pradesh, Himachal Pradesh, Assam and Orissa grew at the lowest rate. Clearly, western and southern states were the best performers in this phase and eastern states performed the worst and had negative growth rates.

Hence, there is both evidence of rising spatial disparity across states and also of catching up in the sense that some of the states like Gujarat and Maharashtra in the west, which were comparatively poorly performing in earlier phases were recovering in the later sub-phases. This catching up process will be empirically tested using beta convergence estimation in the next section.

Table 1- growth performance across Indian states

Figure 2: Levels and growth of NSDP agriculture per rural person

Figure 3 plots the coefficient of variation (CV) of levels of per capita NSDP from agriculture and key infrastructure like roads, electricity, irrigation and state expenditure on agriculture across states from 1967 to 2010 to have a better idea of pattern of inter-state disparity. All the key infrastructure and per capita income show a decline in CV in the 1970s (sub-phase 1). In sub-phase 2, the decline continues except for income and power. In sub-phase 3 however, CV increases for all except expenditure on agriculture and power consumption.

[Figure 3]

Results

Spatial dependence across states

The empirical analysis begins with testing for spatial dependence through local and global Moran's I-tests described earlier. These tests are carried out for all the four alternative spatial weight matrices defined on the basis of state-contiguity based matrix, inverse-distance between two states, district-contiguous based matrix and length of borders shared between two states.

The results of global Moran's I computed have been given in Table 2 which shows that it is significant for all the weight structures from 1970. Moran's I result for significant years shows positive autocorrelation i.e. regions with similar levels of per-capita income were also geographically closer. The value of the Moran's I statistic can be interpreted as the level of spatial dependence[7]. Moran's I values for inverse distance based spatial weight matrices are the lowest compared to all other spatial weight matrices.

Table 2: Results of global Moran's test

The plot of global Moran's I in Figure 4 shows that spatial dependence has declined from 1970 to 1990 but there is a turn-around since late 1990s after which there seems to be a positive trend in spatial dependence. But it was particularly high in early 70s and 90s.

[Figure 4]

While global Moran's I detects the aggregate spatial pattern, local Moran test (Anselin, 1995) detects local dependence and helps locate areas of strong spatial linkages. Local Moran's I

[7] Rey and Montouri (1999).

for 1966 and 2010 are given in Table 3[8]. States have significant local spatial dependence in 1966 when there was no significant global spatial dependence.

Table 3-Results of Local Moran's test

States which had significant local spatial dependence for almost all the years were Northern states like Punjab, Haryana, Himachal Pradesh and Uttar Pradesh and eastern states like Bihar, West Bengal, Orissa, Assam , western states like Madhya Pradesh, Maharashtra, Rajasthan and Gujarat and Andhra Pradesh in south.

Sigma convergence

Figure 5 which plots the standard deviation of log of NSDP per rural person from agriculture for the entire time shows evidence in favour of sigma convergence in phase 1 as it can be seen that standard deviation of income across states follows a declining trend only in phase 1. However, we find evidence against sigma convergence in the later phases.

[Figure 5]

Figure 6 plots the global Moran's I statistics and standard deviation of log of per capita income over time for the full and different sub-periods. These plots point to a negative relationship between the two. Indeed, a simple correlation[9] between standard deviation of log of income and global Moran's I statistic for all the spatial weight criteria over the years confirms this. The correlation coefficient of Global Moran's I using contiguity, inverse distance, border and district based spatial weight matrix are -0.65, -0.61,-0.61 and -0.67 respectively and they are statistically significant at less than 1 percent level. This implies that a greater spatial dependence across states can help in reducing the inter-state disparity in per capita income. A similar significant correlation of -0.80, -0.79, -0.86 and -0.85 is seen for contiguity, inverse distance, border and district based spatial weight matrix respectively at less than 1 percent level in the first sub-phase also though in the second and third sub-phases, the correlation coefficient is not significant. This inverse relation between sigma convergence measure and spatial dependence possibly points towards the conceivable role of spatial dependence as a channel in reducing inter-state disparity. The results of beta convergence discussed below bring out this relationship more explicitly.

[Figure 6]

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[8]Results of local Moran's I for other years have not been shown in the table owing to paucity of space. They can be shared on request

[9]Rey and Montouri (1999) also find a statistically significant positive correlation between standard deviation and Moran's I statistic of per capita income of US.

Beta convergence

Table 4 gives the results of conditional beta convergence models. Annual growth rate of per capita income (NSDP) from agriculture is the dependent variable and explanatory variables are per capita income and other state specific characteristics discussed earlier. We estimate non-spatial model in Model 1 of Table 4. Hausman test confirms that fixed effects model performs better than random effects model. Therefore, we find that absolute geography which has been controlled through state fixed effects significantly drives agricultural growth convergence. In models 2-5, we estimate spatial models controlling for state fixed effects. Lagged per capita income (β) is significant and negative in all the models, indicating statistically significant evidence in favour of beta convergence within Indian states over the entire period 1967-68 to 2010-11.

Like other studies on convergence in Indian agriculture, our results show evidence in favour of conditional beta convergence but no such evidence in favour of sigma convergence. Ambivalence in results from beta and sigma convergence is not new in this literature. The concerns in empirical literature regarding these measures of convergence are discussed in Azariadis and Drazen (1990), Quah (1993 b), Durlauf and Quah (1999), and Islam (2003), Young et al, 2008. A negative beta coefficient, implying convergence, is consistent with a rising variance which indicates a lack of sigma convergence. Additionally, in presence of multiple equilibriums this approach tends to reject the null hypothesis of no convergence too often (Bernard and Durlauf, 1996). Further studies like Quah, 1993, a, b; Barro and Sala-I-Martin, 1992 Young, 2008 have acknowledged that beta convergence is not a sufficient condition for sigma convergence. Even existing studies on convergence in Indian agriculture like Ghosh (2006), Birthal, et al (2011) find no evidence of convergence when measured through sigma convergence but do find evidence in favour of robust conditional beta convergence.

One plausible reason driving this lack of unanimity can be that these two measures explore different aspects. While sigma convergence measures whether the distribution of the levels of variable of interest is becoming more equitable, beta convergence measures ask a very different question. Conditional beta convergence explores whether after controlling for region specific characteristics, growth rates are inversely correlated to levels in variable of interest. Young, et al (2008) show in their analysis that it is possible that regions are beta converging towards one another yet random shocks are pushing them away from each other leading to unambiguous results from beta and sigma measures. Another plausible explanation can be possibility of club convergence among regions. That is if states are not all converging to unique steady states after controlling for state specific characteristics, are they converging to multiple equilibriums.

Turning to the role of spatial dependence, if any, on the basis of log-likelihood, AIC and BIC, we find that spatial models (models 2 – 5) perform better than the non-spatial model (model 1) for the entire period (1967-68 to 2010-11) which confirms the presence of significant spatial dependence in income growth in Indian agriculture. As literature does not provide much guidance on the spatial weight criteria, the spatial models have been compared on the basis of log-likelihood, AIC and BIC and the contiguous districts based spatial matrix (model 5) performs the best among all other models. This confirms that spatial dependence across states in India is controlled better through contiguous district based spatial weight matrices where higher weight is given to states with more number of contiguous districts. There is a lot of diversity within the states in India and hence often one can find more homogeneity between contiguous districts of neighbouring states compared to non-contiguous districts on the same state. The contiguous-district based spatial weight matrix controls for this spatial homogeneity among neighbouring states. The results from the other spatial weight matrices (models 2-4) give evidence of significant spatial dependence thereby adding robustness to our results.

Results show that channels of spatial spill-over in income from Indian agriculture has been income growth, rural literacy, gross area irrigated and road quality. Spatial income growth is positive and significant for all the models implying that higher growth of a state has positive spill-over effect over its neighbours. In case of contiguity based matrix (model 2), additionally spatial literacy has a positive coefficient implying that states with higher literacy rate have a positive impact over income growth of their neighbours. In case of inverse distance based spatial matrix (model 3), it can be seen that spatial impact is through road quality i.e. higher road quality accelerates growth in neighbouring regions through better connectivity/networking possibilities. Using length of shared borders between states (model 4) and number of contiguous districts (model 5) as weighing criteria, rural literacy, gross area irrigated and road quality have a positive and significant spatial on growth in income among states. Infrastructure therefore has significant spatial dependence across states and aids in growth in neighbouring states.

The findings are in line with studies on other countries like Tong (2012) found significant spatial spill-over through road infrastructure. Similarly there are a number of studies like Patton and McErlean, 2005 on land market, Schmidtner et al (2011) for farming decisions in Germany, which give evidence of significant spatial lag dependence which has often been interpreted as an agglomeration effect. Studies like Alston (2002) discuss knowledge based channels in detail and conclude that it as a primary source of spatial spill-over in agriculture. We believe that rural literacy acts as a channel of spatial spill over through diffusion of knowledge externalities from neighbouring states. With evidence in favour of increasing inter-state migration (Lusome and Bhagat, 2006) it is conceivable that diffusion of knowledge gets accentuated through migration. Further, demonstration effects can also be a possible channel through which literacy acts as significant channel of spatial spill over. It is widely accepted that literacy increases the prospect of adoption of newer technology, farming techniques thereby further accentuating agriculture growth and income at the state level. With higher inter-state mobility and plausible demonstration effects we believe that literacy acts as an important channel of spatial spill over.

With regard to spatial irrigation, to the best of our knowledge we could not find evidence in existing literature on the plausible reasons for its significant. One possible reason for spatial irrigation to have spill-over effect could be that when neighbouring states receive irrigation investments, especially large surface irrigation projects, its impact does not suddenly stop at the state boundaries. In fact quite often such projects tend to cover several states across multiple agro ecological zones thereby potentially leading to a spatial spill-over across states.

Among inputs, tractors, land and livestock play a statistically significant impact in all the models[10]. Both tractor and land ownership have a positive impact on growth indicating the importance of asset ownership in growth of income. Among livestock, only buffaloes and sheep play a significant role in growth while other forms of livestock remained insignificant and hence were dropped from the analysis. Interestingly, buffaloes have a negative impact on growth in spatial models (insignificant in non-spatial model) while sheep have a positive impact. Livestock not only acts as an input in agriculture production process but also acts as a source of income in the form of wool, meat, milk etc. Although the reason driving the negative relation between buffaloes and growth and insignificant relation between cattle and

[10]Fertilizer consumed per unit of cropped area is not significant in any of the models and hence has been dropped from the analysis.

goats and growth is not very clear, it is possible that these results point towards a non-optimal mix of different types of livestock dominated by bovines[11].

Results show that infrastructural support in a state has statistically significant impact on its income growth. Key infrastructure like gross area irrigated, villages electrified, road quality and state expenditure on agriculture are significant and positive drivers of growth of income in all the models. Results suggest that higher the infrastructural support in the state more is the growth in income from agriculture.

Cropping pattern has been controlled through share of total cropped area under different groups of crops like cereals, pulses, sugar, oil seeds, fibre etc. Share of area under fibre, sugar and oil-seeds are all significant and positively influence the growth of income from agriculture[12]. In India, cropping pattern has shown structural rigidity till 1980s when food grains were the dominant crop in India. However, post 1980s, there has been an increase in area under other crop like oil-seeds at the cost of area under pulses and coarse cereals (Bhalla and Singh, 1997). A change in cropping pattern is based on a number of factors like agro-ecological conditions, profitability of crops, availability of technology and infrastructure etc. These results in favour of significant impact of fibre, sugar and oil-seeds support findings from studies like Joshi, Birthal and Minot (2006) which concludes that diversification has been a dominant source of growth since the 1980s in Indian agriculture. The impact of diversification becomes clearer in the next sub-section where we identify the differential impact across the sub-phases.

Human capital has been controlled through rural literacy rate and as expected it has a positive impact on growth of income from agriculture. Deviation of actual rainfall from its normal level greater than 10 per cent significantly reduces growth of income from agriculture in all the models and the impact on income growth is proportional to the level of deviation of actual rainfall from normal.

Table 4- Results of beta convergence

Beta convergence: sub-phases

Comparison of growth process across sub-phases has been done using district based spatial weight matrices in Table 5 since district based spatial weight matrix performed the best

[11] At the all India level, from 1966 to 2007, on an average bovines account for approximately 65% of all livestock, and within bovines, animals in milk constitute only approximately 35%.

[12]

across all other spatial weight criteria (Table 4). The results (Table 5) on spatial beta convergence for the sub-phases indicate significant conditional convergence in all the sub-phases.

In the first sub-phase i.e. models 1 and 2, land ownership is the most important income generating input. Fertilizer is significant only if year effects are not controlled (model 1). Among infrastructure, density of surfaced roads is the key growth driving factor in first sub-phase. This phase of green revolution witnessed enormous expansion of area under food-grains especially wheat at the cost of area under other crops and results indicate that share of irrigated area under cereals had a positive impact on income growth. However, area covered under fibre and sugar had negative impact on growth. Spatial rural literacy was a significant driver of growth in this phase. Income growth also had significant spatial dependence as growth in this phase owing to the selective introduction of the new technology was concentrated in certain geographically contiguous states. This phase also witnessed severe to moderate droughts which get reflected in the negative year effects (1968, 1969, 1976).

In the second sub-phase (model 3), growth was dominated by inputs namely land, tractors and livestock. Among infrastructure, density of surfaced roads again had a significant impact on growth like sub-phase one. Area under cereals like sub-phase one, again led to positive growth. Additionally, area under fibre and oil-seeds also contributed positively to growth. This again validates the findings from studies like Bhalla and Singh (1997) that unprecedented changes took place in the 1980s in cropping pattern and area under other crops expanded at the cost of area under pulses and coarse cereals. Although area under wheat and rice continued to increase in this phase and hence share of area under cereals continue to be a significant driver of growth but one case see that area under other crops were slowly gaining importance in explaining growth of income from agriculture. Excessive rainfall had a negative impact on growth. Spatial growth and irrigation were significant drivers of growth in this phase.

In the third sub-phase (model 4), again land ownership significantly affected income growth. Irrigation contributed in this sub-phase. However, here cereals no longer were a significant driver of growth. Rather in this phase, growth was because of fibre crops. Again this validates the pattern which emerged in studies like Bhalla and Singh (1997) and Joshi, Birthal and Minot (2006) that impact of diversification was highest in the 1990s compared to earlier sub-phases. Literacy was a significant driver of growth in this phase. Spatial spill-over in this phase was because of irrigation and income growth of neighbouring states.

Interesting pattern which comes up from the comparison across sub-phases is the consistent spatial dependence of growth of income and significance of key infrastructure like roads, rural literacy and irrigation across all the sub-phases. Reduction in impact of cropped area under cereals over phases and gaining significance of area under other crops provide evidence in favour of higher returns from diversification. Primary driver of growth in the first phase was growth in area under cereals and land ownership while the second phase saw the emergence of impact of mechanization of agriculture and diversification and third phase continued to witness the impact of diversification. Among the spatial factors, rural literacy and irrigation have almost consistently had a significant impact on growth of per capita income in agriculture.

Table 5–Results of beta convergence for sub-phases

Conclusion

Inter-state disparity has been an enduring feature of Indian agriculture possibly due to differences across states in agro-ecological conditions, cropping pattern, input usage, infrastructural support etc. States like Punjab and Haryana in the north have always had a higher level of per capita income while states like Bihar and Uttar Pradesh have been always been poor performers. This persistent inter-state disparity provides an empirical basis to analyse the convergence behaviour of per capita income from agriculture. Studies like Bhide et al (1998) and Ghosh (2006) have explored convergence across states in India using sigma and beta convergence measures and find that state specific factors like human capital, physical capital and rural infrastructure play an important role in driving convergence across states.

The broader literature on convergence for aggregate economy has documented the role of geography in the growth convergence process. Two broad pathways through which geography plays a role on growth of a region are absolute geography, i.e., through geographic factors specific to a region and relative geography, i.e., the impact of a region on its neighbour through spatial spill-over.The role of relative geography in particular, has not attracted much attention in the empirical literature on convergence in Indian agriculture, though absolute geography has been controlled in many of the past studies .

This paper tries to fill this gap in literature and explores the role of relative geography on convergence in terms of income per rural person across states in India between 1967 and 2010. We follow the literature on convergence and use sigma and beta convergence measures which are the two most commonly used approaches for analysing convergence and further incorporate spatial dependence in our estimation strategy. The relative location of states was incorporated econometrically using spatial weight matrices. One of the contributions of the study is comparing different spatial weight matrices and identifying the one which explains spatial dependence across states in the best possible manner. Stetzer (1982), Stakhovych and Bijmolt (2009) Elhorst (2010 b) document that it is of extreme importance that spatial weight matrices are correctly specified as this matrix will eventually define and quantify the spatial dependence across regions. For that, in addition to the conventional state-contiguous, inverse-distance based matrices, district-contiguous and length of state borders shared have also been used in the analysis. These matrices help to differentiate the impact of two contiguous neighbours as the one with higher number of contiguous districts or length of border shared gets a higher weight in the matrix. This weighing scheme ensures that the incorporated spatial effects are proportional to the possibility of spatial spill-over.

Global and local Moran's I-tests using these weights found statistically significant spatial dependence across states. Therefore, ignoring relative spatial location in convergence analysis would lead to model misspecification and hence erroneous conclusions.

For spatial convergence analysis, spatially lagged dependent and independent variables were computed using spatial weight matrices. A dynamic fixed effect model was used to correct the autocorrelation problem in panel data. We find that among all spatial weight matrices district based spatial weight matrix explains spatial dependence across states in the best manner. This is potentially because states are large geographical units and therefore spatial structure at the state level masks the heterogeneity existing within the states. For example districts in the eastern Uttar Pradesh are similar to one another in terms of both agro-climatic conditions and performance to its neighbouring districts in Bihar rather than districts in west Uttar Pradesh which are in turn more similar to those of Himachal Pradesh. The district based spatial weight matrix we use incorporates this heterogeneity within states and homogeneity across states.

Like past studies on Indian agriculture which have used sigma convergence measures, we do not find any evidence in favour of sigma convergence, rather we find that disparity across states have increased over the years. However, on the same lines as findings from Ghosh (2006) we too find evidence in favour of conditional beta convergence both in the entire time period and the sub-phases. We find that irrespective of the criteria used for spatial weight matrices, there is consistent significant spatial dependence across states for all the three sub-phases and entire time period. Further, we find that the significant channels of spatial spill over across states are rural literacy and infrastructure like roads and irrigation. Other state specific factors which significantly drove growth in the entire time period were input usage, physical infrastructure and cropping pattern. We find that there has been a reduction in impact of cropped area under cereals over the three sub-phases and increasing significance of area under other crops provide evidence in favour of higher returns from diversification. Primary drivers of growth in the first phase were growth in area under cereals and land ownership while the second phase saw the emergence of impact of mechanization of agriculture and diversification and third phase continued to witness the impact of diversification. Among the spatial factors, rural literacy and irrigation have almost consistently had a significant impact on growth of per capita income in agriculture.

The empirical evidence presented here highlights the importance of inputs and infrastructure in convergence in agriculture. Therefore, economic policy measures targeting improvement and expansion of infrastructural support and literacy for example public investments towards irrigation and electricity, roads and rural literacy and input usage can have an important impact in promoting long run agriculture growth and convergence across Indian states. In particular, our findings point towards the significant role of infrastructure and literacy in reducing regional disparity through their spatial spill-over effects.

Some of the limitations of the present study have to be kept in mind while drawing conclusions. A major limitation here is the quality of data availability. It is widely accepted that there is discrepancy in data from government sources on agricultural production, land use etc. because of irregularity of publications and updating the records. Moreover, data on livestock and machinery etc. are not annually available and they had to be interpolated to obtain an annual series. Interpolation potentially might have introduced some errors in the data. Spatial analysis is dependent on spatial weight matrices. Nevertheless, the results confirm spatial dependence in Indian agriculture and point towards channels of intervention which can potentially reduce inter-state disparity.

Tables

TABLE 1- growth performance across Indian states

	Income levels				Compound growth rate			
State	1966	1977	1989	2010	1966-2010	1966-77	1978-89	1990-2010
Andhra	4936	5126	6421	10652	1.72	0.32	1.89	2.44
Assam	4023	4592	5086	5039	0.50	1.11	0.85	-0.04
Bihar+Jharkhand	755	2483	2113	2784	2.94	10.43	-1.34	1.32
Gujarat	2220	6241	6491	10953	3.61	9.00	0.33	2.52
Haryana	3188	9420	11487	14966	3.50	9.45	1.67	1.27
Himachal Pradesh	2714	5627	7068	7135	2.17	6.26	1.92	0.04
Jammu & Kashmir	2502	5362	4840	6673	2.20	6.56	-0.85	1.54
Karnataka	2922	6122	6389	9159	2.57	6.36	0.36	1.73
Kerala	1875	3696	4109	6859	2.92	5.82	0.89	2.47
Maharashtra	1507	3825	4605	7774	3.71	8.07	1.56	2.52
MP+Chhattisgarh	2238	3491	5229	6145	2.27	3.78	3.42	0.77
Orissa	1668	3527	6066	4945	2.44	6.44	4.62	-0.97
Punjab	2195	10322	14871	17950	4.78	13.77	3.09	0.90
Rajasthan	1855	4742	4889	7687	3.21	8.14	0.25	2.18
Tamil Nadu	2467	4613	4173	6913	2.32	5.35	-0.83	2.43
UP+Uttarakhand	3091	4138	4390	4874	1.02	2.46	0.49	0.50
West Bengal	1374	3794	4820	7024	3.69	8.83	2.02	1.81
India	2449	4615	5009	6793	2.29	5.42	0.69	1.46
CV	41.30	40.04	49.22	46.77	39.26	51.75	78.37	49.87

Source: author's computation

TABLE 2: Results of global Moran's test

year	contiguous states	inverse distance	shared-border	contiguous districts
1966	-0.036	-0.030	0.090	0.062
1970	0.355***	0.153***	0.418***	0.412***
1978	0.351***	0.152***	0.492***	0.468***
1990	0.269**	0.136***	0.412***	0.384***
2010	0.192**	0.066**	0.317**	0.283**

Note: *: p<0.10;**: p<0.05;***: p<0.01 Source: author's estimations.Note: results of other years can be shared on request

TABLE 3-Results of Local Moran's test

Year	State	Moran's I	Year	State	Moran's I
	Contiguity			District	
1966	West Bengal	0.735**	1966	Bihar+Jharkhand	0.925**
1966	Bihar+Jharkhand	0.72**	1966	West Bengal	2.198***
2010	Punjab	0.747**	2010	Haryana	0.606*
2010	Bihar+Jharkhand	1.389***	2010	Bihar+Jharkhand	1.202**
			2010	Punjab	1.667***
	Inverse Distance			Border	
1966	West Bengal	0.393**	1966	Bihar+Jharkhand	1.087**
2010	Assam	0.164**	1966	West Bengal	2.446***
2010	Orissa	0.152**	2010	Haryana	0.855**
2010	Punjab	0.367**	2010	Bihar+Jharkhand	1.211***
2010	Haryana	0.399**	2010	Punjab	1.885***

Note: *: P<0.10;**: P<0.05;***: P<0.01 Source: Author's Estimations.Note: Results Of Other Years Can Be Shared On Request

TABLE 4- Results of beta convergence

Dependent variable is growth rate defined as annual growth rate i.e. $\ln(y_t)-\ln(y_{(t-1)})$ where y_{it} is the income per rural person in i-th state and t-th year.					
Variable	non-spatial	contiguity	inverse-distance	shared border	contiguous districts
	[1]	[2]	[3]	[4]	[5]
lagged income	-0.623***(0.094)	-0.627***(0.074)	-0.625***(0.083)	-0.625***(0.071)	-0.624***(0.069)
lagged growth	-0.197***(0.032)	-0.162***(0.028)	-0.167***(0.027)	-0.163***(0.028)	-0.160***(0.028)
per capita tractor	0.959** (0.340)	1.304***(0.398)	1.241***(0.296)	1.378***(0.361)	1.359***(0.377)
per capita land	2.060*** (0.380)	2.034***(0.343)	1.991***(0.358)	2.052***(0.370)	2.046***(0.362)
buffaloes per sq. km.		-0.167**(0.076)	-0.123*(0.063)	-0.183**(0.085)	-0.178**(0.085)
sheep per sq. km.	0.153*** (0.038)	0.122***(0.041)	0.106***(0.036)	0.139***(0.039)	0.134***(0.032)
irrigation	0.121*** (0.030)	0.113***(0.023)	0.119***(0.029)	0.126***(0.023)	0.127***(0.023)
village electricity dummy	-0.053** (0.020)	-0.058***(0.021)	-0.034*(0.021)	-0.054***(0.020)	-0.055***(0.019)
road quality	0.154* (0.084)	0.110*(0.064)	0.135**(0.065)	0.126**(0.052)	0.122**(0.052)
agriexp per area	0.003** (0.001)	0.003***(0.001)	0.002**(0.001)	0.003***(0.001)	0.003***(0.001)
share of oil	1.105***(0.168)	1.107***(0.186)	0.999***(0.188)	1.041***(0.172)	1.033***(0.173)
share of fibre		0.915***(0.322)	0.846**(0.383)	0.923***(0.335)	0.906***(0.328)
share of sugar	2.948* (1.469)	3.139**(1.274)	2.989**(1.262)	2.835**(1.255)	2.926**(1.221)
rural literacy	0.009*** (0.002)	0.004*(0.002)	0.006***(0.002)	0.004*(0.002)	0.004*(0.002)
rain dummy 2	-0.014** (0.006)	-0.014**(0.007)	-0.014**(0.006)	-0.012*(0.007)	-0.012*(0.007)
rain dummy 3	-0.042***(0.013)	-0.040***(0.012)	-0.040***(0.012)	-0.039***(0.012)	-0.039***(0.012)
spatial rural literacy		0.006***(0.001)		0.003**(0.002)	0.003**(0.002)
spatial irrigation				0.101***(0.037)	0.094***(0.036)
spatial road quality			0.685***(0.215)	0.164**(0.071)	0.160**(0.072)
spatial growth		0.267***(0.044)	0.319***(0.062)	0.258***(0.044)	0.273***(0.047)
STATISTICS					
No. of observation	663	646	646	646	646
log-likelihood	587.857	607.532	602.566	612.487	615.42
AIC	-1147.713	-1183.065	-1173.131	-1192.973	-1198.84
BIC	-1084.758	-1111.532	-1101.599	-1121.44	-1127.307
R-square	0.525	0.567	0.565	0.571	0.573

Note: *:p<0.10;**:p<0.05;***:p<0.01 Source: author's estimations, se within parenthesis

TABLE 5 –Results of beta convergence for sub-phases

Dependent variable is annual growth rate i.e. ln(y_t)-ln($y_{(t-1)}$) where y_{it} is the income per rural person in i-th state and t-th year.				
Variable	phase1	phase 1	phase2	phase3
	[1]	[2]	[3]	[4]
Time lagged income	-0.402***(0.045)	-0.409***(0.030)	-0.940***(0.110)	-0.582***(0.059)
Time lagged growth				-0.211***(0.046)
Fertilizer per sq. km.	0.125**(0.056)			
per capita land	1.369***(0.316)	1.658***(0.246)	2.813***(0.413)	1.759***(0.322)
per capita tractor			2.268**(1.025)	
livestock per sq. km			0.130***(0.047)	
surf. Road per sq. km	0.060**(0.028)	0.074**(0.029)	0.102***(0.024)	
gross irri per sq. km.				0.176***(0.044)
share of cereals	0.617**(0.274)	1.120***(0.385)	0.579**(0.252)	
share of pulses		1.959**(0.913)		
share of fibre	-3.212**(1.403)	-3.012**(1.348)	1.303**(0.646)	0.903***(0.344)
share of sugar	-6.979***(2.676)			
share of oil			1.707**(0.750)	
rural literacy	0.006***(0.002)	0.006**(0.002)		0.007***(0.002)
rain dummy_3			-0.074***(0.020)	
spatial rural literacy	0.011***(0.004)	0.016***(0.004)		
spatial irrigation			0.465*** (0.148)	0.201***(0.065)
spatial growth	0.547***(0.070)	0.176**(0.087)	0.150***(0.048)	0.218***(0.076)
year effects	NO	YES	YES	YES
STATISTICS				
No of observations	170	170	187	340
Pseudo-log likelihood	77.449	98.944	197.183	356.437
AIC	-132.899	-169.888	-364.367	-688.874
BIC	-98.405	-125.987	-315.9	-642.926
R-sq.	0.453	0.696	0.753	0.55

Note: *:p<0.10;**:p<0.05;***:p<0.01 Source: author's estimations, se within parenthesis. Significant years were 1968, 1969, 1970, 1976 in first sub-phase, 1979, 1983 and 1984 in second sub-phase and 1994, 2007 and 2010 in third sub-phase

Figures

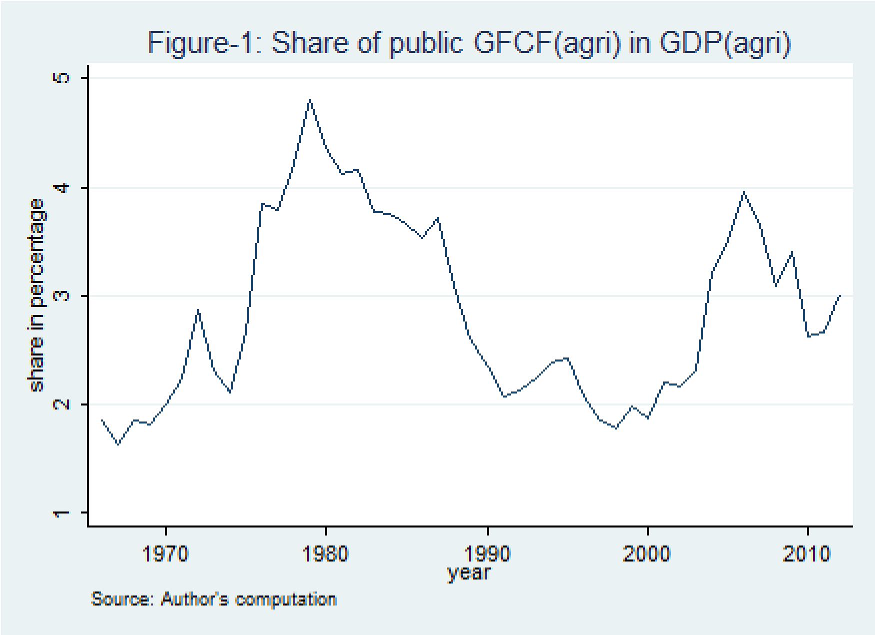

Figure 1: Share of public GFCF (agri) in GDP (Agri)

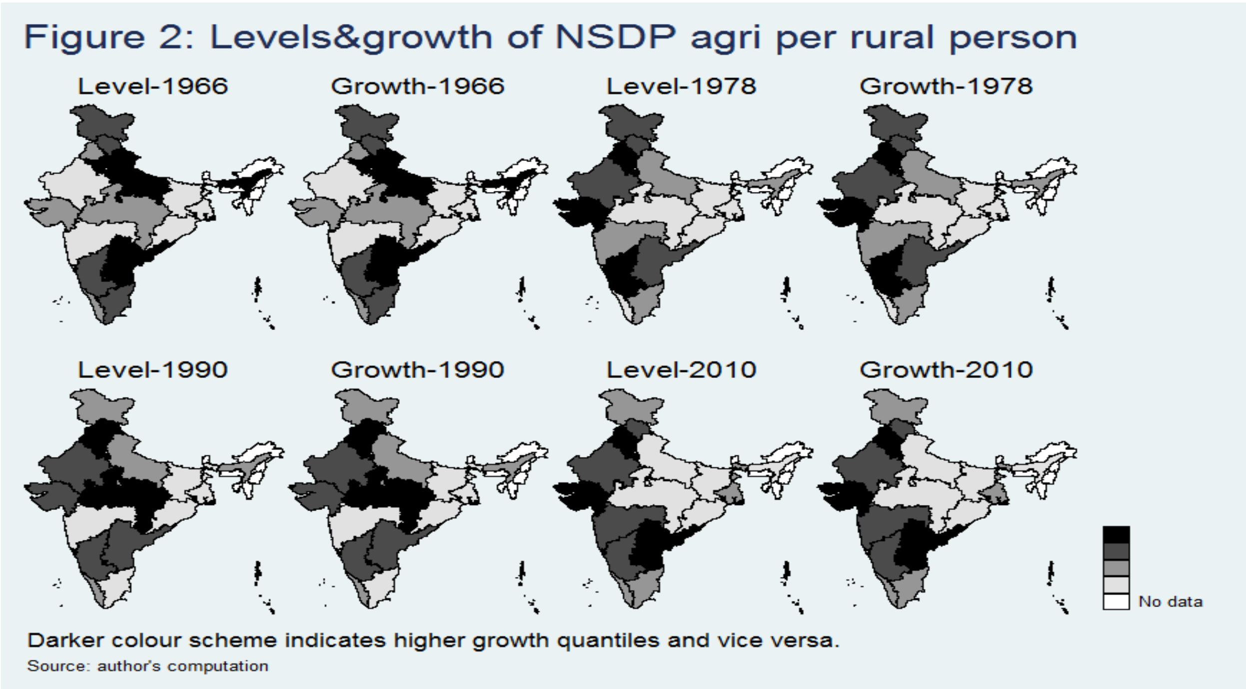

Figure 2: Levels & growth of NSDP agri per rural person

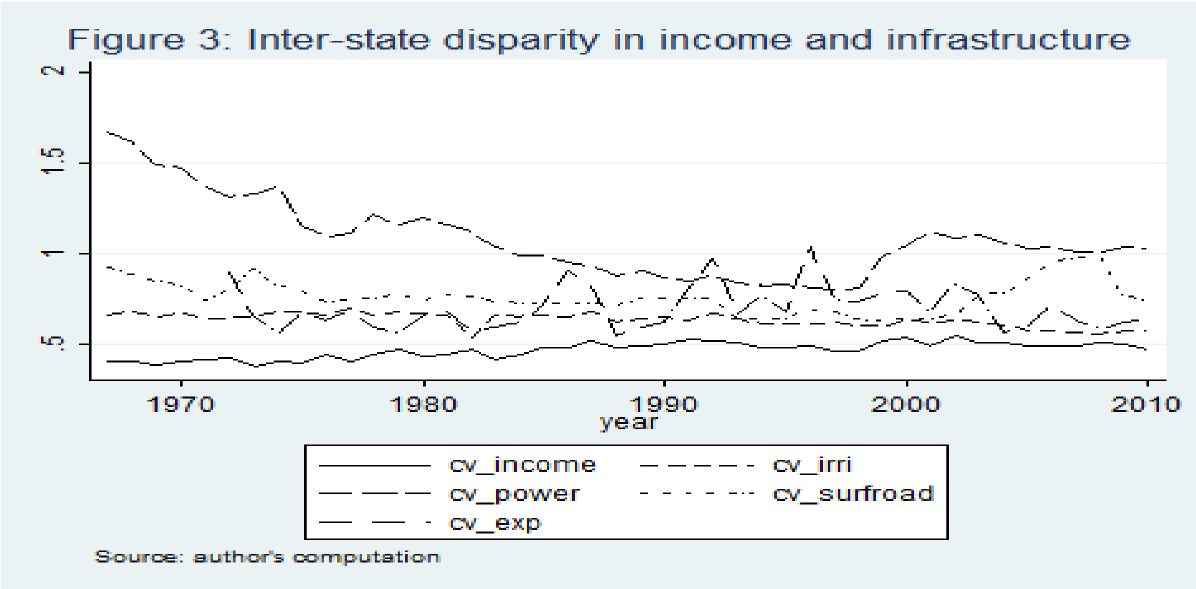

Figure 3: Inter-state disparity in income & infrastructure

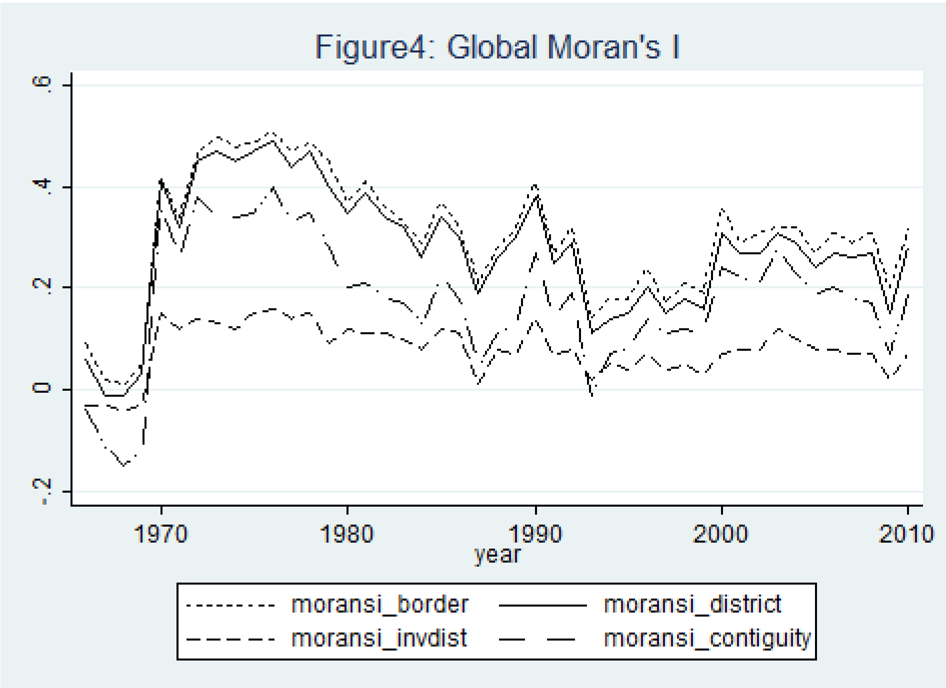

Figure 4: Global Moran's I

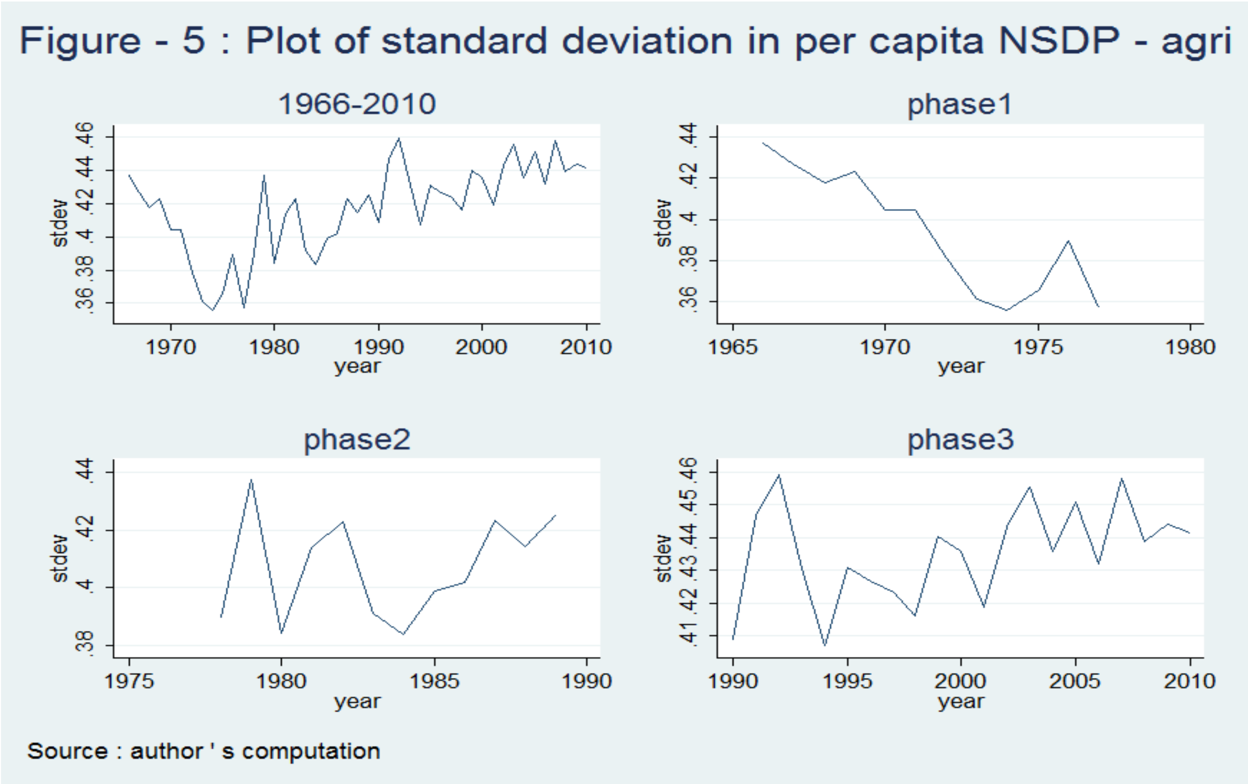

Figure 5: Plot of standard deviation

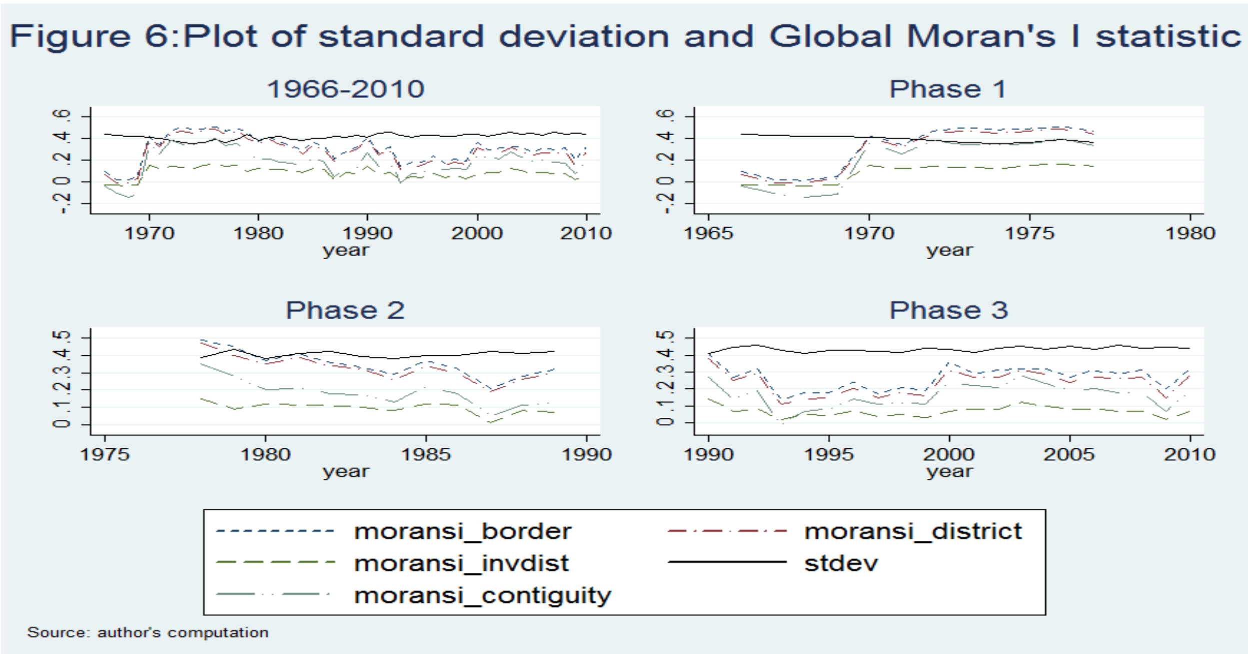

Figure 6: Plot of standard deviation & Global Moran's I statistic

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Inference and diagnostics in spatial linear models: an application to wheat productivity

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Abstract

The wheat production has been grown along the years and is one of the most important food grain source for humans. We analyze the productivity of two varieties of wheat planted in a regular sampling grid in an experimental area in south region of Brazil. We considered as explanatory variables the variety of wheat, spike length, average plant height and average number of tillers in 60 days. To model the mean of the wheat productivity we fitted a Gaussian spatial linear model, with different geostatisticals models for the variance-covariance matrix. To asses the influence of some observations we considered local diagnostics techniques based on Cook's approach. We considered appropriate perturbation scheme in the response variable. Then, we have substantial information to select the final model.

Keywords: Geostatistical; Maximum Likelihood; Spatial Variability; Precision Agriculture.

1 Introduction

Wheat (*t*riticum spp.) originated in southwestern Asia. According to Curis (2002), wheat was one of the first domesticated food crops and for 8000 years has been the basic staple food of the major civilizations of Europe, West Asia and North Africa, whilst is grown on more land area than any other commercial crop and continues to be the most important food grain source for humans. World wheat production increased dramatically during the period 1951-1990, although the expansion of the area sown to wheat has long ceased to be a major source of increased wheat output (CIMMYT, 1996). In Brazil the production is concentrated in south region.

The wheat grain is used to make flour for bread, pasta, pastry, etc. Wheat is also a popular source of animal feed, particularly in years where harvests are adversely affected by rain and significant quantities of the grain are made unsuitable for food use (Curis, 2002). It is considered a good source of protein, minerals, B-group vitamins and dietary fiber (Shewry, 2007). Davy et al (2002) has shown that whole wheat, rather than refined wheat, is a good choice for obese patients. Sidorova et al (2012) performed a geostatistical analysis of the spatial variability of the soil properties, the sowing parameters, and the wheat yield in a field experiment under precision agriculture conditions.

We analyze the wheat productivity data and four explanatory variables from an agricultural area in south Brazil. To consider the dependence between observations, the analysis were conducted using geostatistics techniques, where the data are collected at known sites in space, from a process that has a value at every site in a certain domain. To model the mean of the wheat productivity we fitted a Gaussian spatial linear model (GSLM) by maximum likelihood (ML) method given in Section 2. To asses the influence of some observations we considered local diagnostics techniques based on Cook's approach. We considered appropriate perturbation scheme in the response variable as shown in Section 2. The results are presents in Section 3 and some conclusions are given in Section 4.

2 Methodology

Let $\mathbf{Y} = \mathbf{Y}(\mathbf{s}) = (Y_1(\mathbf{s}_1), \ldots, Y_n(\mathbf{s}_n))^\top$ be an $n \times 1$ random vector of an isotropic and stationary stochastic process, that belong to the family of Gaussian distributions and depend on the sites $\mathbf{s}_j \in S \subset \mathbb{R}^2$, for $j = 1, \ldots, n$, $\mathbf{s} = (\mathbf{s}_1, \ldots, \mathbf{s}_n)^\top$. This stochastic process can be written in matrix form by

$$\mathbf{Y}(\mathbf{s}) = \boldsymbol{\mu}(\mathbf{s}) + \boldsymbol{\epsilon}(\mathbf{s}).$$

where, the deterministic term $\boldsymbol{\mu}(\mathbf{s})$ is an $n \times 1$ vector, the means of the process $\mathbf{Y}(\mathbf{s})$, $\boldsymbol{\epsilon}(\mathbf{s})$ is an $n \times 1$ vector of a stationary process with zero mean vector, $\mathrm{E}[\boldsymbol{\epsilon}(\mathbf{s})] = \mathbf{0}$, and $n \times n$ covariance matrix $\boldsymbol{\Sigma} = [C(s_u, s_v)]$. The mean vector $\boldsymbol{\mu}(\mathbf{s})$ can be written as a spatial linear model by $\boldsymbol{\mu}(\mathbf{s}) = \mathbf{X}(\mathbf{s})\boldsymbol{\beta}$, where, $\boldsymbol{\beta} = (\beta_1, \ldots, \beta_p)^\top$ is a $p \times 1$ vector of unknown parameters, $\mathbf{X} = \mathbf{X}(\mathbf{s}) = [\mathbf{x}_{j1}(\mathbf{s}) \ldots \mathbf{x}_{jp}(\mathbf{s})]$ is an $n \times p$ matrix of p explanatory variables, for $j = 1, \ldots, n$.
The matrix $\boldsymbol{\Sigma}$ is symmetric and positive defined, where the elements $C(\mathbf{s}_u, \mathbf{s}_v)$ depend on the Euclidean distance $d_{uv} = ||\mathbf{s}_u - \mathbf{s}_v||$ between points $\mathbf{s}_u$ and $\mathbf{s}_v$, sometimes $C(\mathbf{s}_u, \mathbf{s}_v)$ is also denoted by $C(d_{uv})$ or $C(d)$. The covariance matrix structure which depends on parameters $\boldsymbol{\phi} = (\phi_1, \ldots, \phi_q)^\top$ as given in Equation (1) (Uribe-Opazo et al, 2012):

$$\boldsymbol{\Sigma} = \phi_1 \mathbf{I}_n + \phi_2 \mathbf{R}, \tag{1}$$

where, $\phi_1 \geq 0$ is the parameter known as nugget effect; $\phi_2 \geq 0$ is known for sill ; $\mathbf{R} = \mathbf{R}(\phi_3, \phi_4) = [(r_{uv})]$ or $\mathbf{R} = \mathbf{R}(\phi_3) = [(r_{uv})]$ is an $n \times n$ symmetric matrix, which is function of $\phi_3 > 0$, and sometimes also function of $\phi_4 > 0$, with diagonal elements $r_{uu} = 1, (u = 1, \ldots, n)$; $r_{uv} = \phi_2^{-1} C(\mathbf{s}_u, \mathbf{s}_v)$ for $\phi_2 \neq 0$, and $r_{uv} = 0$ for $\phi_2 = 0$, $u \neq v = 1, \ldots, n$, where r_{uv} depends on d_{uv}; ϕ_3 is a function of the model range, ϕ_4 when exists is known as the smoothness parameter, and $\mathbf{I}_n$ is an $n \times n$ identity matrix. The Matérn (Matern, 1960) is a covariance function particularly attractive. Table 1 presents few special cases of the Matérn class of models.

Table 1: Special cases of the Matérn covariance function.

smooth parameter	covariance function	model
$\phi_4 = 1/2$	$C(d_{uv}) = \phi_2 \exp(-d_{uv}/\phi_3)$	exponential
$\phi_4 = 1$	$C(d_{uv}) = \phi_2 (d_{uv}/\phi_3) K_{\phi_4}(d_{uv}/\phi_3)$	Whittle
$\phi_4 \to \infty$	$C(d_{uv}) = \phi_2 \exp(-(d_{uv}/\phi_3)^2)$	Gaussian

Let $\boldsymbol{\theta} = (\boldsymbol{\beta}^\top, \boldsymbol{\phi}^\top)^\top$ be the vector of unknown parameters. The log-likelihood and score functions for the GLSM are given by

$$\mathcal{L}(\boldsymbol{\theta}) = -\frac{n}{2}\log(2\pi) - \frac{1}{2}\log|\boldsymbol{\Sigma}| - \frac{1}{2}(\mathbf{Y} - \mathbf{X}\boldsymbol{\beta})^\top \boldsymbol{\Sigma}^{-1}(\mathbf{Y} - \mathbf{X}\boldsymbol{\beta}), \tag{2}$$

$$\begin{aligned} \mathbf{U}(\boldsymbol{\beta}) = \frac{\partial \mathcal{L}(\boldsymbol{\theta})}{\partial \boldsymbol{\beta}} &= \mathbf{X}^\top \boldsymbol{\Sigma}^{-1} \boldsymbol{\epsilon}, \\ \mathbf{U}(\boldsymbol{\phi}) = \frac{\partial \mathcal{L}(\boldsymbol{\theta})}{\partial \boldsymbol{\phi}} &= -\frac{1}{2}\frac{\partial \, \mathrm{vec}^\top(\boldsymbol{\Sigma})}{\partial \phi} \mathrm{vec}(\boldsymbol{\Sigma}^{-1}) + \frac{1}{2}\frac{\partial \, \mathrm{vec}^\top(\boldsymbol{\Sigma})}{\partial \boldsymbol{\phi}} \mathrm{vec}(\boldsymbol{\Sigma}^{-1}\boldsymbol{\epsilon}\boldsymbol{\epsilon}^\top \boldsymbol{\Sigma}^{-1}), \end{aligned}$$

where $\boldsymbol{\epsilon} = \mathbf{Y} - \mathbf{X}\boldsymbol{\beta}$. From the solution of the score function of $\boldsymbol{\beta}$, $\mathbf{U}(\boldsymbol{\beta}) = \frac{\partial \mathcal{L}(\boldsymbol{\theta})}{\partial \boldsymbol{\beta}} = \mathbf{0}$, the maximum likelihood estimator $\boldsymbol{\beta}$ is given by $\hat{\boldsymbol{\beta}} = (\mathbf{X}^\top \boldsymbol{\Sigma}^{-1}\mathbf{X})^{-1}\mathbf{X}^\top \boldsymbol{\Sigma}^{-1}\mathbf{y}$. The derivatives of first and second-order of the scale matrix $\boldsymbol{\Sigma}$, with respect to ϕ_1, ϕ_2 and, ϕ_3, for some covariance functions are presented in Uribe-Opazo et al (2012), however the score equation for $\boldsymbol{\phi}$ do not lead to a closed-form solution for $\hat{\boldsymbol{\phi}}$. We consider the parameter ϕ_4 as fixed. The criteria considered to choose the geostatistical model for the covariance matrix were the cross-validation (CV), trace of the asymptotic covariance matrix of an estimated mean (Tr) and the log-likelihood maximum value (LMV) (De Bastiani et al, 2015).
Asymptotic standard errors can be calculated by inverting either observed information matrix, $I(\boldsymbol{\theta})$ or the expected information matrix, $\mathbf{F}(\boldsymbol{\theta})$, where $I(\boldsymbol{\theta})$ is $I(\boldsymbol{\theta}) = -\mathbf{L}(\boldsymbol{\theta})$, evaluated in $\boldsymbol{\theta} = \hat{\boldsymbol{\theta}}$, with $\mathbf{L}(\boldsymbol{\theta}) = \partial^2 \mathcal{L}(\boldsymbol{\theta})/\partial\boldsymbol{\theta}\partial\boldsymbol{\theta}^\top$ and $\mathbf{F}(\boldsymbol{\theta})$ is given by (see Waller & Gotway, 2004)

$$\mathbf{F}(\boldsymbol{\theta}) = \mathbf{F} = \begin{pmatrix} \mathbf{F}_{\beta\beta} & \mathbf{0} \\ \mathbf{0} & \mathbf{F}_{\phi\phi} \end{pmatrix},$$

where $\mathbf{F}_{\beta\beta} = \mathbf{X}^\top \boldsymbol{\Sigma}^{-1}\mathbf{X}$, and $\mathbf{F}_{\phi\phi} = \frac{1}{2}\frac{\partial\, \mathrm{vec}^\top(\boldsymbol{\Sigma})}{\partial \boldsymbol{\phi}}(\boldsymbol{\Sigma}^{-1} \otimes \boldsymbol{\Sigma}^{-1})\frac{\partial\, \mathrm{vec}(\boldsymbol{\Sigma})}{\partial \boldsymbol{\phi}^\top}$.

2.1 Local Influence

One of the purposes of diagnostic techniques is to evaluate the stability of the fitted model in a data set and should be part of all statistical analysis, since influential observations may distort the values of the statistic interest and lead us to misleading results.
In the local influence method, introduced by Cook (1986), a perturbation scheme is introduced into the postulated model through a perturbation vector $\boldsymbol{\omega} = (\omega_1, \ldots, \omega_k)^\top$ ($\boldsymbol{\omega} \in \Omega \subset \mathbb{R}^k$), generating the perturbed model, where $\mathcal{L}(\boldsymbol{\theta}|\boldsymbol{\omega})$ is the corresponding log-likelihood function. The influence measure is constructed using the basic geometric idea of curvature of the likelihood displacement given by

$$LD(\boldsymbol{\omega}) = 2[\mathcal{L}(\hat{\boldsymbol{\theta}}) - \mathcal{L}(\hat{\boldsymbol{\theta}}_\omega)],$$

where $\hat{\boldsymbol{\theta}}$ is the ML estimator of $\boldsymbol{\theta} = (\boldsymbol{\beta}^\top, \boldsymbol{\phi}^\top)^\top$ in the postulated model, with $\boldsymbol{\beta} = (\beta_1, \ldots, \beta_p)^\top$, $\boldsymbol{\phi} = (\phi_1, \ldots, \phi_q)^\top$ and $\hat{\boldsymbol{\theta}}_\omega$ is the ML estimator of $\boldsymbol{\theta}$ in the perturbed model.
The plot of the elements $|l_{max}|$ versus index (order of data) can reveal what type of perturbation has more influence on $LD(\boldsymbol{\omega})$, in the neighbourhood of $\boldsymbol{\omega}_0$, Cook (1986). Poon & Poon (1999) proposed the conformal normal curvature $B_l = C_l/\,\mathrm{tr}(2\mathbf{J})$, where $\mathbf{J} = \Delta^\top \mathbf{L}^{-1}\Delta$. The conformal curvature in the unit direction with j-th entry 1 and all other entries 0 is given by $B_i = 2|j_{ii}|/\,\mathrm{tr}(2\mathbf{J})$. The plot of B_i versus index can reveal potential influential observations.
To verify if a perturbation scheme is appropriate, Zhu et al (2007) proposed to use the Fisher information matrix of $\boldsymbol{\omega}$ in the perturbed model considering the vector $\boldsymbol{\theta}$ as fixed. In the following Section we give the results for the response variable perturbation scheme.

2.1.1 Perturbation on the response variable

Let consider as perturbation scheme the model shift in mean, i.e. $\mathbf{Y} = \boldsymbol{\mu}(\boldsymbol{\omega}) + \epsilon$, with $\boldsymbol{\mu}(\boldsymbol{\omega}) = \mathbf{X}\boldsymbol{\beta} + \mathbf{A}\boldsymbol{\omega}$ where $\mathbf{A}$, $n \times n$, is a matrix that does not depend on $\boldsymbol{\beta}$ or on $\boldsymbol{\omega}$. In this case $\boldsymbol{\omega}_0 = \mathbf{0}$. Equivalently we can write $\mathbf{Y}_\omega = \mathbf{X}\boldsymbol{\beta} + \epsilon$, with $\mathbf{Y}_\omega = \mathbf{Y} + (-1)\mathbf{A}\boldsymbol{\omega}$, that corresponds to a perturbation scheme of the response vector.
The perturbed log-likelihood is given by

$$\mathcal{L}(\boldsymbol{\theta}|\boldsymbol{\omega}) = -\frac{n}{2}\log(2\pi) - \frac{1}{2}\log|\boldsymbol{\Sigma}| - \frac{1}{2}[\mathbf{Y} - \boldsymbol{\mu}(\boldsymbol{\omega})]^\top \boldsymbol{\Sigma}^{-1}[\mathbf{Y} - \boldsymbol{\mu}(\boldsymbol{\omega})].$$

To select an adequate matrix $\mathbf{A}$ we can use the methodology proposed by Zhu et al (2007). In effect, the score function for $\boldsymbol{\omega}$ in the perturbed log-likelihood function (2.1.1) is given by

$$\mathbf{U}(\boldsymbol{\omega}) = \frac{\partial \mathcal{L}(\boldsymbol{\theta}|\boldsymbol{\omega})}{\partial \boldsymbol{\omega}} = \mathbf{A}^\top \boldsymbol{\Sigma}^{-1}[\mathbf{Y} - \boldsymbol{\mu}(\boldsymbol{\omega})].$$

Let $\mathbf{G}(\boldsymbol{\omega}) = E_\omega[\mathbf{U}(\boldsymbol{\omega})\mathbf{U}^\top(\boldsymbol{\omega})] = \text{diag}[\mathbf{g}_{11}(\boldsymbol{\omega}_1), \ldots, \mathbf{g}_{nn}(\boldsymbol{\omega}_n)]$ be the Fisher information matrix with respect to the perturbation vector $\boldsymbol{\omega}$. A perturbation $\boldsymbol{\omega}$ is appropriate if it satisfies $\mathbf{g}_{jj}(\boldsymbol{\omega}_0) = c\mathbf{I}_n$, where $c > 0$. In our case, we have $\mathbf{g}_{jj}(\boldsymbol{\omega}_0) = c\mathbf{A}^\top \boldsymbol{\Sigma}^{-1}\mathbf{A}$, with $c = 1$. Notice that usually $\mathbf{A}^\top \boldsymbol{\Sigma}^{-1}\mathbf{A} \neq \mathbf{I}_n$. However if $\mathbf{A} = \boldsymbol{\Sigma}^{1/2}$, then $\mathbf{g}_{jj}(\boldsymbol{\omega}_0) = c\mathbf{I}_n$ and so $\boldsymbol{\mu}(\boldsymbol{\omega}) = \mathbf{X}\boldsymbol{\beta} + \boldsymbol{\Sigma}^{1/2}\boldsymbol{\omega}$ is a perturbation scheme appropriate, as shown in De Bastiani et al (2015).
Considering the appropriated perturbation scheme for the response variable, where Δ_β is an $p \times n$ matrix and Δ_ϕ is an $3 \times n$ matrix given by

$$\Delta_\beta = \frac{\partial^2 \mathcal{L}(\boldsymbol{\theta}|\boldsymbol{\omega})}{\partial \boldsymbol{\beta} \partial \boldsymbol{\omega}^\top} = -\mathbf{X}^\top \hat{\boldsymbol{\Sigma}}^{-1/2} \quad \text{and}$$

$$\Delta_\phi = \frac{\partial^2 \mathcal{L}(\boldsymbol{\theta}|\boldsymbol{\omega})}{\partial \boldsymbol{\phi} \partial \boldsymbol{\omega}^\top} = -\frac{\partial\, \text{vec}^\top(\boldsymbol{\Sigma})}{\partial \boldsymbol{\phi}} \text{vec}(\boldsymbol{\Sigma}^{-1} \otimes \boldsymbol{\Sigma}^{-1/2})\, \text{vec}(\epsilon \otimes \mathbf{1}^\top).$$

evaluated in $\boldsymbol{\omega} = \boldsymbol{\omega}_0$ and $\boldsymbol{\theta} = \hat{\boldsymbol{\theta}}$, where $\hat{\epsilon} = (\mathbf{Y} - \mathbf{X}\hat{\boldsymbol{\beta}})$ and $\mathbf{1}$ is an $n \times 1$ vector of ones.

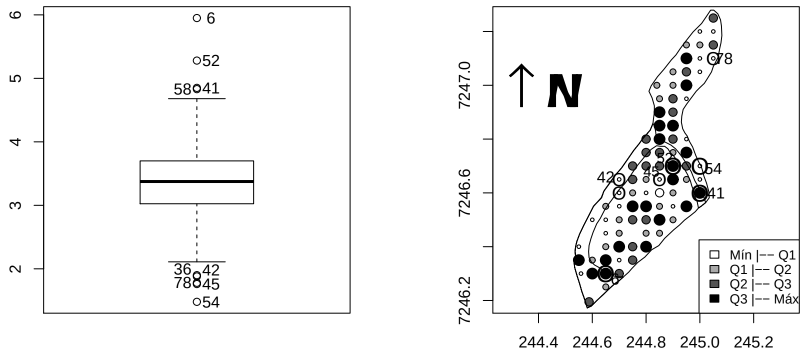
3 Results

The data were collected in 2003 in Cascavel city, south region of Brazil in an area of 22.63 hectares. The climate, according to Kppen is Cfa, temperate mesothermal and super humid. We analyze 84 element samples of two varieties of wheat CD101 and CD103, corresponding to 4.46 ha and 18.17 ha, respectively, collected in a regular grid of $50 \times 50m$. The explanatory variables are: average plant height - `alt60` and average number of tillers - `perfilho60` in 60 days, spike length - `cespigas` and the wheat variety treated as a `dummy` variable (0 or 1). So, $\mathbf{Y}$ represents a vector 84×1.
Table 2 presents a descriptive analysis of the response variable `wheat`, wheat productivity, and the explanatory variables. The wheat productivity mean is $3.372\, t\ ha^{-1}$. The average plant height in 60 days varies from $13.40\, cm$ to $36.60\, cm$. The average number of tillers presents the greatest value for the variance coefficient, however it still can be considered homogeneous. The mean and median of the spike length are the same considering one decimal.

Table 2: Descriptive analysis of response and explanatory variables.

Variable	Min.	1st Quartil	Median	Mean	3rd Quartil	Max.	var. coef.
`wheat`	1.480	3.037	3.375	3.372	3.680	5.950	0.23
`alt60`	13.40	20.65	22.50	23.17	24.62	36.60	0.17
`perfilho60`	0.40	1.200	1.700	1.661	2.100	3.40	0.38
`cespigas`	5.00	6.10	6.45	6.47	6.80	7.90	0.09

Figure 1(a) presents the boxplot for wheat productivity where the observations 06, 36, 41, 42, 45, 52, 54, 58 and 78 are outliers with wheat productivity values of 5.95, 1.90, 4.85, 1.88, 1.76, 5.28, 1.48, 4.83 and $1.78\ t\,ha^{-1}$, respectively. The site of these observartions are highlighted in Figure 1(b).



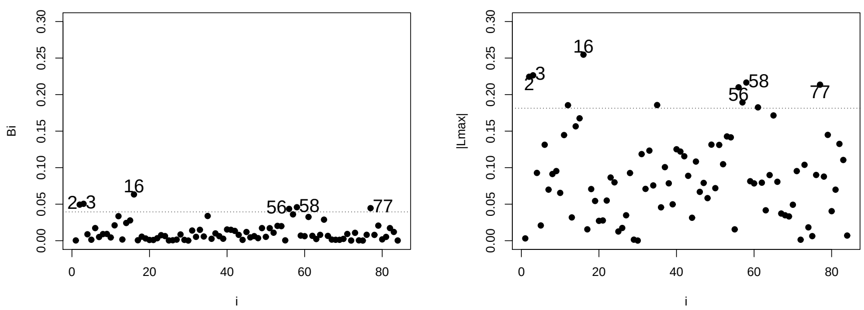
(a) (b)

Figure 1: (a) Boxplot and (b) postplot for wheat productivity samples in a regular grid, $50 \times 50\,m$.

We considered the Matérn family class to model the covariance matrix function. We considered values for ϕ_4 from 0.3 to ∞. According to the criteria LMV, Tr and CV, the choosen covariance matrix function is the value of $\phi_4 \to \infty$, which corresponds to the Gaussian covariance function. According to the likelihood ratio test, all the explanatory variables are significant at a level of 5%. The final choosen model (in parenthesis is given the corresponding asymptotic standard errors) is given by

$$\hat{\boldsymbol{\mu}}(\mathbf{s}_i) = \underset{(1.257)}{0.122}+ \underset{(0.266)}{0.354}\texttt{dummy}(\mathbf{s}_i)+ \underset{(0.024)}{0.069}\texttt{alt60}(\mathbf{s}_i)+ \underset{(0.142)}{0.078}\texttt{perfilho60}(\mathbf{s}_i)+ \underset{(0.146),}{0.188}\texttt{cespigas}(\mathbf{s}_i)$$

with spatial parameters estimates given by $\hat{\phi}_1 = 0.000(0.4058)$, $\hat{\phi}_2 = 0.548(0.4281)$ and, $\hat{\phi}_3 = 0.0349(0.0001)$. Figure 2 presents B_i versus index and $|L_{max}|$ versus index plots where observation #16 is detected as the most potential influent. Non of the observations pointed out where identified in the boxplot given in Figure 1(a).



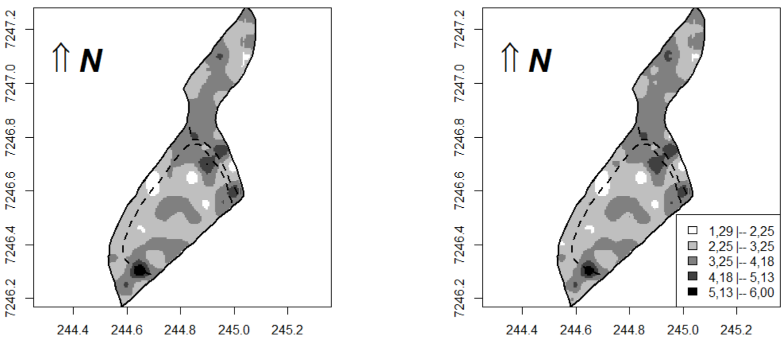
(a) B_i versus index (b) $|L_{max}|$ versus index

Figure 2: Local influence plots, (a) B_i versus index and (b) $|L_{max}|$ versus index considering the appropriate perturbation scheme.

We analized the data set without observation #16, and the chosen model for the covariance function remain the Gaussian one. The model is given by

$$\hat{\boldsymbol{\mu}}(\mathbf{s}_i) = \underset{(1.268)}{0.255}+ \underset{(0.276)}{0.307}\texttt{dummy}(\mathbf{s}_i)+ \underset{(0.024)}{0.070}\texttt{alt60}(\mathbf{s}_i)+ \underset{(0.151)}{0.083}\texttt{perfilho60}(\mathbf{s}_i)+ \underset{(0.146),}{0.175}\texttt{cespigas}(\mathbf{s}_i)$$

with spatial parameters estimates given by $\hat{\phi}_1 = 0.000(0.2323)$, $\hat{\phi}_2 = 0.560(0.278)$ and, $\hat{\phi}_3 = 0.040(0.0002)$. We can note a decrease on the estimate of the asymptotic standard error for $\hat{\phi}_2$.
Figure 3 shows the maps with all observations and without observation #16 where we can note a slightly difference between the maps in the north area. We have information to select the model considering all the observations as the final model.



(a) with all observations (b) without observation #16

Figure 3: Mean wheat productivity maps considering the model (a) with all observations (b) without observation #16.

Figure 3 shows the maps with all observations and the scenarios mentioned above. The maps constructed by kriging with external drift present well defined zones. Note: there is a slight difference between the maps in the northern area. A difference between the varieties CD101 and CD103 was also noted.

4 Conclusions

We proposed a measure based on the likelihood displacement to assess the stability of the likelihood function, using the perturbation on the response variable. We applied the methodology to a data set of wheat productivity collected in south region of Brazil. The spatial linear models enabled us to verify the spatial dependence between the wheat productivity data in the study area, according to the two varieties and plant attributes.
The maps constructed allowed us to estimate the wheat productivity in the study area, allowing us to create management zones with low or high productivity with the purpose of unifying similar areas, apply localized inputs and then maximize the the profit reducing the environment impact. It was observed the deletion of potential influential observations according to Zhu, caused changes in the parameters estimates that define the spatial dependence structure. Then, we have substantial information to select the final model considering all the observations.

5 Acknowledgements

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Inferring the big picture from data: Combining different data sources to understand the operation of the dairy sector in Malawi

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ABSTRACT

Dairy is a key investment sector for the Government of Malawi. The strategies proposed to develop the sector have been three: (1) reinforcement of the formal supply chain (i.e., farmers delivering milk to milk bulking groups and these to processors, who pasteurise it and transformed into a number of dairy products); (2) generation of mini dairies (i.e., micro-processing of milk delivered to a milk bulking group); (3) selling directly raw milk to consumers. The purpose of this paper is to explore the aforementioned strategies in terms of the sector economic growth and food security. To study them a spatial multimarket model was constructed for the Malawian dairy sector using census data and milk collection data, which considers milk production in the three regions (North, Central and South), the different processors, consumers and the interaction with the informal market. The results from the simulation indicate that strategies (1) and (3) have more possibilities in terms outcomes than strategy (2). The paper also explores potential roles for the Government and donors.

Keywords: Dairy sector, Malawi, multimarket model.

1. Introduction

Dairy is a key investment sector for the Government of Malawi, and donors such Belgium, Japan, USA and the UK have also been committed to its development. Several value chain analyses (IMANI Consultants, 2004; CYE Consult, 2009; Kawonga et al, 2012; M-Livestock Consultants, 2013) have discussed strategies to improve the dairy sector performance and raise its contribution to poverty alleviation and food security. The strategies discussed by the aforementioned analyses have been three: (1) reinforcement of the formal supply chain (i.e., farmers delivering milk to milk bulking groups and these to processors, who pasteurise it and transformed into a number of dairy products); (2) generation of mini dairies (i.e., micro-processing of milk delivered to a milk bulking group); (3) selling of non-pasteurised of good quality milk directly to consumers.

The purpose of this paper is to explore the impact that the aforementioned strategies could have on the sector economic growth and food security. This is motivated by the fact that the three strategies may have different effects on the smallholder agriculture (more than 80 per cent of the dairy production in Malawi is in the hands of smallholder farmers) and they imply different roles for government policy and governance of the dairy sector. To study the aforementioned alternatives a spatial multimarket model was constructed for the Malawian dairy sector, which considers milk production in the three regions (North, Central and South), the different processors, consumers and the interaction with the informal market in each region. Multimarket models have a long tradition in partial equilibrium modelling and particularly in policy evaluation in agricultural sectors (Braverman and Hammer, 1986 and Sadoulet and De Janvry, 1995 for a review of models). They provide a way to represent the most important markets affected by a policy, leaving aside other markets where the effects of the policy would be negligible. An example of their use in an African dairy market can be found in Kaitibie et al. (2010), where it is used to study the effect of the policy change in the Kenyan dairy sector.

The results indicate that assumptions of strategies (1) and (2) may be flawed. Moreover, there is enough production of milk for the formal market to operate at full capacity; however, the major constraint is the demand for dairy domestic products given the low purchasing power of most of the population. Micro dairies suffer from two problems: first, efficiency in the pasteurisation of milk in comparison with processors, and second, the fact that they cannot offer higher prices to farmers (at least initially) because of they are concentrated on low value added products. Due to the latter, they cannot expand the supply of affordable of milk products for the population. Strategy (3), whilst has the potential of expanding the supply of low price milk to consumers, and therefore, improve food security, requires figuring out how to ensure that good quality milk is delivered to consumers.

The structure of the paper is as follows: it starts with the description of the multimarket model used to simulate the development strategies and the data. The next section presents and discusses the results of the model and the final section provides the conclusions.

2. A multimarket model of the dairy sector

Let us consider the following partial equilibrium model for the Malawian dairy sector. The starting point of the model is the production of milk, which to simplify will be considered to come either from the native zebu or from other breeds (these include exotic breeds or mixed breeds). Hence, the supply of milk from zebus (Y_i^Z) from region i, where i=North (N), Central (C), and South(S). The total production of milk from zebus is given by equation (1).

$$(1) \qquad Y_i^Z = y_i^Z \cdot V_i^Z$$

Where y_i^Z is the milk yield per zebu in region i and V_i^Z is the number of zebus in region i. It is assumed in the model that all the milk coming from the zebus is consumed in the farms (i.e., it is not marketed). Therefore, this is presented in equation (2):

$$(2) \qquad C_i^Z = Y_i^Z$$

Y_i^Z can therefore be considered as milk going/consumed to the informal market. The next step is to characterise the supply of milk produced by non-zebu cows (Y_i^{NZ}). This is given by equation (3), which is analogous to equation (1).

$$(3) \qquad Y_i^{NZ} = y_i^{NZ} \cdot V_i^{NZ} = y_i^{NZ}\left(P^N, P_I^N, W^F\right) \cdot V_i^{NZ}$$

Where y_i^{NZ} is the milk yield per non-zebu cow in region i and V_i^Z is the number of non-zebus cows in region i. It is hypothesised that the yields are a function of the average price paid by the i MBGs (P^i), the price paid by the informal market in region i (P_I^i), and the price of inputs (W^F). The number of non-zebu cows is assumes to be exogenous, as in the past it has depended on donors, Government policy or the pass on programme.

In the Northern region it will be assume that all the milk from non-zebus will go to the milk bulking group (MDFA) (B_N), i.e., (4):

$$(4) \qquad B_N = \phi_N \cdot Y_N^{NZ} = \phi_N\left(P^N, P_I^N\right) \cdot Y_N^{NZ}$$

Where ϕ_N is the proportion of the production of milk from non-zebus in the North, which is a function that depends on P^i and P_I^N. Note that $\phi_N < 1$ because the remaining part goes to the informal market. All the milk collected in the North and pasteurised by MDFA is assumed to be sold within the region. This is given by (5):

$$(5) \qquad YP^{MDFA} = \alpha_{MDFA}\left(B_N\right)$$

Where α_{MDFA} is the proportion of the milk collected by the North milk bulking group for MDFA that is being pasteurised. It is expected that this proportion to be lower than 1 due to losses.

In the case of the Central region, the amount of milk that goes to the milk bulking groups which deliver to processor j (B_C^j) is given by (6):

$$(6) \qquad B_C^j = \phi_C^j \cdot Y_C^{NZ} = \phi_C^j\left(P_C^j, P_I^C\right) \cdot Y_C^{NZ}$$

Where ϕ_C^j is the proportion of the production of milk from non-zebus that goes to processor j in the Central region and j=Lilongwe Dairies (LD-1), Suncrest Creameries (SC-2), Dairibord Malawi (DM-3), Sable Farming (SF-4), MDI (MD-5). Similar nomenclature is used for the prices paid to farmers by processor j (i.e., P_C^j). Note that not all the ϕ's will be greater than zero as some of the dairy processors do not collect milk in the Central region. In addition, the sum of the ϕ's sums less than one, since part of the produced milk will find its way to the informal market. P_I^C is the price prevalent in the informal market.

The equation of the milk going to milk bulking groups in the South is similar to the Central region and given by (7):

$$(7) \qquad B_S^j = \phi_S^j \cdot Y_S^{NZ} = \phi_S^j\left(P_S^j, P_I^S\right) \cdot Y_S^{NZ}$$

The quantity of milk pasteurised by the processors (YP^j) is given by equation (8):

$$(8) \qquad YP^j = \alpha_j\left(B_C^j + B_S^j\right)$$

Where α_j is the proportion of the milk collected in MBGs for processor j that is being pasteurised. Note that α_j is lower than 1 because some of the milk is lost, and also the processors use part of the collected milk to other purposes (e.g., chambiko, liquid yoghurt, yoghurt, ice cream).

The total supply of pasteurised milk in region i (CP_i) is given by (9):

$$(9) \qquad CP_i = \sum_{j=1}^{J_i} s_i^j \cdot YP^j$$

Where s_i^j is the share of the production of pasteurised milk from processor j that it marketed in region i, where J_i is the number of processors selling in region i. Finally, note that the total consumption/purchases of pasteurised milk, can be in some cases understood as residual demand, are given by equation (10):

$$(10) \qquad CP_i = C_i - CM_i - CI_i$$

Where C_i is the total consumption of milk in region i, CM_i is the total consumption of powder milk and CI_i is the total consumption of unpasteurised milk coming from the informal market. It is assumed in the model that whilst processors can sell in several regions, the informal market can only sell milk within its region. Note that the actual consumption of pasteurised milk depends on the retail price set for the product. This price, although suggested by processors, is ultimately set by retailers as shown in Akaichi et al. (2013). Therefore, the price paid by consumers, i.e., the retail price in region i, (P_i^R) is given by (11):

$$(11) \qquad P_i^R = P_i^{W,j} \cdot \left(1 + m_i^j\right)$$

Where m_i^j is the retail marketing margin set by retailers up over the basis of the prices proposed by processor j $P_i^{W,j}$. Given the above expressions, the total size of the informal market (I) is given by (11):

$$(12) \qquad I = \sum_{i=N}^{S} Y_i^Z + (1 - \phi_N) \cdot Y_N^{NZ} + \left(1 - \sum_{j=1}^{6} \phi_C^j\right) \cdot Y_C^{NZ} + \left(1 - \sum_{j=1}^{6} \phi_S^j\right) \cdot Y_S^{NZ}$$

The total milk marketed to the formal sector is equal to (13):

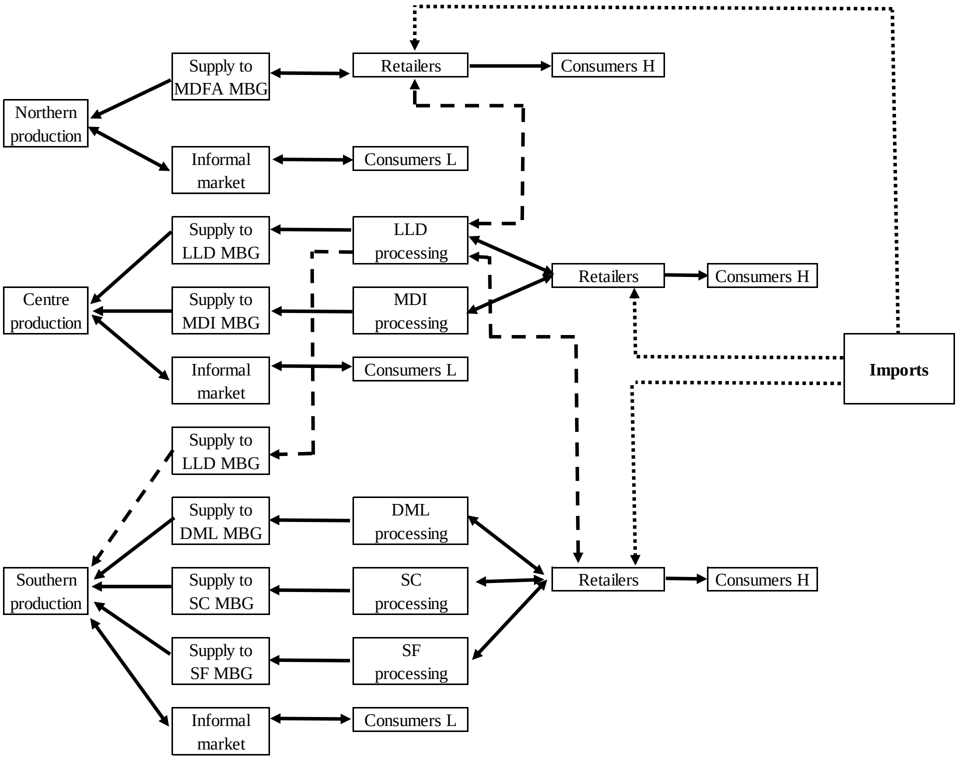
$$(13) \qquad M = \phi_N \cdot Y_N^{NZ} + \sum_{j=1}^{6} \phi_C^j \cdot Y_C^{NZ} + \sum_{j=1}^{6} \phi_S^j \cdot Y_S^{NZ}$$

Let us consider that the plant of capacity (i.e., engineering plant capacity) of processor j is equal to PC^j, then the observed idle capacity of processor j, as a ratio of the plant capacity, can be expressed as PC^j (13):

$$(14) \qquad IC^j = \frac{\left(\phi_C^j \cdot Y_C^{NZ} + \phi_S^j \cdot Y_S^{NZ}\right)}{PC^j}$$

The structure of the model presented in equations (1) to (14) is represented by Figure 1. Three features are important to highlight: The first one is related to the different types of consumers. These are those that demand milk of high quality (H), which comes from the formal sector (i.e., processors and retailers) and/or from imports; and those that consume raw milk from the informal market. The key difference between both groups is there income (i.e., their purchasing power is different). Moreover, given the country's poverty level, the group that demands milk type L is much larger than the one that demands milk type H.

Figure 1. Overall structure of the model



The second feature is that Lilongwe Dairies, which is the most important processor in terms of volume, processes milk in the Central region; however, it collects milk from the South and Central region and they sell their products all over the country (their operations outside the Central region are represented by dashed lines). The third feature is the fact that retailers' imports are destined to consumers who demand high quality, and therefore, imports compete with domestic processors products.

The data used for the model were compiled from a number of sources (Revoredo-Giha and Toma, 2016). The information on production, were from the livestock census carried out by the National Statistical Office of Malawi. The information was broken down by Zebus (meat purpose animals) and Non-zebus (dairy animals), which is the adding up of pure breeds and crosses. The distribution of the total milk produced was from the information provided by the Malawi Milk Producers Association (MMPA), the Central Milk Producers Association (CREMPA) and the Shire Highland Milk Producers Association (SHMPA) (South region).

3. Results and discussion

The full model was implemented in a MS Excel Workbook and solved and simulated with the aid of Visual Basic routines. The results are presented in Table 1, which considers the baseline result (2014 situation) and three discussed strategies/scenarios: strengthening the formal sector ("Formal market"); micro processing ("Micro dairies"); and selling directly raw milk ("Raw milk market"), which presented below:

Table 1: Results from the simulation

Summary of variables	Baseline 1/	Development strategies					
		Strategy (1) Formal market		Strategy (2) Micro dairies		Strategy (3) Raw milk market	
		Result	Change 2/	Result	Change 2/	Result	Change 2/
Total non-zebu production of milk (tonnes)							
North	4,723	4,917	4.1	4,723	0.0	4,444	-5.9
Centre	11,358	12,254	7.9	11,597	2.1	9,552	-15.9
South	32,517	37,109	14.1	34,601	6.4	32,842	1.0
Average price paid to farmers (2014 Kwachas/ltr)							
North	147.0	169.0	15.0	154.0	4.8	133.0	-9.5
Centre	114.1	140.1	22.8	123.2	8.0	107.6	-5.7
South	113.9	149.4	31.2	147.6	29.6	119.0	4.5
Per capita consumption of domestic milk - raw (kg/year) 3/							
Malawi	1.9	2.7	42.3	1.6	-13.2	2.3	21.8
Per capita consumption of domestic milk - processed (kg/year) 3/							
Malawi	45.6	67.8	48.8	26.8	-41.2	27.0	-40.7
Total demand for milk - processors							
North	90	135	49.6	90	0.0	0	--
Centre	1,316	1,920	45.9	0	--	0	--
South	18,361	27,349	49.0	11,535	-37.2	11,728	-36.1
Demand for milk - farmers MBGs 4/							
North - MDFA	90	135	49.6	90	0.0	0	--
Centre - Lilongwe Dairies	1,316	1,920	45.9	1,408	7.0	0	--
South - Lilongwe Dairies	4,962	7,240	45.9	5,309	7.0	0	--
South - Dairibord Malawi	4,439	6,803	53.2	4,811	8.4	0	--
South - Suncrest Creameries	2,530	3,796	50.0	2,736	8.1	0	--
South - Sable Farming	138	207	50.0	138	0.0	332	140.0
Demand for milk - traders MBGs							
South - Lilongwe Dairies	3,331	4,859	45.9	6,439	93.3	6,439	93.3
South - Dairibord Malawi	97	149	53.2	245	151.9	245	151.9
South - Suncrest Creameries	2,863	4,295	50.0	4,712	64.6	4,712	64.6
Total supply to the informal sector (tonnes)							
North	4,633	9,788	111.3	4,633	0.0	4,444	-4.1
Centre	10,042	16,825	67.5	10,188	1.5	9,552	-4.9
South	14,156	14,412	1.8	10,211	-27.9	21,114	49.1
Average wholesale price (Kwachas/ltr) 5/							
North	194.0	200.8	3.5	213.4	10.0	--	--
Centre	181.7	199.1	9.6	206.0	13.4	--	--
South	200.3	220.7	10.2	272.6	36.1	219.8	9.7

Note:
1/ Corresponds to the 2014 situation.
2/ Change with respect the baseline.
3/ Raw milk comes from the informal market and is consumed in rural areas and by 80% of the urban population.
4/ In the case of strategies 2 MBGs operate as microprocessors and strategy 3 MBGs do not collect milk only check quality.
5/ Processors' price.

3.1 Strengthening the formal sector

The column "Formal market" in Table 1 presents the results for strengthening the formal sector. As shown in the Table, producers are encouraged to deliver more milk to the processors through higher prices. The milk collection increases by about 50 per cent.

The higher prices paid by processors not only increase the collection of milk by MBGs but also encourage a rise in the total production of milk in the three regions. Production in the South increases the most with respect to the baseline (14.1 per cent). This compensates the reallocation of milk from the informal to the formal market such that the milk destined to the informal market still grows.

The growing in the production of milk implies that the per capita consumption of raw milk and processed milk (from domestic origin) will increase (note that the high socioeconomic group in urban areas also consumes imported dairy products). In the case of the raw milk, this is due to the fact that surplus milk will go the informal market. Note that wholesale prices of processed products will increase due to the rise in the cost of the milk (processors are paying a higher price for it); however, it could be expected that not all of this cost will be passed to urban consumers (they make the demand for processors) due to the fact that the expansion of production will reduce the average fixed costs, which are currently high due to idle capacity. It is important to point out that under this scenario it being assumed that the additional production by processors will be sold at high prices (if not in the domestic market, probably abroad in the neighbour countries).

A potential role for Government and donors under this scenario is to improve the public infrastructure (e.g., roads, energy), which certainly would provide positive externalities and reduce the operational costs of the dairy processors. Although, not simulated, this could bring an expansion of the domestic dairy industry.

3.2 Micro processing

Under this scenario the mini dairies will compete with processors on the supplies of milk. As explained, all the farmers-managed MBGs are assumed to become micro dairies. It is important to note that under the assumption that they will only produce pasteurised milk (low value added product) these MBGs cannot afford to pay high prices to farmers for the raw milk. However, as they slightly increase the payments to farmers, there is a small rise in the milk collected by those MBGs (about 7 per cent).

The scenario also shows that processors increase substantively their collection from traders' MBGs due to their higher prices. This is needed due to the fact that otherwise they have an enormous increase in their idle capacity, which was estimated in 30 per cent in the baseline scenario. Nevertheless, as shown in Table 1, their collection is down due the loss of the farmers' MBG. This situation affects particularly Dairiboard Malawi, which depended to great extent of farmers' MBGs for their milk collection. It is highly probably that under this scenario, processors will decide not to produce anymore pasteurised milk and they just concentrate on products with more value added. This (and also the fact that the change in situation will increase their costs) is expressed on the rise in their wholesale price. In the medium term, there is the possibility that processors will expand the number of MBGs under traders in order to capture more milk.

Under this scenario, it is expected that the consumption of the per capita milk will decrease in both the raw milk and the processed milk market. The decrease in the raw milk market is because the product micro dairies is pasteurised milk, which is more expensive than raw milk and can only be afforded by the more affluent group. It should be mentioned although it is not capture in the model that there is the implicit assumption that the micro dairies will successfully make the transition from collecting milk to processing and marketing it. This is a very important assumption as experience shows in the case of the Bumbwe cooperative, which stopped operating in 2012 due to low margins, management problems and the inability to satisfy food safety standards (M-livestock consultants, 2013). For this scenario to succeed Government and donors will require significant investment not only on the facilities but also on training (including business management) to ensure the sustainability of the enterprise.

3.3 Selling directly raw milk

The results of this scenario show that farmers' MBGs will stop collecting milk but will be in charge of controlling milk quality, whilst traders' MBGs will continue supplying processors. In this sense, the scenario has commonalities with the micro dairies scenarios. Under this scenario, farmers would be selling directly raw milk avoiding the cost of pasteurising (milk will be boiled by households). Urban households, who can afford it, will probably substitute pasteurised milk by imported dried milk and the remaining of the urban population will consume raw milk.

Processors are under this scenario to focus on dairy products with greater value added, which as in the previous scenario will increase wholesale prices. Furthermore, as show in Table 1, milk collection for processors will concentrate in the South of the country (assuming that in the short term no additional MBGs in the hands of traders are established). Due to the fact that the prices for selling milk are lower it is expect that the aggregated production of milk will decrease, except in the South, where could be expect to remain at similar levels as in the baseline. Note that prices paid to farmers in the South are higher because processors will concentrate their milk collection there at high prices. In addition, under this scenario the amount of milk sold raw increases, and therefore, the per capita consumption of milk of poor urban and rural population will also rise; whilst the per capita consumption of processed milk from domestic origin will decrease. This scenario shows a trade off between economic growth (via production of greater value added) and production destined to massive consumption (food security).

A role for the Government and donors under this scenario is to create the conditions to ensure that the quality of the milk that is sold is good and safe. Given the potential size of the informal market, this could be a laborious and expensive task. The lessons from the Kenyan process will be important under this strategy.

4. Conclusions

The results from the simulation indicate under the first scenario that if processors are able to increase the prices paid to farmers in order to expand their milk collection, it is possible to expand both the amount of milk going to processed products together with the sales of raw milk (this is due to the fact that milk production reacts to prices). Under this conditions, market prices of dairy products (i.e., wholesale prices) are expected to increase due to the higher milk prices paid by processors but probably not as much as the increase in milk prices due to the reduction in processors' average fixed costs (i.e., due to the fact that there is a reduction in their idle capacity). The increase in the milk prices paid by processors is expected to raise the price of milk in the informal market (if the former is a reference or indicator for the latter) and therefore make milk less affordable in the informal market.

Under the second scenario, micro dairies, the situation indicates that production will remain basically the same except than in South due to the higher price paid by processors to traders' MBG to collect more milk. Micro dairies, which are an aspiration for farmers' MBG, will in the short term only be able to produce pasteurised milk, which has low value added and therefore pay farmers a low price for their milk. This will imply that production in the North and Central regions, will in the best case situation, remain the same (assuming that the micro dairies operate properly, which might be given past experiences, not very probable) and showing growth in the South.

The third scenario, allowing the selling of raw milk, it is similar to the second scenario, the difference is that farmers' MBG will only have the role of supervising the quality of milk; therefore, the price paid of raw milk will expected to be lower. Due to this, the production of milk might be expected to decrease in the North and Central regions and increase in the South. The amount of raw milk consumed is, as expected, found to increase. The scenario will therefore imply a substitution of pasteurised milk for raw milk at lower prices. This could improve food security of those consuming raw milk.

Overall, what strategy should Malawi follow in terms of dairy development? The results from the exercise indicate that either the development of the formal sector or the following the Kenyan approach have possibilities, since micro dairies would require a potential high investment and will bring a very uncertain outcome. It is important to note that given the size of the informal market, selling directly raw milk to consumers is an option that it is already present. This means that the current situation is something in between the first and the third scenario. In this context, probably the role of the Government and donors should be to ensure that the raw milk that it is sold in the informal market it is of good quality and the formal dairy sector benefit with improvement of infrastructure (particularly roads and electricity power), which will reduce their costs.

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A Dynamic spatial modeling of agricultural price transmission: Evidence from Niger millet market

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ABSTRACT

Spatial interactions are essential drivers of price transmission mechanisms and may significantly affect any food policy's outcomes. However, spatial aspects seem to be generally overlooked when analyzing price transmission. This paper attempts to fill this gap by highlighting the usefulness of spatial interaction and models for market integration analysis. A Spatial Dynamic Panel Data model is presented and applied to Niger's millet market. Empirical results show that (1) the millet market is partly integrated, (2) locally traded commodities (millet and sorghum) are linked by a cross-commodity price transmission, (3) most imported cereals prices, which for Niger is maize and rice, did not affect the millet market, and (4) no cross-regions price transmission occurred for the millet market.

Keywords: Spatial econometrics, panel data, agricultural commodities, market integration, Niger.

1. Introduction

In recent years, agricultural products have undergone huge price variation in international markets. Such variation in world markets is not without effect on local markets. The extent of these shocks vary across countries as some are more dependent on international markets than others. A number of factors determine the degree of price transmission in a country, such as trade flows, transactions costs, trade policies, availability of price information across markets, and installed infrastructures. For example, if domestic products dominate the local markets, price transmission will be less severe than in markets where foreign goods dominate local goods. In addition,

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transaction costs (transport, margins, risk premium, cost of information), distance, quality of infrastructure and trade barriers reduce price transmission by limiting trade flows.

Price transmission analysis measures how well different spatially separated markets are connected. If markets are perfectly integrated, price signals are transmitted from a selected location to other locations. This implies a price adjustment in response to existing excess supply and demand conditions in other locations of the integrated area.There is extensive theoretical and applied research on the mechanisms of price transmission. As applied studies often focus on policy implications, a large portion of the literature deals with methodological improvements in the fields of price transmission analysis. Therefore, various approaches can be found in the literature. The first studies began using correlation coefficients of prices to test market integration between spatially separated markets (Jones, 1972). Other research employed regression based models (Monke and Petzel, 1984), or time-series analysis techniques such as dynamic regression (Ravallion 1986)and cointegration analysis (Baulch 1997). Furthermore, a number of studies have proposed nonlinear approaches (Meyer and Cramon-Taubadel 2004, Greb et al. 2013).The common feature of these approaches is that they are mainly based on time-series analysis.

Since price transmission occurs between different locations, it is essential to include spatial interactions in price transmission models. The failure to take this fact into account may bias the results of an analysis. For example, Lesage (1999) stated that, due to spatial dependence and heterogeneity, Gauss-Markov assumption is violated. Spatial econometrics that successfully model those issues and draw appropriate inferences is a straightforward solution for price transmission analysis. Unfortunately, this tool seems to be rarely used in price transmission analysis. To the best of our knowledge, Keller and Shiue (2007) presented the only research that used the spatial econometric approach to study market integration for China’s rice market.

Spatial features are accordingly important as they influence the degree of market integration. In addition,the price dynamic in a given location is influenced by its neighboring prices (Keller and Shiue 2007).LeSage and Pace (2009) pointed out five reasons to include spatial features (spatial autoregression) in a regression model: (a) a time-dependence motivation; (b) an omitted variables motivation; (c) a spatial heterogeneity motivation; (d) an externalities-based motivation; and (e) a model uncertainty motivation. Interestingly, these motivations are relevant in market integration analysis.Therefore, the main aim of this paper is to add to the literature by highlighting the usefulness of the spatial econometrics approach for price transmission analysis.

The remainder of this paper continues as follows. Section 2 presents the dynamic spatial panel framework. Section 3 provides the results of the application of the proposed frameworkto millet market in Niger. The final section is devoted to conclusion and policy implications.

3. Methodological framework

An appealing spatial econometrics models for price transmission analysis is the Spatial Dynamic Panel Data (SDPD) model proposed by Lee and Yu (2010). This framework allow three types of interactions in price transmission. First, temporal dependency is taking into account. Previous price is allowed to affect the following period price level in a specific location. This is particularly what time series modeling do. Second, endogenous interaction effects is also integrated. The price level in a specific location is assumed to be impacted by adjacent locations price level. This is an interesting characteristic of our framework since separated markets are connected through trade flows and price information. Third, exogenous interaction effects is also integrated. While exogenous variables are present in the price transmission model, our framework is able to account for the observed exogenous variables in adjacent locations.

Let Y_t^k be the vector of price for *N* locations at time *t* for commodity *k* and X_t stand for exogenous variables, which could be the price of other products or weather variables. The SDPD setup is:

$$\boldsymbol{y}_t^k = \tau \boldsymbol{y}_{t-1}^k + \rho \boldsymbol{W} \boldsymbol{y}_t^k + \eta \boldsymbol{W} \boldsymbol{y}_{t-1}^k + \boldsymbol{x}_t \theta + \boldsymbol{W} \boldsymbol{x}_t \beta + \boldsymbol{\mu} + \alpha_t \boldsymbol{l}_N + \boldsymbol{v}_t (1)$$

This model is known as a dynamic spatial Durbin model (Debarsy et al., 2012). $\boldsymbol{\mu}$is a vector spatial fixed effects, α_t stands for time fixed effects, while $\boldsymbol{l}_N$ is a vector of ones. $\boldsymbol{W}\boldsymbol{x}_t$is the exogenous interaction effects term, $\boldsymbol{y}_{t-1}^k$ is the lagged of the dependent variable in time, $\boldsymbol{W}\boldsymbol{y}_t^k$ represents the contemporaneous endogenous interaction effects, $\boldsymbol{W}\boldsymbol{y}_{t-1}^k$ is the lagged endogenous interaction effects.

Based on the proprieties of model 1, it can be classified into three different cases depending on the value of $\boldsymbol{\tau} + \boldsymbol{\rho} + \boldsymbol{n}$. According to Lee and Yu (2010), model 1 is stable if this value is less than one, cointegrated if it equals one and explosive otherwise. To estimate model 1, we followed Yu et al. (2008), Lee and Yu (2010), and Yu et al. (2012), who used a bias-corrected quasi-maximum likelihood (BC-QML) estimator. This method produces consistent parameter estimates when the model is stable. However, when this stability condition is not satisfied, a data transformation is needed to consistently estimate model 1 using BC-QML. In fact, when the stability condition is not satisfied, Lee and Yu (2010) and Yu et al. (2012) proposed the spatial first-difference transformation of model 1 using the matrix (**I-W**) where **I** denotes the N x N identity matrix. See Elhorst (2014) for more details.

To interpret the effect of a change in an explanatory variable in this SDPD framework, one has to compute the reduced form of (1), which is presented

$$\boldsymbol{y_t} = [(\boldsymbol{I} - \boldsymbol{\rho W})^{-\boldsymbol{1}}(\boldsymbol{\tau I} + \boldsymbol{\eta W})]\boldsymbol{y_{t-1}} + (\boldsymbol{I} - \boldsymbol{\rho W})^{-\boldsymbol{1}}[\boldsymbol{x_t \theta} + \boldsymbol{W x_t \beta})] + (\boldsymbol{I} - \boldsymbol{\rho W})^{-\boldsymbol{1}}[\boldsymbol{\mu l_N} + \boldsymbol{\alpha_t l_n} + \boldsymbol{v_t}] \quad (2)$$

The short-term impacts of a change in a specific explanatory variable $\boldsymbol{x_i}$(or the lagged endogenous variable) on the dependent variable can be computed as:

$$\frac{\partial \boldsymbol{y}}{\partial \boldsymbol{x}_i} = [(\boldsymbol{I} - \rho \boldsymbol{W})^{-1}(\boldsymbol{x}_i \theta + \boldsymbol{W} \boldsymbol{x}_i \beta) \quad (3)$$

$$\left.\frac{\partial \boldsymbol{y}}{\partial \boldsymbol{y}_{t-1}}\right] = [(\boldsymbol{I} - \rho \boldsymbol{W})^{-1}(\tau \boldsymbol{I} + \boldsymbol{\eta W})] \quad (4)$$

The results of (4) are named the convergence effects (impact of the lagged endogenous variables). These partial derivatives (3) and (4)are*N*x*N*matrixes. As noticed in Debarsy et al. (2012), diagonal elements of equation (3) are different for each cross section, and off-diagonal elements differ from zero and the matrix is nonsymmetric. This model is richer than the traditional linear model. The average of diagonal elements represent own-partial derivatives (called direct effects), meaning the impactof a change in the selected explanatory variable in location *i*on the dependentvariable in this location.The average of the off-diagonal elements (cross-derivative elements) of (3)-(4) is thus labeled indirect effects and showsthe response of the dependent variable in location*i* to a change in explanatoryvariables in any of the other locations.

In price transmission framework, direct effects of (4) gives the extent of price transmission across years in the same region. It is to say how a price change for a selected market (millet, rice

…) in a location affects futureprices for this market in this location. The indirect effects of (4) shows the response of price in a region to a previous price change in any of the other regions. Therefore, price transmission analysis in our framework helps to know if a price shock originated from one location is transmitted only inside this location or to neighboring locations. Thus,price transmission has two components: intra-region price transmission and cross-regions price transmission. When price of substitute commodities were used as explanatory variables, a cross-region and cross-commodities price transmission can be examined. Such situation is examined in this study, which analyzed millet's market integration accounting for sorghum, maize and rice prices. One issue here is that these price series are clearly endogenous. The price of sorghum may affect the price of millet and vice-versa or both prices may be affected by unobserved factors.In this paper, we addressed this issue byusing the average of m[3] previous observations of the prices of sorghum, maize and rice.

4. Millet's market price transmission in Niger

In this section, the SDPD model was applied to analyze price transmission on cereals market in the eight regions of Niger (Agadez, Diffa, Dosso, Maradi, Niamey, Tahoua, Tillaberi and Zinder), with a special focus on millet, which is the most consumed cereal (food) in Niger (FAO, 2009). The attention paid to the millet market is justified because this cereal represents 78 percent of cereals consumption and 62 percent of food consumption in Niger (FAO, 2009). In addition, the millet consumed in Niger is totally produced locally (USDA, 2016). According to USDA database, around 2 percent of sorghum consumption are from imports, while maize and rice's consumption depend mainly on imports with more than 80 percent of demand satisfied by imports.

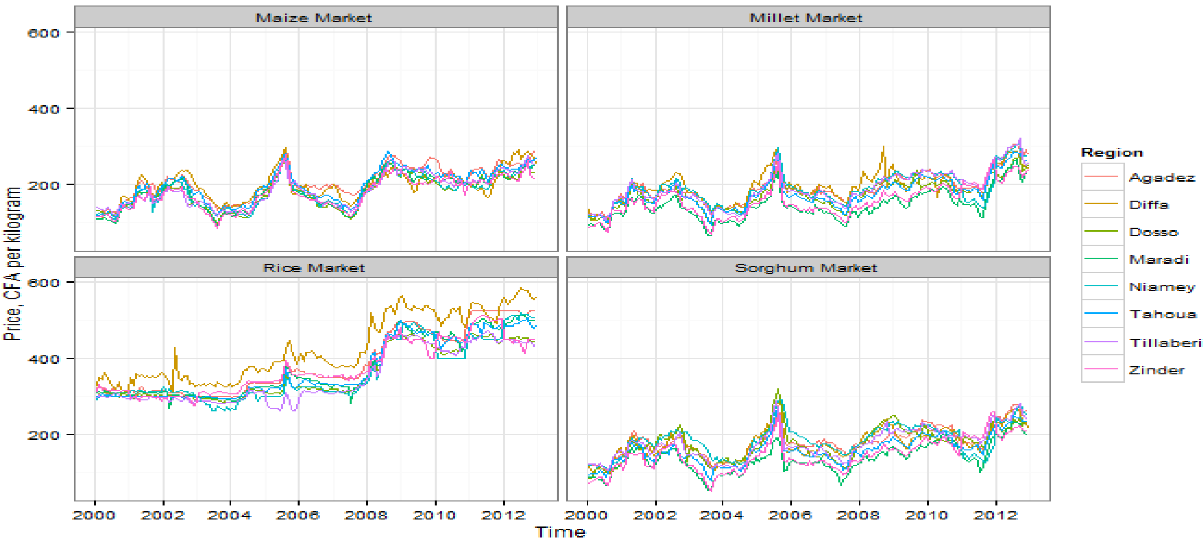

Figure4.1*Trends in Niger cereals prices, 2000–2012*

Source: SIMA, 2013

[3]We also used the average of the three, four, and five previous months

Price series used in this study were provided by the Niger's System of Agricultural Market Information (SIMA). Established in 1989, SIMA is a specialized service of the government of Niger, which is operated by the Ministry of Trade and Private Sector Promotion. The main mission of SIMA is to collect, process, and disseminate information about agricultural markets for better decision making by policy makers. Prices used here concerned monthly retailer prices over 2000-2012 (per kg price level in local currency, CFA) for the main cereals consumed in Niger, namely millet, sorghum, maize and rice. The dynamics of various cereals prices considered are depicted in Figure 4.1.

Table 4.1 presents the results of price transmission analysis on Niger's millet market when accounting for other cereal prices. The results, as stated in the table's heading, are related to the spatial first-difference of model (1) since the latter is found unstable. Due to space constraints, we don't present nor discuss the results of the direct estimation of model (1) here. For these details and others, the interested reader is referred to the *Discussion Paper* version of this study (Goundan and Tankari, 2016).

Column (1) of Table 4.1 reports the estimation results of the spatial first-difference of model (1), columns (2) to (4) show the results for the direct, indirect and total effects of explanatory variables as formulated in section 3. The t-statistics of the derived effects are obtained by carrying out a Monte Carlo simulation experiment over the estimated parameters.

Only four parameters over the nine estimated are significant (column 1). They are the first three parameters related to the endogenous variables and the one related to sorghum as own region's sorghum price observed at current period. The temporal lagged millet price seems to have a positive and significant correlation with its next period level (**0.68**). The second and third parameters correspond to cross-region millet price transmission. They are both significant with different signs. The contemporaneous millet price of adjacent locations has a positive impact (**0.28**) while its lagged term has a negative (**-0.23**).This fact may lead a neutral indirect effect (to be confirmed by results in columns 2 to 4). The last significant parameter equals **0.09,** which means sorghum price could have a positive direct effect on the millet price. Other parameters are not significantly different from zero. These results have to be confirmed by results in columns 2 to 4.

Table 4.1 ***Millet market integration results using SDPD***

Explanatory variables	Spatial first-differences SDPD and effects estimates			
	Coef	Direct	Indirect	Total
	(1)	(2)	(3)	(4)
Millet (-1)	**0.68**	**0.67**	-0.00	**0.67**
	24.4	17.58	-0.49	16.6
W*Millet (-1)	**-0.22**			
	-3.26			
W*Millet	**0.28**			
	3.71			
Maize	0.02	0.02	0.000	0.02
	0.60	0.50	-0.06	0.48
Rice	0.04	0.051	-0.00	0.05
	1.15	1.04	-0.22	1.00
Sorghum	**0.09**	**0.10**	0.00	**0.10**
	3.96	2.63	0.79	2.57
W*Maize	-0.01			
	-0.34			
W*Rice	-0.02			
	-1.10			
W*Sorghum	0.01			
	0.50			
Number of Observations	1057			
Fisher Stat	0.26			
tau+rho+eta	**0.79**			
Wald-test	**23.35**			
P-value Wald test	0.00			

Source: Authors' calculations.

Note: The numbers in (.) are the asymptotic t-statistic.

The convergence effect, the effect due to the temporal or spatial lag of the dependent variable, here the millet price, showed a positive and significant direct effect (**0.68)** and a non-significantindirect effect. The direct convergence effect means that there is a price transmission over time of **68**percent for Niger millet market. An increase in the previous price of millet is transmitted to its current level for about 68 percent. This parameter is the price transmission elasticity of millet price from one period to the next. Since the indirect convergence effect is not significant, this 68 percent price transmission is only a region specific price transmission. There is no cross-regions price transmission in Niger millet market. Concerning the impact of the price of millet's substitute commodities (maize, sorghum, and rice), we found that a change in the price of maize or rice had no direct nor indirect impacts on the millet price. Conversely, an increase of the price of sorghum significantly increased the price of millet. In fact, the direct effect of sorghum price is significantly positive and equals **0.10.** This means that a change in the price of sorghum is transmitted to millet price for about 10 percent. This finding could be seen as evidence of the fact sorghum is a substitute for millet.

Two interesting findings are from these results. First, there is no cross-regions price transmission for millet market in Niger. This means that a price change in one location had likely no effect on price level in other locations. Many reasons could be given to explain such situation. Among them, we found (1) high transportation cost, (2) malfunctioning transport service (lagged transmission), (3) imperfect substitution of goods, (4) lack of price information, and (5) installed infrastructures (Badiane and Shively 1998, Ghosh 2011, Rashid et al. 2008, Minot 2010). Even though each of these factors could explain the inexistence of price transmission across regions, transport-related factors and infrastructure would be the most important factors in Africa in general and Niger specifically. Limited road infrastructure is available in Africa. Therefore, transports costs are high compared to other regions of the world (Macchi and Raballand , 2009; Teravaninthorn and Rabelland, 2009). Due to a lack of adequate infrastructure, the transportation of commodities took too much time. This situation could constitute a caveat for price transmission since traders cannot access readily available price information.

Second, only sorghum, a locally produced and consumed cereal (less than 2% of imports), affects the price of millet. Maize and rice, which mainly depend on imports, have no impact on millet market. Even though each of the aforementioned cereals were natural substitutes, their availability on local markets and the associated prices would determine consumers' choices. Millet and sorghum, which are locally produced and consumed, are likely to be the first choices of the population. Results also confirmed that Niger's top cereal imports, rice and maize, are not substitutes for locally traded commodities such as millet and sorghum. In the local market, exception to rice, these cereals have similar prices and dynamics (Figure 4.1). Therefore, the inexistence of price transmission from maize to millet is likely due to availability and consumers behavior. For rice, this could be explained by the price gap—rice price is about 2 to 4 times the price of millet (SIMA, 2013)— and the fact that in many West African countries, rice is considered a luxury good, and is generally only consumed during special events (FAO, 2009).

5. Conclusion

Price transmission is an important research topic from a scientific and policy perspective. The recurring commodity price spikes, especially the recent food price crisis, have revived the debate on the issue of market integration and best policy response. Price transmission occurs from one period to another and between separate locations. This study is one of few that suggest the use of a dynamic spatial econometrics framework for the analysis of price transmission and thus the integration of markets. As an application, the SDPD model has been used to analyze the price transmission on the millet market. Our results revealed (i) a cross commodities price transmission between locally traded commodities (millet and sorghum), (ii) no significant price transmission between locally traded cereals (millet and sorghum) and regionally, or internationally traded cereals (rice and maize), and (iii) nosignificant spillover or diffusion effects (cross regions price transmission) for cereals market. These findings have some policy implications. Since absence of cross regions price transmission (market integration) is due to poor infrastructures and institutional facilities, government of Niger should strategically invest in appropriate infrastructures that will improve cereal markets integration. Millet and sorghum are essential for food security in Niger, and given the fact they are segmented from most imports cereals, it would be interesting for government to promote their production, which may be a good resilience strategy for consumers. In addition, storage facilities development can reduce their post-harvest losses and allow a better food availability in the country.

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THEMATIC SET

G42

ESTIMATION AND CLASSIFICATION OF LAND COVER AND LAND USE AREAS

Session Organizer
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Validation of copernicus land monitoring services and area estimation

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The Italian land use inventory for assessing land use changes in Italy during last decades

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Land cover change and rural livelihoods: a spatial analysis on Northern Ghana

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Area estimation by integration of line transect sampling and multi-source remote sensing data

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Use of Remote Sensing in Estimation of Agricultural Land

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ABSTRACT

Mexico's staple crops such as corn, kidney bean, wheat and sorghum are present throughout the country, therefore, it is important to identify their distribution patterns and estimate their area every agricultural cycle. For that purpose, we identify the areas that concentrate 90% of the planted area per state, then, we select samples by means of statistical and environmental criteria. Along with the field work, we acquire satellite imagery. Before the classification process, it is necessary to apply geometric and radiometric corrections and identify the crop mask. Ground truth, obtained from the field work, serves to analyse spectral signatures, histograms and scatter plots of crops or other land cover. Maximum likelihood is the classification method used and, in order to improve the agricultural parcels geometry, a post-classification is applied. Prior to the publication of these results a Kappa analysis is implemented, the results accuracy is regularly above 85%. The general results show, for the agricultural year 2015, an estimation of 5 897 499 hectares for corn, 1 545 766 for kidney bean, 1 884 748 for sorghum and 810 840 hectares for wheat.

1. Introduction

Mexico’s population growth and the increase of foreign demand for agricultural productshave resulted in a biggerrequest of farmingresources for this country. So, the knowledge about the amount of production and its localization increases in relevancy. Because of this, to get timely and reliable information about the sown area for the crops of interest in favour of the agri-food security at a national scale becomes essential.

Remote Sensing (RS), Statistics, *Geographical Information Systems* (GIS) and *Global Positioning Systems* (GPS) provide accurate information about the elementsalong the Earth's surface. Through RS, information about the land cover can be achieved without being in direct contact with it (Chuvieco, 1995). Statistics provides sampling methods applied to the natural communities, GIS processes contribute with the data analysis and output generation (Gómez y Barredo, 2005) and using the GPS technology, any object can be geographically located.

Traditionally, agricultural surfaces were estimated using methods which didn't include precision parameters. Nowadays, they are obtained through the *Area Frame Method*, where sown areas can be estimated using statistical sampling and RS (Ambrosio y Alonso, 1993; Gallego, 1995).Since the 90's decade, in Mexico, it has being planned to get the farming statistics through anAreaFrame, agricultural stratum collection and use of RS. In 2004, collegiate organizations of the *Ministry forAgriculture, Livestock, Rural Development, Fishery and Food Supply* (SAGARPA because of its name in Spanish) launched the *National Surface, Production and Efficiency Estimation Plan*, and, based on this, the *Agri-food and Fishery Information Service* (SIAP, because of its name in Spanish) adopted, in 2007, part of the European Union's *Monitoring Agriculture with Remote Sensing* (MARS) method, to generate the geo-referenced crop areas.

The MARS methodstates a sampling strategy for the evaluation. It is a stratified random area sampling, in which (i) the sampling frame is part of the territory, supported by topographical maps, (ii) the sampling unitsare 700 meters long per side squares and (iii) the stratification criteria is the land use, considering from 6 to 10 stratum or land use types (Gallego y Delince, 1991a in Deppe, 1998). The relative accuracy of this method has being estimated as 1.53 for wheat and 1.31 for barley. For the rest of the principal crops, accuracy has resulted similar (Gallego y Delince, 1991b in Deppe, 1998).

Mexican variety of ecosystems causes a heterogeneous agricultural development. Because of this, the method to estimate the crop surface has being adjusted through RS, considering the MARS method principles (Gallego, 1995). Specifically, SPOT sensor imagery is used, which has being used for diversepurposes (Valdez, González y De los Santos, 2006; Aguilar et al, 2012).

Considering all of these, we have set the objective of estimating, at national level, the area for crops of interest through Remote Sensing.

2. Method

Figure 1presents a general overview ofthis method. It consists of the following stages: sampling design, fieldwork, satellite images acquisition, digital image processing and supervised classification. It was performed for thetwoagricultural cycles considered in México: spring-summer (PV because of its name in Spanish; from April to October) and autumn-winter (OI because of its name in Spanish; from November to March).

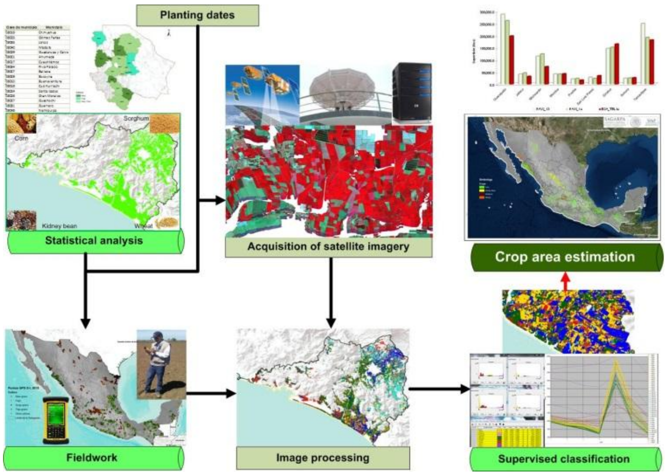

Figure 1: *General overview of the method*

2.1 Sampling Design

The sampling universe was the list of municipalities (4,475) in the Web Agriculture and Livestock Network (RAW, because of its name in Spanish) database. It contains information at national, state and municipality level about sowing and harvesting progress corresponding to both cycles, for irrigation and seasonal regimes. Specifically, the reported information for 2014 was used.

The sampling method is targeted, stratified by conglomerate in a single stage and systematized with a distribution proportional to the whole of the sowed surface for each conglomerate. It is targeted because the information is obtained in sampling units which the field technician assumes as representative. It is stratified by the land use and crop type; and it is conglomerated by the geographical location of each federal entity. It is considered as in one stage because the primary sampling unit for each conglomerate is the municipality, and the sampling unit is a geographical point registered inside an area sowed of the crop of interest. It is systematized because the basic units are organized from most to less sowed surface, so the bigger amount of the sampling units will be placed where most of the sowed surface is located, in a proportional distribution.

2.2 Sampling Selection and Calculation

For each strata (corn, kidney bean, sorghum and wheat) and federal entity, the municipalities which together represent 90% of the sowed surface, are selected. The sampling space for each municipality considered 3% of the sowed surface. The MARS method (Gallego, 1995) was modified as a response to the specific heterogeneity and crop diversity conditions and the available resources. The number of sampling points was determined with the following formula:

$$n = \frac{Z^2 pqN}{(N-1)\varepsilon^2 + Z^2 pq} \tag{1}$$

Where

n= Number of points.
Z= Confidence level (90%).
p= Positive variability (90%).
q=Negative variability (10%).
N= Population size.
ε= Accuracy error (15%)

2.3 Fieldwork

22,573 GPS points were considered for the 2015 exercise, being 17,805 for the PV cycle and 4,768 for the OI cycle. Table 1 presents their distribution.

Table 1:*Stratified samplingdistribution*

Cycle	Corn		Kidney Bean		Sorghum		Wheat	
	Surface (ha)	Points	Surface (ha)	Points	Surface (ha)	Points	Surface (ha)	Points
PV	172,232	11,855	39,564	3,317	24,651	1,989	2,625	644
OI	30,673	2,435	5,584	1,007	22,676	569	19,430	757
Total	202,905	14,290	45,148	4,324	47,327	2,558	22,055	1,401

Once the number of samples was defined for each crop and municipality, the sowing dates are consulted. Considering this, field work and the acquisition of satellite images are scheduled, which is planned to be when crops are in flowering and fruiting(Fernandez, Gepts y López, 1986).

Each GPS point should be 50 m inside the plot, being each one about 1 km far from the nearest. Each plot should be at least 0.5 ha big. The information collected at each pointwas: crop, crop's height (in meters), approximated property's surface, phenological stage, variety, water regime, percentage of ground covered by the crop, weed percentage, sinister, north, south east and west bordering crops, and 2 geo-referenced pictures.Besides local particularities, from July to September, for the PV cycle; and from January to March, for the OI cycle, have resulted the adequate months for the fieldwork.

2.4 Satellite Image Acquisition

Considering the sowing dates, the satellite image acquisition is requested to the *Mexico Receiving Station* (ERMEX because of its name in Spanish), which is the Mexican facility for the management of the SPOT images. For this study, they should be ortho-rectified, a maximum cloud cover of 10% and an incidence angle range of 20° to 25°.In the PV cycle, there were used 1,475 images, and in the OI cycle 1,064 images were used.

2.5 Digital Images Processing

In order to perform the supervised classification, the digital levels (DL) of the image should be expressed in reflectance values. For this, a radiometric correction should be performed.

As long as the surface estimation should be focused on the agricultural area, the satellite images were cut with the geographical delimitation of said areas, which SIAP has available (Figure 2).

a) b)

Figure 2: *Satellite image before (a) and after (b) cutting of non-agricultural areas*

2.6 Supervised Classification

A supervised classification is performed to the satellite images, supported by the fieldwork, to get the above stated classes, including the “other coverings” one (other crops, highways, roads, canals and water bodies). The band configuration to make this identification is false color, which is obtained by placing the near infra-red, red and green bands in the red, green and blue order, which is the 4,3,2 combination for SPOT 6/7. These bands are chosen because they have the greater original variance content (Chuvieco, 1995).

The training phase is fundamental in the supervised classification. In it, several factors should be considered, since they influence in the reflectance for each selected band. For example, this can result in a category expressed in several spectral classes, two or more categories expressed in a single spectral class, or several categories expressed in several classes. For each training field, homogeneous samples or variable surfaces for the same category are sampled. Each one of these should be composed of a number of pixels between 10m and 100 m for each category (Jensen, 1986& Mather, 1987 in Chuvieco, 1995), considering the physical variations of the Earth surface.

These variations are evaluated through a spectral signature and a separability analysis. The advantage of the spectral signature analysis is to highlight the pixels that belong to a certain category, according to the parallelepiped decision rule. Meanwhile, the separability analysis calculates the statistical distance between signatures, which can be used to determine the best group of elements that will be used in the classification.

In the assignation phase, using the maximum likelihood method each element is assigned to a category assuming it has a normal distribution. Considering this, knowing the mean and standard deviation for each category, the probability of association to it can be estimated. The post classification process consists in a generalization according to the variability of the categories, according the neighbor ones and, if applicable,integrates them. When there are isolated pixels, they are assigned to the dominant category. Also, when a pixel is smaller than 0.25 ha, it is assigned to the neighbor category.

To evaluate the classification, 3% of the field samples are used in a confusion matrix, which expresses the conflicts between classes. Due to its configuration, it can be identified what was correctly classified according to what was sampled in the fieldwork, and mistakes of classifying what is not present in field or elements in reality which are not represented in the classification. The proportion of the correctly classified points and the overall is the reliability of the map (Chuvieco, 1995).

3. Results

In the 2015 exercise, geo-referenced information was sampled for 25,392 plots, being 18,157 for the PV cycle and 7,235 for the OI cycle (Table 2).

Table 2: *Plots sampled during 2015*

Cycle	Corn	Kidney Bean	Sorghum	Wheat
PV	12,690	2,528	2,511	428
OI	3,450	807	1,020	1,958
Total	16,140	3,335	3,531	2,386

About the separability analysis, the "other crop", "forest", "soil" and "protected agriculture" are easily distinguished form the crops of interest. Separability between the crops of interest defines that it is easily identifiable from sorghum, sorghum from wheat and kidney bean from sorghum. In order to validate the sowed surface for the crops of interest, 3% of the points of each one were used. They were 2% more than those stated by Congalton (1988b) in Chuvieco (1995).

Based on the fieldwork information, agriculture coverage, satellite images and these processed, the spatial distribution of the sowed surface of the crops of interest is presented. Specifically about the PV cycle, corn is present almost in all the agricultural area of the country, principally in the Transversal Volcanic System, meanwhile kidney bean has is more present in Zacatecas and Durango, and sorghum and wheat are dominant principally in Tamaulipas, Sinaloa and Guanajuato.

This evaluation assigned correctly 484 of 542 GPS points (Table 3). Corn and sorghum were confused, because in their development stage they have a similar spectral behavior. Also corn and kidney bean were confused, that is because, especially in the central and southern part of the country, they are sowed associated. Other factor that affect is the continuous presence of clouds. The overall reliability of this cycle is of 89.3%

Table 3: *Confusion matrix for the PV cycle*

	Map class	Corn	Kidney bean	Sorghum	Wheat	Total	User's accuracy	Commission error
Field class	Corn	366.0	21.0	9	0	396.0	92.4	7.6
	Kidney bean	4.0	50.0	0	1	55.0	90.9	9.1
	Sorghum	15.0	3	61.0		79.0	77.2	22.8
	Wheat	3	2	0.0	7.0	12.0	58.3	41.7
	Total	388.0	76.0	70.0	8.0	**542.0**		
	Producer's accuracy	94.3	65.8	87.1	87.5			
	Omission error	5.7	34.2	12.9	12.5			

For the OI cycle, corn was located principally in Sinaloa, wheat in Sonora and Baja California, sorghum in Tamaulipas and kidney bean is relatively low in presence.

The classification for the OI cycle assigned correctly 201 GPS points of the 215 of the total (Table 4). As happened in the PV cycle, corn still presents confusion with kidney bean and sorghum. The reliability of this classification was of 93.5%. This is because most of the agriculture is of irrigation regime and also this classification has improved because there were fewer clouds in the images.

Table 4: *Confusion matrix for the OI cycle*

	Map class	Corn	Kidney bean	Sorghum	Wheat	Total	User's accuracy	Commission error
Field class	Corn	98.0	1.0	2	0	101.0	97.0	3.0
	Kidney bean	5.0	20.0	0	0	25.0	80.0	20.0
	Sorghum	3.0	0	30.0	2	35.0	85.7	14.3
	Wheat	0	1	0.0	53.0	54.0	98.1	1.9
	Total	106.0	22.0	32.0	55.0	**215.0**		
	Producer's accuracy	92.5	90.9	93.8	96.4			
	Omission error	7.5	9.1	6.3	3.6			

Based on the analysis of these results, the surfaces inTable5 were obtained. It can be appreciated that the PV cycle has more sowed surface, since all the country is benefited by the rainy season, from May to August.

Table5: *Estimatedsowedsurface*

Cycle	Sowed Surface (Millions hectares)			
	Corn	Kidney Bean	Sorghum	Wheat
PV	5.0	1.1	1.2	0.2
OI	0.9	0.2	0.7	0.7

4. Discussion and Conclusions

The results obtained by the modified MARS method and those obtained by a traditional agriculture surface estimation are presented inTable 6. In the PV cycle, the difference is 0.1 ha (1.3%) and for the OI cycle is 0.2 ha (8%).

Table 6: *Estimated surfaces by both methods*

	Surface (Million Ha)	
Method	PV	OI
Modified MARS	7.5	2.5
Traditional	7.4	2.3
Difference	0.1	0.2

Both methods were different in the estimated amount of surfaces. These differences may have being caused by the physical configuration of the terrain or the specific parameters the sensor had at the moment the image was taken.

The use of a method supported by RS and Statistics provides various benefits to the agricultural land estimation, such as the possibility of performing it on big surfaces. Also, due to the stock images, comparisons along time can be done. Also, the possibility of coordination between the dates of the fieldwork and capture of the satellite image allow a more detailed estimation. In this scenario, the satellite information will match to that reported in the RAW, so some specific variations can be ignored.Applying specific statistical methods, the sampling process presents a concrete focus. In this way, integrating the RAW information will provide important improvements to the sample design.

It is important to establish that merging the benefits of the incorporation of these two disciplines, big optimizations of economical and human resources will be achieved. Although, it has to be considered that this innovations is in a development stage and it has to be subject to different evaluation process.

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Validation of Copernicus Land Monitoring Services and Area Estimation.

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ABSTRACT

Small photographs.

Keywords: Land cover area estimation, High resolution satellite images, Area frame sampling.

1. Introduction

The Land Monitoring Service of the EU (European Union) Copernicus programme (land.copernicus.eu) includes High Resolution Layers (HRL) that provide information on specific land cover characteristics produced from 20 m resolution satellite imagery. The main 5 themes covered are: imperviousness, (sealed soil), tree cover density and forest type, permanent grasslands, wetlands and water bodies. Pixels of 20 by 20 m are aggregated into 100 by 100 m grid cells for final products. The imperviousness layer was the first one to be produced in 2006-2008. New imperviousness layers have been produced for 2009 and 2012. They cover the 33 Member States of the European Environment Agency (EEA) and 6 associated West-Balkan countries representing a total of 6 million km². Some countries are missing at the time of drafting this paper (Spain, Greece, Cyprus and the French overseas regions are missing). The imperviousness HRL captures the spatial distribution of artificially sealed areas, with a degree 1-100% is produced using an automatic algorithm based on a calibrated normalised difference vegetation index (NDVI). The methodology was described by Gangkofner et al. (2010) for the 2009 update and by Lefebvre et al (2013) for the 2012 update. Similar methods have been also applied in the USA for the development of the National Land Cover database (Xian et al. 2011). A density threshold of 30% was used to derive a 0-1 mask. In Europe, it is currently estimated that artificial areas represent less than 5% of the total EEA39 (Büttner et al. 2012) and impervious surfaces only represent a subset of this area. Because of this relatively low share, commission and omission errors may be high even when the overall accuracy of the layer is apparently good.

2. Sampling Scheme.

Similar products are provided by the National Land Cover Database of the Conterminous United States (Wickham et al. 2013) and a recent study from Hansen et al. (2014). Wickham et al. (2013) applied a stratified random sampling approach using the land cover classes as strata. For the European Imperviousness layer, a similar approach was applied but based on a stratified systematic sampling approach using the LUCAS sampling frame (Gallego and Delincé 2010) targeting also imperviousness changes for which relatively low accuracies are reported, in part because the area increase occupies a very small proportion of the total land area. Using the LUCAS based approach improves traceability and sample sharing for assessing several products. Estimation domains are countries or groups of countries with an area greater than 90,000km². In each domain 6 strata were determined as follows:

- Commission 2006-2009-2012: Imperviousness Degree 30-100% in 2006-2009-2012. This category is divided into two strata defined by intersection with the CORINE Land Cover (CLC) artificial and non-artificial classes.
- Omission High Probability 2006-2009-2012: Imperviousness Degree 0-29% & CLC impervious classes 2006-2009-2012
- Omission Low Probability 2006-2009-2012: Rest of the area 2006-2009-2012
- Commission Change 2006-2009: all changes
- Commission Change 2009-2012 : all changes

A sample of 20,164 PSUs (primary sampling units) was selected. PSU were squares of 100 m × 100 m. It was decided to select a minimum of 50 PSU per stratum in each of the 23 zones. In each PSU a grid of 5 x 5 Secondary Sample units (SSUs) with a 20 m step is selected and photo-interpreted on orthophotos (figure 1). If a point falls on the boundary of an impervious element, a shifting rule is applied so that roughly half of the points in this situation are classified as impervious.

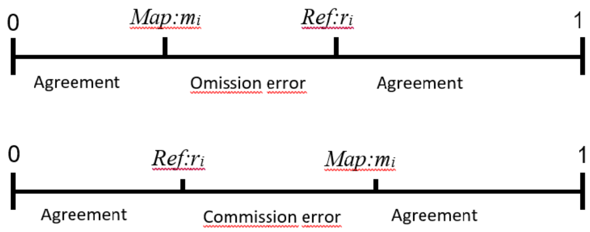
Figure 1: *Example of PSU with a grid of points.*

3. Thematic accuracy.

The usual validation scheme for land cover maps or satellite image classification is based on confusion matrices that assume sharp categories (Congalton and Green, 1999): each point is allocated to one single category as well as each validation unit. When both validation data and product under validation are continuous, a confusion matrix approach can be used by applying a threshold to produce a mask. For the Copernicus imperviousness layer, a threshold of 30% had been foreseen. However better alternatives can be found in the modelling literature to deal with quantitative products (Wilmott, 1981, Legates and Mc Cabe, 1999, Duveiller et al., 2016). Agreement indicators for quantitative parameters have been also widely used in the remote sensing literature (Ji and Gallo, 2006, Silván Cárdenas and Wang, 2008, Meroni et al., 2013).

Among the indicators that have been proposed, we have chosen to quantify the disagreement at the PSU level as the difference between the map value m_i and the reference r_i. If the map value is larger than the reference value for a PSU, it will contribute to the commission error, but it will contribute to the omission error if the oposite happens (Figure 2).

Figure 1: *Commission and omission errors with continuous data between 0 and 1.*



The commission φ and omission ψ errors would be computed as:

$$\varphi = \frac{\sum_i w_i\, pos(m_i - r_i)}{\sum_i w_i\, m_i} \qquad \psi = \frac{\sum_i w_i\, pos(r_i - m_i)}{\sum_i w_i\, r_i} \qquad (1)$$

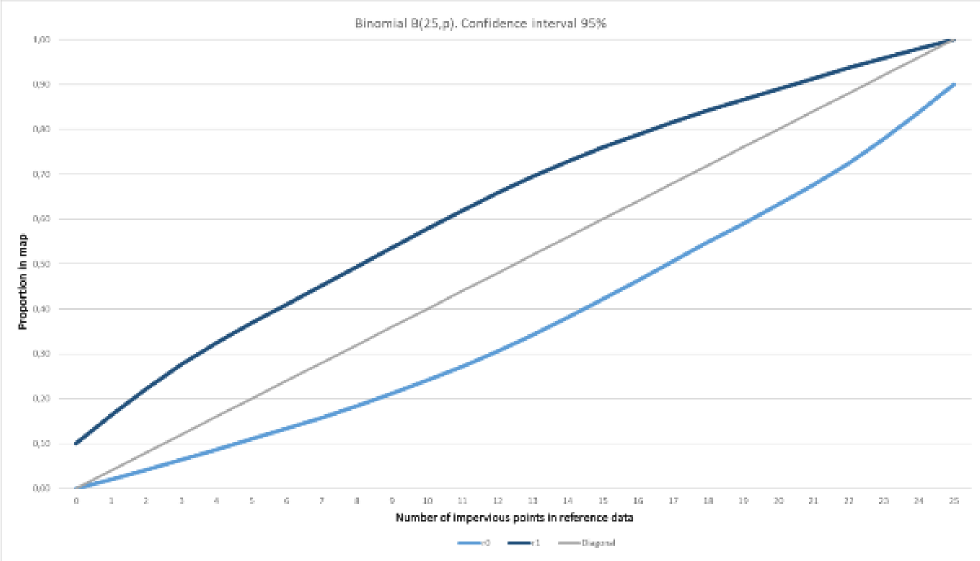
and the overall accuracy $$\theta = \frac{\sum_i w_i\, (min(r_i, m_i) + min(1 - r_i, 1 - m_i))}{\sum_i w_i} \qquad (2)$$

where w_i is the extrapolation weight (inverse of the sampling probability) and $pos(x)$ is the positive part. With these criteria we have a commission error of 21.9% and an omission error of 40.2%, even if the overall accuracy is 98.4%. Part of the disagreement between reference comes from the incomplete information on the cell for our reference data: if we assume that the map and the reference data are in perfect agreement, there would be still a difference between m_i and r_i because the spatial support is different: m_i refers to the whole PSU while r_i refers to a sample of points inside. Our r_i has a probabilistic distribution that we can approximate by a binomial B(25, p_i) with a somewhat lower variance due to the systematic sampling. This has an impact on the expected commission and omission errors. One possible way to take this into account is delineating a confidence band under the null hypothesis $m_i = p_i$ (figure 3). For any pair (r_i, m_i) inside this band we are not reasonably sure that $m_i \neq p_i$. A possible way to deal with this source of uncertainty is quantifying the commission and omission errors:

$$\varphi = \frac{\sum_i w_i\, pos(m_i - r_{0i})}{\sum_i w_i\, m_i} \qquad \psi = \frac{\sum_i w_i\, pos(r_{1i} - m_i)}{\sum_i w_i\, r_i} \qquad (3)$$

where r_{0i} and r_{1i} are the closest points in the confidence band. With these criteria the commission error is around 10% and the omission error around 20%.

Figure 3: *95% confidence band (r_i,m_i) under the hypothesis $m_{i=}$ p_i.*



4. Area estimation.

A naïf approach for area estimation using classified satellite images is pixel counting or equivalent for classifications that focus on the proportion of a parameter, as it happens in our case:

$$\tilde{A} = \sum_i m_i \qquad (4)$$

The result for this estimator for the zones covered at the moment (excluding Spain, Greece, Cyprus and French overseas territories) is 2.06%, approximately 107,000 km^2. It is well known that this area estimation has a bias that can be very large (Bauer et al, 1978, Houston and Hall, 1984, Czaplewski, 1992) and roughly corresponds to the difference between the commission and the omission errors (Carfagna and Gallego, 2005). A simple reasonable idea may be correcting the bias with the difference between the commission and omission errors computed on a confusion matrix. Unfortunately it is still frequent that remote sensing practitioners compute confusion matrices on the basis of a purposive set of units instead of a proper probability sample. In the scientific literature purposive samples have nearly disappeared thanks to the effort of a number of authors (Congalton and Green, 1999, Stehman, 2009, Olofsson et al., 2014), but they are still frequent in reports of projects carried out for various institutions and remain unpublished. We can simulate a purposive sample using our sample by omitting the weights in equations (1). We would get table 1 that suggests us reducing the estimate by approximately the difference between 26.6% (apparent commission error) and 20.8% (apparent omission error) to obtain an estimate just above 100,000 km^2. If we apply the correct weights we get the confusion matrix in table 2, in which we find that the omission error (40.7%) is much higher than the commission error (21.9%). The figures of the confusion matrix can be interpreted as area in km^2 and we can obtain an area estimation by adding something that is close to the difference (40.7-21.9)%. A better estimate is obtained by simply adding the difference between the off-diagonal terms: 107,000+57,000-23,200 ~ 140,000 km^2, i.e the 2.74% of the territory.

Table 1: *Unweighted confusion matrix.*

		Map Impervious	Other	Total	Omission error
Reference	Impervious	4280.4	1124.1	5404.5	**20.8%**
	Other	1553.3	13041.2	14594.5	
	Total	5833.7	14165.3	19999	
	Commission error	**26.6%**			

Table 2: *Weighted confusion matrix.*

		Map Impervious	Other	Total	Omission error
Reference	Impervious	82859	56981	139840	40.7%
	Other	23232	4961592	4984824	
	Total	106091	5018573	5124664	
	Commission error	21.9%			

The most reasonable principle is combining the two sources of information we have: more accurate data on a sample and less accurate but nearly-exhaustive information from the image classification (i.e. the imperviousness layer we are validating). We have given above a coarse view on starting with remote sensing based estimates using reference data on a sample. The opposite approach is more frequent: a sample-based estimate modified using the co-variate provided by a classified image. At the first step of this approach we compute an estimate of 139.800 km^2 with a coefficient of variation of 3%. The estimate is very close to the estimate obtained with a simple correction on commission-omission errors computed from the weighted confusion matrix. The observation of the variances by stratum, not reported here, suggests that major improvements can be obtained by applying a Neyman allocation in the future.

A better estimator is generally obtained combining the more accurate data on a sample (reference data) with less accurate exhaustive data obtained from satellite images. If both data are quantitative, the standard technique to do so is the regression estimator (Cochran, 1977). For the impervious areas in 2012 in the zones considered for the Copernicus validation, table 3 reports the naïf estimator obtained directly from the image-derived values, the stratified sampling estimator from the reference data and the stratified regression estimator. Just by chance the overall regression estimator for the study area nearly coincides with the extrapolation from the reference data (139,800 km^2) with a coefficient of variation of 2.77%. This means that the relative efficiency is around 1.17, a rather modest value.

Table 2: *Different estimates of impervious areas in 2012 (in km^2).*

	Naïf from image	From reference data	Regression estimator	CV regression (%)
Turkey	6342	11032	10914	23
France	15566	21111	21827	5
Sweden	2156	5223	5196	15
Germany	18346	16999	17269	4
Finland	2010	2472	2448	15
Norway	895	1395	1457	11
Poland	7831	8354	8239	9

Italy	11449	19894	19776	7
UK-Ireland	9611	16212	15641	7
Romania	3915	4044	3864	14
Bulgaria	2154	1680	1692	6
Iceland	142	81	82	3
Hungary	2987	2830	2708	10
Portugal	2719	2778	2798	7
AT-CH-LI	2877	4397	5629	7
BENELUX- DK	7237	9535	8650	7
AB-MN-MK-SB-KO	2194	1833	1784	8
SI-HR-BH	2116	2488	2284	13
CZ-SK	3989	5410	5350	9
Baltic Republics	2426	2065	2225	15

5. Conclusions.

The direct area estimation by pixel counting in a classified image, or equivalent approaches, is known to have a bias because commission and omission errors. We have illustrated with the example of the estimation of impervious areas in Europe that a simple correction of bias using a confusion matrix gives acceptable results if the confusion matrix has been properly weighted with the inverse of sampling probabilities. In exchange if these weights are ignored, the correction can be completely wrong and even "correct" the estimates in the wrong direction. In our example the bias of the naïf (direct) estimation of impervious area from classified satellite images is above 20%, even if the overall accuracy of the classification is above 98%. This observation has an implication on the use of remote sensing for area estimation that is not new, but is worth reminding:

- the risk of bias in direct area estimation from classified images is particularly strong if the targeted classes occupy a small proportion of the geographic area.
- Bias correction with a sample of more accurate and approximately unbiased data requires applying the correct weights from the sampling plan.

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The Italian Land Use Inventory for assessing land use changes in Italy during last decades

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ABSTRACT

The aim of this paper was to collect research regarding the analysis of land use and land cover changes (LULCC) made with the different approaches and methodologies in the last few years on the Italian territory. The LULCC can be analysed using both cartographic and inventory approaches. The latter, in particular, provide estimates of the accuracy of the sampling strategy adopted , allowing objective and scientifically sound comparisons of the estimates at different times. The possibility to assess the statistical accuracy and the possibility of frequent updates, suggest the inventory approach as a valid and reliable instrument for the LULCC assessment. The evaluation of LULCC and the selection of a reliable and accurate approach usable as a standard for

a large series of experiences, plays a primary role as a support for future land use planning. In this perspective, the Italian Inventory of Land Use has been further implemented during last years to better understand LULCC, their causes and possible effects on ecosystem services, thus offering a valuable support for future land use planning.

Keywords: Land Use, Land Cover, Multitemporal analysis, Inventory, monitoring

1. Introduction

Since the Industrial Revolution, and particularly after the World War II, the socio-economic dynamics have strongly exacerbated the land use and land cover changes (LULCC), particularly in Developed Countries, such as e.g., Italy. LULCC alter the ecosystems' structure, functionality, as well as their capacity to provide goods and services supporting human wellbeing (e.g., Foley et al., 2005). Furthermore, it is now evident that rapid changes in ecosystems, especially if driven by human activities, significantly affect the ecological resilience (Vizzarri et al., 2015). Monitoring LULCC and assessing the related impacts on resilience and Ecosystem Services (ES) are crucial to support adaptive governance, as well as to evaluate the effects of the currently implemented actions on sustainability. Consequently, the development and implementation of new methodologies and approaches to face these needing represent active and stimulating fields of research (e.g. Vizzarri et al. 2015).

Cartographic and inventory approaches are used for LULCC analysis, through applying different methodologies and nomenclatures strictly according to their aims and scopes (Corona, 2010). For example, land use inventories aim to provide statistically sound estimators of land-use proportions and related changes for a given time-span in a study area. This need is satisfied by applying different sampling strategies aimed at maximizing statistical accuracy and data reliability, while minimizing sampling costs and duration. Otherwise, for mapping, the demand is for a graphical depiction of attributes location within a study area, which is useful for the spatially-explicit investigation of certain phenomena. The choice of the most appropriate approach is not then an easy task, since it is related to different aspects, such as time, costs, objectives and data reliability. In this context, the aim of this contribution is to briefly present some recent outcomes and methodological remarks obtained by testing, improving and implementing the Italian Land Use Inventory (IUTI from the Italian acronym of *Inventario dell'Uso delle Terre d'Italia*) at national or regional scale in Italy. The manuscript is divided into four main sessions describing *i*) the characteristics and main aspects of IUTI; *ii*) the LULCC affecting the Italian landscape during the last 20 years; *iii*) the maximisation of the informative power of IUTI through integrating inventory and cartographic approaches, as well as LU and LC meanings; and *iv*) some final comments and remarks.

2. The Italian Land Use Inventory (IUTI)

IUTI has been promoted and implemented by The Italian Ministry of Environment and Protection of Land and Sea in the framework of the Extraordinary Plan of Environmental Remote Sensing as a key instrument of the National Registry for forest carbon sinks (Marchetti et al., 2012). The Italian territory was covered by a network of 1,217,032 quadrats of 25 ha, in a way that each quadrat contained at least a portion of this territory. Hence, in accordance with the protocol of tessellation stratified sampling (TSS), a point was randomly selected in each quadrat (Fattorini, 2014). The large sample size adopted in IUTI was due to the need for estimating LULCC with adequate statistical accuracy, even estimating small changes that are likely to occur during brief temporal intervals (Corona et al. 2012a). The sample points were photo-interpreted on high resolution imagery available for the years 1990, 2000 and 2008 to estimate LULCC over the time. Those points that fell outside the Italian territory were classified in an additional class (i.e. "outside area"), while the others were classified in 9 LU classes divided into 3 hierarchical levels. The analysis of LU and LC changes is based on the construction of a transition matrix, also known as a cross-tabulation matrix (Pontius et al. 2004) (e.g., Table 1 shows the Italian transition matrix from 1990 to 2008).

		2008									
		Forest land	**Arable land**	**Orchards, vineyards and nurseries**	**Forest plantations**	**Natural grassland and pastures**	**Other wooded land**	**Wetlands**	**Settlements**	**Other land**	**Total**
1990	**Forest land**	9,014,117	30,192	13,573	975	13,446	37,213	9,497	21,118	1,225	9,141,355
	Arable land	184,398	9,586,594	789,148	69,470	154,166	128,526	15,374	387,391	150	11,315,217
	Orchards, vineyards and nurseries	35,547	272,931	2,269,752	775	21,650	16,571	575	64,962	0	2,682,761
	Forest plantations	3,847	51,692	1,249	67,659	2,773	2,349	1,249	3,273	0	134,091
	Natural grassland and pastures	138,121	60,692	22,573	4,224	1,662,343	276,904	5,349	24,998	550	2,195,754
	Other wooded land	256,716	48,566	17,072	750	9,449	1,513,565	7,399	13,097	525	1,867,138
	Wetlands	14,696	1,225	425	400	2,999	11,224	476,768	1,500	825	510,061
	Settlements	5,023	4,174	950	125	5,250	3,724	1,250	1,623,439	75	1,644,010
	Other land	750	75	25	0	2,373	1,125	1,125	1,125	651,691	658,288
	Total	9,653,216	10,056,141	3,114,765	144,376	1,874,449	1,991,200	518,586	2,140,903	655,040	30,148,676

Table 1: *Transition matrix of the changes which occurred in LU from 1990 to 2008 in Italy.(Source: Marchetti el al., 2014a).*

Additionally, during 2013, the IUTI database was updated using a 1% subsample within the whole national territory (about 13,000 sample points), thus obtaining an estimation of the LULCC trends for that year. For reducing the sampling efforts, the one-per-stratum stratified sampling (OPSS) has been adopted. The results from Fattorini et al. (2015) showed that in front of a reduction of the on-screen classification effort of 100 times, the RSE estimates increased by approximately 10 times. In absolute terms, these results are then rather encouraging, because the largest LU classes show RSE estimates invariably smaller than 3%, while the smallest ones show RSE estimates always below 9% (Pagliarella et al., *in press*).

3. LULCC in Italy during last decades

IUTI allows to identify and quantify in a quick way and at low cost the key dynamics characterizing the landscape changes, including their impact in ecological and functional terms. At national scale, several studies have shown that, during the last 50 years, the Italian landscape has been deeply marked by industrialization, urbanization, agricultural and livestock intensification, mostly in downhill and plains. On the contrary, mountain areas are currently affected by land abandonment and spontaneous forest revegetation. Summarizing, the most important LULCC in Italy, during the last decades, were: (i) urban growth and soil sealing; (ii) loss of arable lands, meadows and pastures; and (iii) natural reforestation (e.g., Falcucci et al., 2007). In particular, forest regrowth (+1.7% of the Italian territory), primarily occurred at the expense of croplands in the hills, pastures and grasslands in the mountains; the shrinkage of arable lands (-4.2% of the Italian territory) is due to urban growth in lowlands, conversions to permanent crops in hills (mainly orchards and vineyards) and natural reforestation in mountain areas; urban area increased by 1.6% with a total coverage of settlements reaching 7.1% of the whole Italian territory in 2008. Preliminary results of the updating process in 2013, show a decreased rate of annual variation, if compared with that from the first monitoring period (1990-2008) (Sallustio et al., 2015a). Considering the first two changes (natural reforestation and land abandonment), IUTI showed that in Italy they are following a latitudinal gradient as shown in table 2. In fact, the decreases in arable lands, meadows and pastures are more marked descending from North to South (Sallustio et al., 2015a). Moreover, it is worthy to note that the loss of arable lands primarily occurs on agricultural land uses marginal in economic terms, despite it is very important from an ecological perspective (see e.g., biodiversity and cultural landscapes conservation) (Marchetti et al., 2014a). Furthermore, Marchetti et al. 2013 showed that the trends registered at national scale in Italy are not very different from those observed within the National Parks. These findings are particularly important to deeper understand to what extent the policy instruments and regulations are currently used and implemented in these areas to address conservation issues.

	North			*Centre*			*South*			*Italy*		
IUTI class	**1990**	**2008**	**Variation 1990-2008 (% of North land area)**	**1990**	**2008**	**Variation 1990-2008 (% of Centre land area)**	**1990**	**2008**	**Variation 1990-2008 (% of South land area)**	**1990**	**2008**	**Variation 1990-2008 (% of national land area)**
Forest land	33.4	34.8	+1.43	38.8	41.0	+2.24	23.3	25.0	+1.70	30.3	32	+1.7
Arable land	36.9	33.6	-3.30	38.4	34.1	-4.29	37.7	32.7	-4.97	37.5	33.4	-4.1
Orchards, vineyards and nurseries	4.2	4.6	+0.43	8.2	9.0	+0.79	13.8	16.6	+2.72	8.9	10.5	+1.6
Forest plantations	1.0	0.8	-0.11	0.1	0.3	+0.12	0.1	0.2	+0.14	0.4	0.5	+0.1
Natural grassland and pastures	7.0	6.4	-0.65	3.8	3.1	-0.76	9.2	7.6	-1.61	7.3	6.2	-1.1
Other wooded land	3.2	3.4	+0.21	3.5	3.5	+0.02	10.4	11.2	+0.79	6.2	6.6	+0.4
Wetlands	2.7	2.7	+0.01	1.1	1.1	+0.01	1.0	1.0	+0.06	1.7	1.7	+0.0
Settlements	7.0	9.0	+2.01	5.7	7.6	+1.87	3.8	5.0	+1.18	5.5	7.1	+1.6
Other land	4.7	4.7	-0.02	0.2	0.2	-0.01	0.7	0.7	-0.01	2.2	2.2	+0.0

Table 2: *Forest dynamics occurred in Italy and in the three macro-regions between 1990 and 2008. Values are expressed as surface (ha) and relative values (%) with respect to the total surface of each macro-region. (Source: Sallustio et al. 2015a).*

The urban growth is one of the most worrying LULCC in Italy, and occurs especially at the expense of arable lands and croplands in general (approximately 75%, Marchetti et al., 2012). In particular, land take occurs in lowlands and gentle slope territories, which are usually attractive for brick and mortar investments (Marchetti et al., 2014a). Moreover, this phenomenon is still also affecting regions with negative demographic balance (e.g., Basilicata, Calabria, Liguria and Molise), with a subsequent increase of their per-capita built-up area (Sallustio et al., 2013).

Using two different definitions of mountain (statistical and juridical) and comparing the LULCC occurred during the same time-span even on the entire national territory and within the National Parks, Sallustio et al., (2015b) highlighted the importance of using a clear and unambiguous definition of the study area to obtain reliable results able to effectively support a certain policy, strategy or plan (the one related to mountain areas in the specific case). In particular, they found that LULCC are very similar (for type and magnitude) both in the statistical mountain and Protected Areas case, despite they appear quite different according to the "statistical mountain" definition, and the whole national territory. This finding turned out to be an essential need also for future policies and management strategies, such as those related to the oncoming Common Agricultural Policy.

4. Beyond IUTI: how to maximize the informative power at low costs?

The lack of data and funding sources limits the research activities, and encourages researchers to optimize the freely available data, as well as maximize their informative power. This section shows the results of the two works carried out by using IUTI data to integrate inventory with cartographic approach, as well as LU with LC meaning.

4.1 The integration of inventory and cartographic approaches

Sallustio el al. (2015c) proposed and tested a method to quantify land take dynamics associated with urban growth, and estimate their effects in terms of carbon stock loss. Specifically, a method used for urban forest coverage assessment over Italy (Corona et al., 2012b) was implemented in order to estimate urban patch abundance and average size. This approach is based on integration between the inventory and cartographic approaches to estimate not only the extension of a given LU or LC class, but also the number and average size of the patches. The sampled urban patches were then used as inputs for the assessment of change in carbon loss, both in biophysical and economic terms, through using the InVEST model (Tallis et al., 2013). Analyses were performed in two very different study areas in central Italy, such as the province of Rome, the most populated and urbanized area in Italy, and the Molise region, the least dense and urbanized area in Italy. The main results are reported in Table 3, in which it is possible to appreciate the satisfactory level of accuracy of the estimates.

Study area	Year	$\hat{N}$	$se_{\hat{N}}$ (%)	$\hat{A}$ (ha)	$se_{\hat{A}}$ (%)	$\hat{\bar{a}}$ (ha)	$se_{\hat{\bar{a}}}$ (%)
Molise Region	1990	2449	10.1	9000	5.2	3.68	7.6
	2008	3455	8.5	12,850	4.3	3.72	6.2
Province of Rome	1990	10,763	4.9	81,037	1.7	7.53	4.4
	2008	13,989	4.2	109,026	1.4	7.79	3.8

Table 3: *Estimates of number of urban patches (N), urban coverage (A) and urban patch average area (a), and their estimated relative standard errors (expressed in percent).(Source: Sallustio et al., 2015c).*

Despite the low realization and updating costs, the integration of inventory and cartographic approaches is demonstrated to be a reliable estimate, enhancing their information power. Moreover, the possibility to couple such estimates with spatially-explicit tools allows the identification of ES or functions loss due to a certain LULCC of ecosystems' modification, and provides useful information for land use planning.

4.2 The integration of LU and LC inventories

There are both semantic and technical differences between LU and LC measurements. The most common definitions of LU and LC are those adopted in the Land Cover Classification System by FAO (2000), in which the former is referred to the socio-economic function of a given piece of territory, while the latter is usually related to its biophysical cover that can be directly observed in the field and registered by orthophotos. The confusion between the two concepts has existed in the literature for at least forty years (Anderson et al. 1976), leading to the spread of hybrid classification systems. However, the ability to distinguish or integrate use and cover concepts can represent a challenging opportunity for researchers.

Recently, Sallustio et al. (2016) presented an example of LU and LC inventories integration applied to the Molise region. Changes in LU and LC were evaluated from 2000 to 2012 using the IUTI sample points. The analysis was performed using both the original LU classification and through a new classification system addressing the LC. The sampling points were classified through a visual interpretation of aerial photographs for both LU and LC in order to estimate their surface and changes over time. The results demonstrated that a comparison between the two classification schemes provides an understanding of the causes of their misalignment. In fact, the aggregation proposed in table 4 indicates a good correspondence between the LU and LC estimates only for *Arable lands and Orchards, vineyards and nurseries*, whose differences are not significant. In the other cases (e.g., *Forest lands and forest plantations*, *Settlements and artificial lands*, and *Other lands*), the differences between the LU and LC estimates are highly significant. In the case of *Forest lands*, for example, such difference is 2.16%, mainly due to the LU parameters of classification used, such as the height of mature trees, the crown coverage, the extension and the minimum width of the woods (FAO, 2000), which are neglected by the LC classification.

	LU classes	**LC classes**	**LU (%)**	**LC (%)**	**LU (ha)**	**LC (ha)**	**absolute differences (%)**	**absolute differences (ha)**	**significance**
Forest lands and forest plantations	1.1- 1.2- 2.2.2	33	35.23	33.06	161,525	151,600	2.16	9,925	0.00001(*)
Arable lands	2.1	34- 43	43.33	42.66	198,675	195,625	0.67	3,050	0.19821
Orchards, vineyards and nurseries	2.2.1	32	5.82	5.89	26,700	27,025	0.07	325	0.77257
Grasslands and other wooded lands	3.1- 3.2	35- 44	8.85	9.50	40,600	43,575	0.65	2,975	0.03140(*)
Wetlands	4	36- 37- 38	0.50	0.68	2,300	3,125	0.18	825	0.02464(*)
Settlements and artificial lands	5	From 11 to 24	3.03	3.71	13,875	17,025	0.69	3,150	0.00027(*)
Other lands	6	39- 40- 41- 42	0.07	1.16	325	5,325	1.09	5,000	0.00000(*)

Table 4: *Comparison of the estimates achieved for LU and LC aggregated categories in 2012, their differences and their corresponding significance. (Source: Sallustio el al., 2016).*

The combined use and interpretation of the LU and LC estimates are helpful for deeper analysing and understanding the processes and dynamics occurring within a certain study area. For example, from the repartitioning of the sampling points classified as *Settlements* among the LC classes for the Molise region, Sallustio et al. (2016) found that 31.9% of them fall in unsealed (permeable) classes. This value gives insights on the density and compactness of urban areas. In fact, the higher is the degree of the unsealed surface, the higher its degree of permeability, corresponding to more scattered and fragmented urban areas. The extension of this permeable surface in urban areas offers a great potential to enhance and implement urban green spaces to improve the people wellbeing (Haase et al. 2014). The comparison of the estimates from the two classification systems may constitute a quick and effective instrument able to provide essential information to support land use planning.

5. Final remarks

The evaluation of LULCC and the selection of a reliable and accurate approach usable as a standard for a large series of experiences, plays a primary role as a support for future land use planning. This turns to be extremely important to make the future-oriented management guidelines coherent with the bioeconomy bases and to frame other key questions for sustainable development policies, like the set-up of environmental-economic accounting systems (Marchetti et al., 2014b).

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Land Cover Change and Rural Livelihoods: A Spatial Analysis on Northern Ghana

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ABSTRACT

Land use and land cover change accounts for about 80% of the global cost of land degradation, and one fifth of the land degradation that took place globally between 1982 and 2006 occurred in Africa south of the Sahara. We map the land cover of the three Savannah Regions of Northern Ghana twenty years apart (1994 – 2014) using remote sensing data, and subsequently employ spatial regression analysis to examine the relationship between long-term land cover change and current total value of harvest and maize productivity. Through the construction of a unique dataset combining information from georeferenced household surveys, remote sensing, and other secondary data sources, we propose a method to observe the relationship between landscape-level transformation and household-level outcomes. We find that areas that are currently cultivated or urbanized but were green vegetation in 1994 show higher agricultural production and productivity than areas currently cultivated or urbanized that were previously bare land. This suggests that the expansion of crop land into degraded areas with poor quality soils may not yield the expected positive gains, thus threatening the sustainability of agricultural production upon on which millions of poor smallholders rely.

Keywords: Land cover change, agricultural productivity, spatial regression, spectral analysis.

1. Introduction

The world population is expected to reach nine billion people by 2050 (United Nations 2009), requiring a steady growth in the production of food, feed and bioenergy sources for its subsistence (FAO 2011). This evolution is expected to put significant pressure on the natural vegetation and cropland on which millions of poor people rely heavily for their livelihood, therefore increasing the vulnerability of households living in rural areas (Biggelaar et al. 2004; Berry et al. 2003). Poverty, in turn, prevents farmers from investing in the measures necessary to protect the natural resource base, creating a poverty-environment vicious circle (Bremner et al. 2010; Bhattacharya et al. 2006; MEA, 2005; Perrings 1989; IPCC 2000; Wood et al. 2004). This negative spiral of poor livelihoods and resources degradation is further magnified by factors such as imperfect market and institutional failures (Duraiappah 1996).

About 40% of the global land surface is devoted to cropland and pastures, and in sub-Saharan Africa the rate of agricultural expansion has been steadily increasing over the period 1961-2005 (Foley et al. 2005; Nkonya et al. 2012). At the same time, about 65% of Africa's arable land is too degraded for sustainable food production, posing serious challenges for supporting the growing population that depends on it (Montpellier Panel 2014). This threat could be especially severe in arid and semi-arid environments, such as the semi-arid savannah region of West Africa (Pinstrup-Andersen and Watson 2010).

Existing literature on household welfare shows a strong spatial dimension in livelihood strategies, whose understanding is crucial to properly design effective poverty-alleviating policy interventions (Ayadi et al. 2009; Benson et al. 2005; Minot et al. 2003; Okwi et al. 2007). Yan et al. (2009) show how the transition of cultivated land into infertile soil, taking place in China following the dramatic urban expansion, significantly reduced overall agricultural productivity. Wiebe (2003) further discusses how the negative effects of land degradation on crop yields tend to be particularly important in areas with already high poverty rates, thus underlining the strong interdependence between household welfare, agricultural activity, and land cover dynamics.

Spatial analysis has been previously proposed to study these linkages (Bremner et al. 2010; Berry et al. 2003; Dasgupta et al. 2003; Dang 2014; Gyawali et al. 2004; Nkonya et al. 2008). Nevertheless, while the understanding of the spatial patterns of land cover changes and welfare has significantly improved during the last decade (Ayadi and Amara 2008; Okwi et al. 2007; Paraguas and Kamil 2005), empirical evidence on this relationship remains limited and seldom complemented with socioeconomic analysis (Barrett and Carter 2013; Galford et al. 2013; Mali 1998; Turner 2002).

The focus area of this paper is northern Ghana, comprising o Upper East, Upper West, and Northern regions. This area covers 40% of the nation's surface, while 80% of its population relies primarily on agriculture. These three regions also show the lowest levels of welfare in the country and, in contrast with the rest of the country, poverty rates have been increasing over the past years (Diao et al. 2007; World Bank 2011). Finally, the area is also highly affected by land degradation as a result of unsustainable farming practices due to the dominant bush-fallow rotation system, the removal of natural vegetation cover, and urbanization (Braimoh and Vlek 2005; Diao and Sarpong 2007; FAO 2000; World Bank 2007). These characteristics render the three regions under study particularly vulnerable to the poverty-environment vicious cycle, therefore understanding the underlying dynamics at play would be crucial to suggest interventions to break the cycle. The paper starts by describing the changes in land cover that occurred between 1994 and 2014. Next, it shows a spatial regression analysis that examines the link between long-term land cover change and current rural livelihoods, after controlling for regional trends in poverty and population over the period. Results show that households living in natural cover areas in 1994 that turned into productive areas in 2014 are associated to higher harvest value and maize yield than households currently living in productive areas that were previously bare land. This finding suggests that expanding crop cultivation to relatively low fertile soils may not lead to sustainable agricultural production, and that once land becomes degraded it is very difficult to reverse the process. While this study shows that crop cultivation in areas previously covered by vegetation bear positive effects on production, the loss of natural resources is likely to be detrimental in the longer term that goes beyond what is captured by this analysis. Results bear important policy implications calling for enhanced investments in land conservation practices in the regions - including reforestation -, and for sustainable intensification in areas already under cultivation.

The novelty of the study lies in the ability to combine household-level analysis with geo-spatial information at the landscape level to examine the interdependence between land cover change and rural livelihoods. The methodology used to derive the land classification is also new. First, it takes advantage of the georeferenced boundaries of 278 plots collected at the household level to precisely derive the 2014 cropland distribution for the entire northern Ghana. Second, it uses spectral prediction out of sample to recover the complete land cover distribution two decades ago (1994).

The rest of the paper is organized as follows. Section 2 outlines the conceptual framework; Section 3 describes and summarizes the data. Section 4 outlines our identification strategy and Section 5 discusses regression results. Finally, Section 6 concludes.

2. Conceptual Framework

There is a vast literature describing the spatial concentration of poverty in clusters of indigence (Ayadi and Amara 2009; Benson et al. 2005; Demombynes et al. 2002; Lanjouw et al. 2013; Minot and Baulch 2005), which – especially in Sub-Saharan Africa - are often located in rural areas where subsistence farming constitutes the main livelihood strategy (Amarasinghe et al. 2005). While transient poverty is mainly caused by temporary shocks, chronic poverty depends on the scarcity of productive assets (Barrett 2005), which in the case of subsistence farmers are mostly constituted by the natural capital embedded in the land they cultivate (Dasgupta and Deichmann 2003; Okwi et al. 2007). Therefore, the characteristics of the land-cover define the potential for agricultural production and productivity of the communities that inhabit it, and their evolution influences the dynamics of household welfare (Ikefuji and Horii 2005).

In order to study these linkages, our framework considers three main land-cover classes on the base of their contribution to livelihoods. The first class is defined as the *natural* cover and is composed of forest, water sheds, shrubs, and savannah. It represents the area that has not been transformed by human action. The natural cover is not only a source of fodder, fuel, food, and timber for the adjacent communities, but has also an important role in the farming systems' regenerative processes as well as constituting a stock of genetic resources for future agricultural needs (Alavalapati 2003; Sunderlin et al. 2008). Natural resources therein are non-exclusive and all the members of the community can benefit from them (Shackleton et al. 2007).

The second class is defined as the *productive* cover and is composed of cropland and urban areas. This land type is shaped by human action and constitutes the location where most of the economic activity takes place. Cropland is devoted to agricultural production and livestock breeding while urban areas host the industry and services activities.

Finally, the third class is defined as the *degraded* cover and is composed of bare soil. The process of land degradation describes the dissipation of soil nutrient content that can either be the product of human activities such as overexploitation, or the result of natural phenomena such as climate change. Degraded land is neither productive nor a source of natural capital and thus do not supply any resource for livelihoods (De Sherbinin 2002; Reynolds 2001).

The three land cover classes create nine possible land cover trajectories between 1994 and 2014. Table 1 summarizes them and reports their expected effect on household livelihoods.

Table 1: Land cover changes between 1994 and 2014 and expected impact

Land cover in 1994	*Land cover in 2014*	*Livelihood trend*
Natural	Natural	Same
Natural	Productive	(+/-)
Natural	Degraded	(-)
Productive	Productive	Same
Productive	Natural	(-/+)
Productive	Degraded	(-)
Degraded	Degraded	Same
Degraded	Productive	(+)
Degraded	Natural	(+)

We expect the likelihood of the changes to be heterogeneous, with certain trajectories observed more frequently than others (Lambin et al. 2003; Mustard et al. 2004; Vitousek et al. 1997). In particular, we expect two trajectories to be dominant in northern Ghana. The first is the change from natural cover to productive cover and subsequently to degraded land (mostly caused by human action) (Braimoh and Vlek 2005; Braimoh 2009; Wood et al. 2004). The second is the change from natural cover to degraded land directly (mostly caused by natural factors). On the other hand, we expect the emergence of natural cover from the other two classes to be quite rare, especially in the absence of appropriate conservation practices in place.

In terms of the relation between land cover changes and livelihoods, we expect the shift from natural cover to productive cover to improve household production and productivity up to a certain point, beyond which the increased scarcity of natural resources will start to impact livelihoods negatively (Coomes et al. 2011). For this trajectory to be sustainable, there needs to be a positive tradeoff between the loss of natural capital (biodiversity stock, carbon stock, etc.) and the economic effects of enlarged productive areas (Chhabra et al. 2006). Indeed, the objective of sustainable intensification is to create a balance between productive land and natural stock in order to allow the system to regenerate itself and to avoid overexploitation leading to land degradation (Cao et al. 2012; United Nations Department of Economic and Social Affairs 2012). The change from natural vegetation or productive cover to degraded land is expected to cause a deterioration of livelihoods (Berry et al. 2003; Bhattacharya and Innes 2006; Diao and Sarpong 2011), while the cultivation of land that was previously degraded is expected to improve livelihoods to a certain extent but still result in low productivity, because of the infertile nature of the soils. (Yan et al. 2009). It is also worth noting that these relations could be non-linear and be influenced by a number of economic, environmental, and institutional factors (Wiebe 2003). Finally, since the analysis is based on just two data points, we are not able to account for possible trend reversals that may have happened in-between.

3. Data

3.1 Land Classification

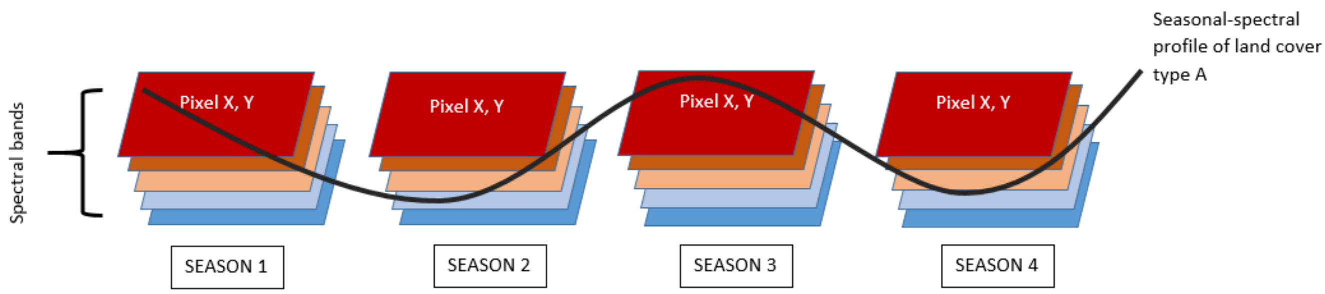
The analysis is based on a unique dataset combining primary data from a georeferenced household survey, micro-data from secondary sources (Ghana Living Standards Surveys -GLSS-), satellite imageries, and census information.

First, we produced two land cover classification (for 1994 and 2014) using Landsat images from USGS (Landsat 5 and Landsat 8) that cover the entire northern Ghana[1]. The year 1994 is selected as the baseline because prior to the 1990s the quality of satellite imageries was significantly lower, making it difficult to identify different land cover types at an adequate resolution. Furthermore, while 1991/92 and 1995 were characterized by some abnormally intense floods (Codjoe and Owusu 2011), 1994 can be considered as a normal year in terms of climatic conditions such as rainfall and temperature. This year is also chosen to match the household survey data year.

The classification is obtained by assigning one of the seven land cover classed defined by FAO to each 30 meter by 30 meter pixel within the images (Campbell 1987). The seven classes are bare soil, crop land, forest, savannah, shrubs, urban settlements, and water bodies. However, the land cover types can look very different from the satellite imageries depending on the time of the year when the picture was taken. For example, cropland changes drastically between the growing and the harvest season while waterbody varies significantly in size between the rainy and dry season. For this reason, each classification is based on four images that capture seasonal variation[2] and, within each image, on several spectral bands that are sensitive to the detection of the different spectral properties of all the seven land cover types.

To produce the land cover maps, the algorithm used calibrates the spectral properties of each land type in comparison to the others. For this reason, the images have to be overlaid with a sufficient number of external ground-truthing points identifying the exact locations where each type can be found. This allows to define and calibrate seven spectral profiles and to apply them to the entire surface. Figure 1 summarizes the identification process.

Figure 1: *Diagram for the identification of land cover types*



The ground-truthing points for cropland are identified with the georeferenced boundaries of 278 plots collected in the household survey, while the ones of the remaining six land cover types are identified

[1] The code of the selected tiles is the following: Path194, Row53; and Path195, Row 53

[2] Since cloud-free good quality images are unavailable for the four seasons in both years, one year time lag (before and after the selected year) has been also considered.

through Google Earth. In total, about 200 ground-truthing points for each land cover type are collected across the three administrative regions, of which two thirds are used to train the system while the remaining one third is used for validation of the final products.

The maximum likelihood classification algorithm is applied to produce the 2014 classification (Johnson and Dean 1988). The latter considers both variance and covariance of the classes across the ground-truthing points and apply them to the remaining pixels. Under normality assumption, a class can be characterized by mean and covariance. Given these two characteristics, the probability of each cell to belong to any class is computed and each cell is assigned to the class showing the highest probability. The final classification is then validated and cross checked with Google Earth as well as shared with local partners for feedback.

This methodology, however, cannot be directly applied to the 1994 images because historical ground-truth data are not available (Mosteller 1977; Richards 1986). For this reason, the 1994 images are analyzed through unsupervised classification methods using the IsoData classification algorithm. The latter clusters pixel observations into groups based on their reflectance values of the multiple spectral bands (Tou and Gonzalez 1974). Since different land covers exhibits their own unique spectral properties, the IsoData unsupervised classification algorithm investigates each pixel's spectral properties and groups them based on similarities. In a second step, the Maximum Likelihood Classification matches the spectral profiles identified in the 2014 with the spectral properties of 1994, to identify the same classes. Appendix Figure A1 and Figure A2 summarize the results of this land classification exercise, suggesting a reduction in shrubs and grassland and an increase in crop and bare land across the three regions.

In order to evaluate the quality of the 2014 land cover map, an accuracy assessment of the prediction is needed. We thus take the 1/3 ground-truthing points that were not used to train the algorithm to perform a statistical accuracy assessment for the entire classification as well as for the assignment of the individual classes. The accuracy matrix is provided in Table 2. The land cover classification results shows satisfactory accuracy rates[3]. The overall accuracy is over 70%. The urban, forest and waterbodies have the highest accuracy among all the land cover types (above 90%), while the rest of the classes have accuracy around 60%. Although cropland is usually recognized as one of the most difficult classes to identify, in our case it has higher accuracy rates than other vegetation types. This could be explained by the higher precision of the ground-truthing points from plot GPS coordinates than the ones based on the visual interpretation of Google Earth photos. Given the relatively high degree of land cover seasonality in northern Ghana and the possibility of land cover misclassification, we considered two years and grouped land cover types into homogeneous clusters.

Table 2: *Accuracy Matrix of the 2014 Land Classification*

		Ground Truthing class							
	Landcover types	Cropland	Forest	Grassland	Shrub	Bareland	Water	Urban	User accuracy
Land Classification 2014	Cropland	861	26	185	106	106	26	146	59.1
	Forest	-	596	-	-	40	13	-	91.8
	Grassland	146	93	728	331	93	-	40	50.9
	Shrub	40	199	225	1,152	185	13	159	58.4
	Bareland	13	13	26	66	331	-	119	58.1
	Water	-	53	-	-	-	887	-	94.4
	Urban	15	-	-	-	20	-	1,497	97.7
	Producer accuracy	80.1	60.8	62.5	69.6	42.7	94.4	76.4	70.8

[3] The producer accuracy indicates the probability of the reference pixel being correctly classified and is a measure of omission error. It is used to indicate how well a certain area can be classified. The user accuracy is a measure of commission error. It indicates the probability that a pixel classified on the map actually represents that class on the ground.

3.2 Household Data

We take advantage of the detailed geo-referenced, socioeconomic household and community Ghana Africa RISING Baseline Evaluation Survey (GARBES)[4] data collected in northern Ghana in 2014 to construct two measures of household livelihoods – maize yield and value of harvest - as well as several socioeconomic controls, including land holding, soil quality on-farm, and two indices of non-agricultural wealth and access to basic services[5]. Furthermore, spatial data matched to the household GPS coordinates were also included among the controls: market access (measured by travel time to the nearest town of 50 thousand people) and elevation, proxies for agricultural potential.

Finally, we construct region-level welfare indicators based on two waves of GLSS (1998/99 and 2012/13) to control for regional-level poverty trends as well as district-level population changes based on two waves of census data[6] (2000 and 2008) to capture broad economic trends.

3.3 Matched Spatial and Household Data

Regarding household-land cover mapping, a land cover type can be assigned to the geo-referenced sample households in a number of ways. One way is to assign a class based on the class of the 30 meter by 30 meter pixel in which the household is located. Alternatively, different buffer zones can be defined around the pixel in which the household is located. When using a buffer zone, as we did in this paper, a decision needs to be made about the size of the buffer zone as well as how to assign a land class to households when there are multiple classes within the buffer zone. A wider buffer zone has the advantage of better representing the environment affecting the livelihoods of the household, especially given that the average walking distance to the closest plot reported in the surveys was of 30 minutes.

On the other hand, the wider the buffer zone chosen, the larger the number of overlapping pixels among households (and villages), and the smaller the variation in land cover changes in our sample. For comparability, we considered four buffer zones based on 9 pixels (p) (3 pixels wide and 3 pixels high around the pixel in which the household is located), 25p (5px5p), 49p (7x7), and 81p (9x9). A summary of the share of each land cover class is shown in Appendix Figure A3. Cropland, savannah/shrubs, and bare land were the three most dominant land cover types in 1994, while, cropland, savannah/shrubs and urban are the three dominant land cover types in 2014.[7] These patterns are consistent regardless the buffer zone considered. Therefore, the empirical analysis is restricted to the 25 pixels buffer zone. We then regroup the initial 7 land cover types into the three defined classes (natural, productive and degraded land) resulting in nine land cover changes (summarized in Table 1). A summary of the re-classified land cover types and changes is provided in Figure 2.

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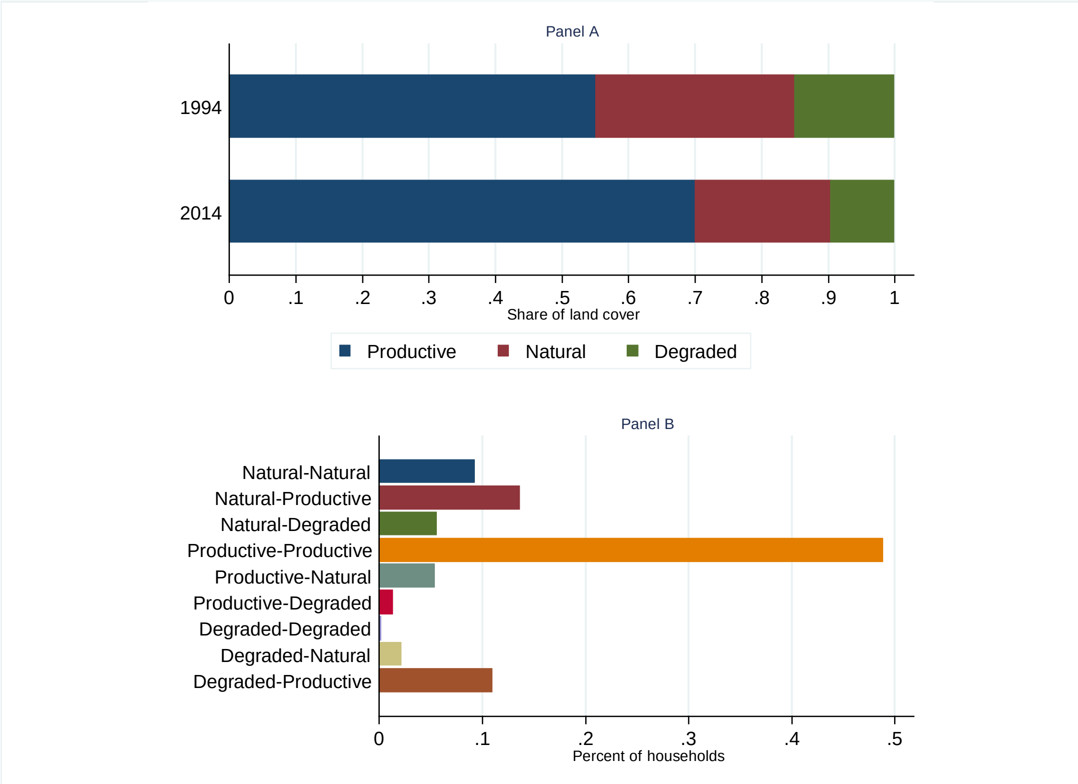
[4] Detailed about the program can be found here. Africa Research In Sustainable Intensification for the Next Generation (Africa RISING) Baseline Evaluation Survey in Ghana (GARBES) gathered detailed socioeconomic data from 1285 households residing in 50 communities in the Upper East, Upper West, and Northern regions.

[5] The indices are constructed using factor analysis (principal-component factor method) following Filmer and Pritchett (2001). The non-agricultural wealth index is constructed based ownership of various non-agricultural household durable assets and dwelling condition while access to basic services index is constructed based on self-reported travel time to get to selected infrastructure (such as asphalt and all-weather roads) and various services (such as weekly and daily market places and bus stops).

[6] Data are available from IPUMS International (Minnesota Population Center 2015) https://international.ipums.org/international/

[7] Shrubs and savanna are difficult to distinguish from google earth resulting in possible measurement errors.

Figure 2: *Re-classified land cover types (level and change) (25 pixels)*

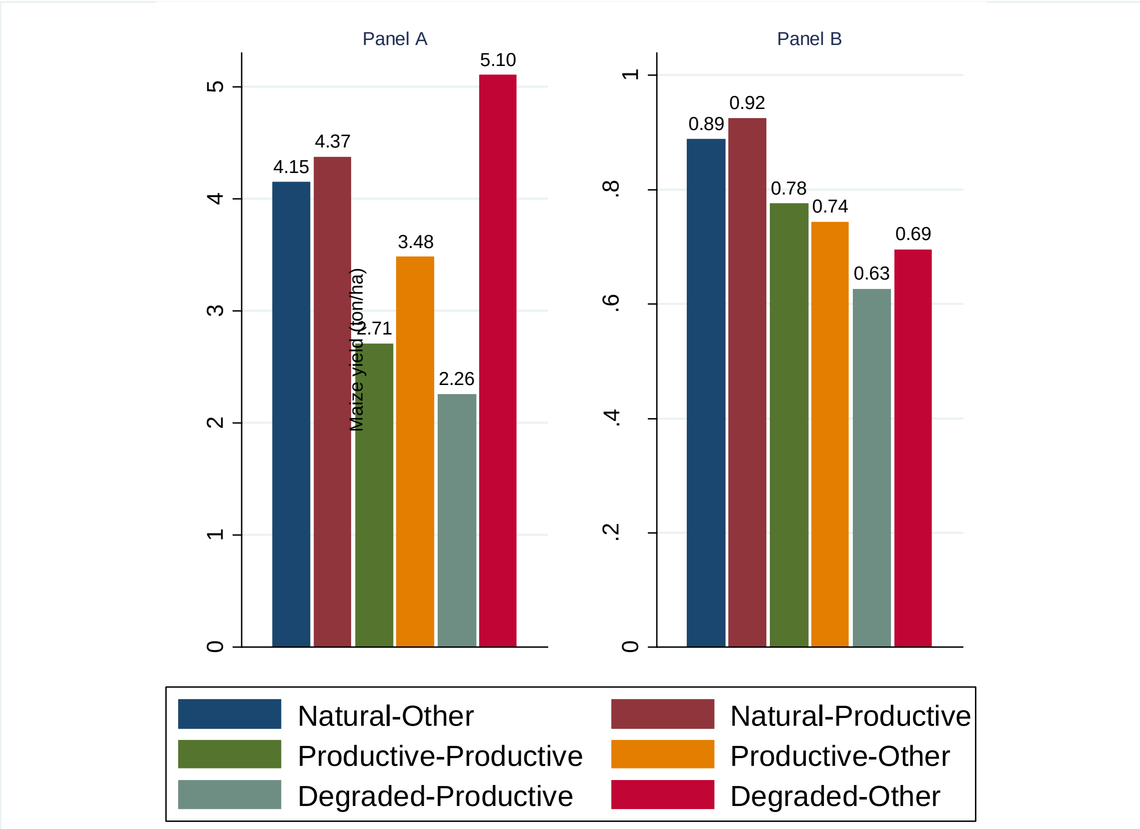


Productive cover accounts for more than 50% of land area in 1994, and reaches 70% in 2014. On the contrary, both natural cover and degraded land appears to have declined during the reference period, more so in the former case (Figure 2, panel A). Panel B summarizes the share of households in each of the nine possible land cover trajectories. About half of the households surveyed in 2014 reside in an area that that was crop land or urban in both 1994 and 2014 (Productive-Productive). Dominant are also land cover changes from natural cover to productive land (Natural-Productive) and from bare land to productive land (Degraded-Productive) (Figure 2, panel B).These patterns are indicative of the rapid expansion of extensive agriculture that is becoming more and more dominant in the landscape, to the point that farmers are starting to cultivate on less fertile soils that were previously bare land.

Given the relatively small sample size for some of the trajectories, and in the interest of improving precision of the estimates, we made further re-grouping of the land cover trajectories for the subsequent analysis. First, Natural-Natural and Natural-Degraded are grouped into one class (Natural-Other) that represents about 14% of the sample. Second, Productive-Natural and Productive-Degraded are grouped into one class (Productive-Other) representing about 7% of the study sample. Third, Degraded-Degraded and Degraded-Natural are grouped into one class (Degraded-Other) associated with 2% of the study sample. Figure 3 summarize our two measures of livelihood in 2014 - value of harvest and maize yield - by land cover trajectories for the 25 pixels buffer zone.

Setting aside the Degraded-Other trajectory (given the small sample size of 2%), households who live in areas with Productive-Productive and Natural-Other trajectories have the highest harvest and maize yield while those who live in areas that used to be bare land but turned into cropland or urban land scored the lowest harvest value and maize yield. A descriptive summary of the other socioeconomic variables used in the empirical analysis is shown in Appendix Table A1.

Figure 3: *Land cover change and welfare (25 pixels)*



4. Identification and Spatial Correlation

Agriculture is the main source of livelihood for more than 80% of the population in northern Ghana. As such, household welfare is highly correlated with agricultural production, which in turn depends on the characteristics of the landscape. Since our outcome variables (harvest value and maize yield) are likely to have a spatial dimension, modeling them without accounting for it would produce biased and inconsistent estimates (Paraguas and Kamil 2005). In addition, the spherical disturbances assumption of the ordinary least squares (OLS) would be violated if the model disturbances are spatially correlated. Finally, our pixel-based indicators of land cover change are expected to be spatially correlated as well, since by construction the buffer zones of neighboring households partially overlap.

To empirically test the existence of spatial correlation, we perform the Moran's I test (Moran 1950) of positive correlation between each of the suspect variables (the two outcome measures and land cover change variables) and its spatial lag[8]. The value of Moran's statistic ranges between –1 and + 1, with

[8] For a given (n x1) vector X, its spatial lag is computed by averaging the values of the variable for "neighboring" units and Moran's I (I) statistic is given by $\frac{n}{\sum_i \sum_j w_{ij}]} * \frac{\sum_i \sum_j w_{ij}(X_i - \bar{X})(X_j - \bar{X})}{\sum_i (X_i - \bar{X})^2}$ where n is the number of observations, w_{ij} parameterizes the distance between i and j, $\forall\, i, j$ and $w_{ij} = 0$ if $i = j$ and $\bar{X}$ is the mean of X. In this paper, w_{ij} is given by $1/d_{ij}$, where d is the haversine distance between households i and j, defined based on the latitude and longitude coordinates of i and j.

values near -1 (1) suggesting high negative (positive) spatial autocorrelation and values near zero implying minimal spatial autocorrelation. Under the null of no spatial autocorrelation, Morain's I has an asymptotically normal distribution with expectation $(-1/n-1)$.[9] A summary of Moran's tests (Jeanty 2010) in Appendix Figure A4 (for the two outcome indicators of rural livelihood) and Figure A5.a - Figure A5.c (for the land cover trajectories) shows the presence of positive spatial autocorrelation. Autocorrelation coefficients for the outcome variables range from 0.05 to 0.07, while those of the land cover change measures range from 0.08 to 0.19.

To explore the link between land cover changes and livelihoods while accounting for these identification challenges, we follow a nested approach and specify a spatial first-order autoregressive model (Drukker et al. 2013; Drukker and Prucha 2013; Kelejian and Prucha 1998; LeSage 1999), which also adds spatially-lagged values of land cover change as follows.

$$\mathbf{y} = \rho\,\mathbf{Wy} + \sum_{k=1}^{5} \beta^k \boldsymbol{LCC}^k + \sum_{k=1}^{5} \phi^k \mathbf{W}\boldsymbol{LCC}^k + \boldsymbol{\Lambda}'\mathbf{Z} + \boldsymbol{\varepsilon} \qquad (1)$$

$$\boldsymbol{\varepsilon} = \lambda\,\mathbf{M}\boldsymbol{\varepsilon} + \mathbf{u} \qquad (2)$$

Equation 1 is a cross-sectional model of livelihoods (measured by harvest value and maize yield) with $\mathbf{y}$ representing an $nx1$ vector and n representing the number of study households in GARBES; $\boldsymbol{LCC^k}$ is a column vector for one of the five land cover trajectories summarized in Section 2, with the sixth one - Degraded-Productive - used as a reference category; $\mathbf{Z}$ is an nxp matrix of conditioning variables where we control for progressively increasing number of household- and landscape-level covariates such as household demography, regional-level poverty trends and district-level population trends; $\boldsymbol{\varepsilon}$ is an $nx1$ vector of error terms allowed to be spatially correlated (as shown in Equation 2); $\boldsymbol{Z}$ is an nxk matrix of household-level socioeconomic covariates; $\mathbf{W}$ is an nxn spatial weighting matrix with elements w_{ij}, parameterizing the distance between households i and j, $\forall\, i, j$ and $w_{ij} = 0$ if $i = j$; $\mathbf{Wy}$ and $\boldsymbol{WLCC}^k$ are the (first order) spatial lags of the column vectors $\mathbf{y}$ ($= \sum_{j=1}^{n} w_{ij} y_j$) and $\boldsymbol{LCC}^k$ ($= \sum_{j=1}^{n} w_{ij} LCC_{ij}^k$), respectively.

Equation 2 models the disturbance terms as a spatially weighted average of the disturbances of the other study households; $\mathbf{M}$ is an nxn spatial weighting matrix with elements m_{ij} with $m_{ij} = 0$ if $i = j$ [10], $\mathbf{M}\boldsymbol{\varepsilon}$ is a spatial lag of $\boldsymbol{\varepsilon}$; and $\mathbf{u}$ is an nx1 vector of errors assumed to be independently and identically distributed. The parameters ρ and λ are the spatial lag and spatial error terms to be estimated[11], along with $\boldsymbol{\beta}$ (the main parameters of interest), $\boldsymbol{\Phi}$ and $\boldsymbol{\Lambda}$. A statistically significant $\widehat{\rho}$ suggests lag dependence in poverty while a significant $\widehat{\lambda}$ indicates spatial error correlation. We estimate Equations 1 and 2 using maximum likelihood (ML) (Drukker et al. 2013; Jeanty 2010) and, based on Lagrange Multiplier tests (Paraguas and Kamil 2015), we reject (could not reject) the null that $\widehat{\rho}$ ($\widehat{\lambda}$) is zero. In the next section, therefore, we present ML estimates of from Equation 1, and report Huber-White standard errors.

[9] See Wont and Lee (2005) for additional details on Moran's I test.

[10] $\mathbf{W}$ and $\mathbf{M}$ can be the same or different (for example, $\mathbf{M} = \mathbf{W}^2$). The analysis herein uses the same spatial weighting matrix ($\mathbf{W}$) for $\mathbf{y}$ and $\boldsymbol{\varepsilon}$. As is commonly done (for the sake of comparability of spatial weighting matrices with different parametrization of distance), $\mathbf{W}$ a row-standardized ($\mathbf{W}^*$) such that $\mathbf{W}^*\mathrm{x}\boldsymbol{T} = \boldsymbol{T}$, where $\boldsymbol{T}$ is an $nx1$ vector with elements $t_{ij} = 1\ \forall\, i, j$.

[11] See Kelejian and Prucha (2004, 1998) for assumptions and conditions about the spatial weighting matrix, the estimated autoregressive parameters, and the spatial lag variables and Drukker et al. (2013) for applications in Stata software.

5. Results

Table 2 shows estimates of the effect of land cover change on harvest value based on 25 pixels buffer zone. We use different specifications, where we first control for just land cover change and progressively control for household socioeconomic variables, agricultural inputs, region-level population and poverty (trends as well as initial levels), and finally elevation and market access (as measures of agricultural potential). Households living in areas that changed from natural cover in 1994 to productive cover in 2014 are associated higher harvest value than those who lived on a degraded land that turned into productive. The difference amounts to about 1,000 GHC ($950 in 2011 PPP terms). As mentioned, a shift from natural cover to productive cover is expected, at least in the short term, to improve the wellbeing of smallholder farmers who primarily rely on agriculture for their livelihood. The welfare of households associated to the Degraded-Productive change could be relatively low given the initial infertility of the soil, particularly unsuitable for agricultural production.

Similar effects appear when looking at the relationship between land cover changes and maize yield (Table 3). Households who reside in areas characterized by Natural-Productive change, with a Natural cover in both years, or with a Natural cover in 1994 and Bare land in 2014 (Natural-Other change) all appear to attain higher maize yield, relative to households in areas characterized by Degraded-Productive change, although the latter association is not significant in the more parsimonious specification (Table 3, column 6). These results seem to confirm that initial conditions matter, and that the land cover twenty years ago can be a good proxy for soil fertility today. Areas covered by vegetation in 1994 are generally suitable for agricultural production, while areas initially degraded are hard to restore.

Parameters of control variables show the expected sign, are generally significant, and consistent across different specifications. Total land area operated by the household is positively associated with harvest value, while it does not seem to be associated with maize yield. This results is consistent with several studies that have documented inverse land size-productivity relationship (Sen 1966; Deolalikar 1981; Carter 1984; Barrett 1996). Female headship, distance to basic services, and soil erosion are all negatively associated with agricultural production and productivity, while household size, non-agricultural wealth, and agricultural inputs (use of hired labor and irrigation) show a positive correlation with the outcome variables.

Table 2: *Effects of landcover change on harvest value (thousands of GHC)*

	m1		m2		m3		m4		m5		m6	
	coef	se	coef	se	coef	se	coef	se	coef	se	coef	se
Natural-Other	0.654	0.441	0.023	0.400	0.016	0.408	-0.107	0.420	-0.114	0.425	0.166	0.468
Natural-Productive	1.256***	0.460	0.878**	0.430	0.925**	0.437	0.848*	0.441	0.843*	0.444	0.985**	0.457
Productive-Productive	-0.090	0.299	-0.100	0.269	-0.105	0.268	-0.059	0.267	-0.071	0.272	-0.040	0.268
Productive-Other	0.506	0.493	0.403	0.465	0.373	0.464	0.424	0.466	0.416	0.467	0.551	0.475
Degraded-Other	1.583*	0.933	1.846**	0.855	1.786**	0.839	1.754**	0.835	1.756**	0.835	1.461*	0.814
Household size			0.021	0.029	0.029	0.028	0.033	0.029	0.033	0.029	0.032	0.028
Female household head			-0.736***	0.204	-0.754***	0.205	-0.759***	0.205	-0.762***	0.206	-0.685***	0.210
Mean years of education in the household			-0.072**	0.033	-0.086**	0.034	-0.093***	0.034	-0.094***	0.035	-0.089**	0.035
Total dependency ratio			-0.099	0.103	-0.064	0.103	-0.073	0.103	-0.073	0.103	-0.087	0.101
Total operated land (ha)			0.458***	0.064	0.444***	0.064	0.435***	0.064	0.437***	0.065	0.477***	0.067
Non-agricultural wealth (index)			0.748***	0.125	0.693***	0.127	0.689***	0.127	0.690***	0.127	0.651***	0.129
Distance to basic services index			-0.294***	0.071	-0.333***	0.071	-0.333**	0.071	-0.336***	0.072	-0.328***	0.071
The household uses irrigation					2.209***	0.628	*	0.635	2.143***	0.644	1.913***	0.641
HH uses hired labor					0.723***	0.180	2.163***	0.182	0.693***	0.183	0.748***	0.184
Practices mixed (crop-livestock) agriculture					0.457	0.514	0.455 0.692***	0.512	0.448	0.514	0.619	0.515
Share of parcels with incrusted soil Affected					0.590*	0.358	0.575	0.358	0.564	0.348	0.476	0.354
by soil erosion					-0.590***	0.185	-0.603***	0.186	-0.608***	0.190	-0.570***	0.190
Soil nitrogen content (g/kg)					0.238	0.826	0.366	0.840	0.336	0.875	-1.997*	1.109
Change in district population (2010-2000)							0.067	0.042	0.066	0.043	0.002	0.045
Change in regional poverty rate (2012-1998)									-0.164	0.794	2.956	3.554
District population in 2000 ('0000 census)											0.110***	0.030
Region poverty rate in 1998 (GLSS)											3.976	6.542
Travel time to nearest town of 50K (minutes)											0.000	0.001
Elevation of household's residence (meters)											-0.008	0.007
Constant	0.832	0.587	-0.315	0.595	-1.120	0.971	-1.348	0.982	-1.299	1.020	-2.637	2.729
/rho	0.433***	0.086	0.415***	0.091	0.368***	0.096	0.365***	0.096	0.366***	0.097	0.331***	0.105
/sigma	3.393***	0.137	3.113***	0.136	3.063***	0.134	3.060***	0.134	3.060***	0.133	3.028***	0.129
Number of observations	1,280											
Log-Likelihood	-3,388.3		-3,277.3		-3,254.8		-3,253.7		-3,253.7		-3,239.0	
chi2	3 33.253		5		6		4		2		2	
p	0.000		234.510		283.657		283.488		285.653		308.058	
Wald	25.407		0.000		0.000		0.000		0.000		0.000	
			20.855		14.818		14.494		14.179		9.998	

*** p<0.01, ** p<0.05, * p<0.1. Reported are heteroscedasticity-robust standard errors. Coefficient estimates of lagged land-cover change variables not shown.

Table 3:. *Effects of landcover change on maize yield (ton/hectare)*

	m1		m2		m3		m4		m5		m6	
	coef	se	coef	se	coef	se	coef	se	coef	se	coef	se
Natural-Other	0.208**	0.092	0.176*	0.090	0.183**	0.091	0.192**	0.091	0.184**	0.091	0.131	0.092
Natural-Productive	0.228**	0.090	0.211**	0.084	0.227***	0.083	0.232***	0.082	0.227***	0.081	0.192**	0.079
Productive-Productive	0.078*	0.045	0.078*	0.044	0.078*	0.045	0.076*	0.045	0.057	0.046	0.035	0.047
Productive-Other	0.047	0.072	0.034	0.069	0.036	0.070	0.032	0.070	0.019	0.070	-0.035	0.074
Degraded-Other	0.050	0.106	0.049	0.110	0.043	0.111	0.045	0.111	0.053	0.112	0.063	0.116
Household size			0.019**	0.008	0.020**	0.008	0.020**	0.008	0.020**	0.008	0.019**	0.008
Female household head			-0.111**	0.045	-0.113**	0.046	-0.113**	0.046	-0.117**	0.046	-0.119***	0.046
Mean years of education in the household			-0.001	0.009	-0.000	0.009	0.000	0.009	-0.001	0.009	-0.001	0.009
Total dependency ratio			0.038	0.029	0.043	0.029	0.044	0.029	0.045	0.029	0.042	0.029
Total operated land (ha)			-0.025*	0.015	-0.025	0.015	-0.024	0.016	-0.022	0.016	-0.025	0.016
Non-agricultural wealth (index)			0.071**	0.030	0.067**	0.030	0.067**	0.030	0.068**	0.030	0.070**	0.031
Distance to basic services index			-0.044**	0.017	-0.046***	0.017	-0.046***	0.017	-0.051***	0.018	-0.051***	0.018
The household uses irrigation					0.310*	0.171	0.313*	0.171	0.275	0.171	0.260	0.168
HH uses hired labor					0.047	0.045	0.049	0.044	0.051	0.044	0.055	0.047
Practices mixed (crop-livestock) agriculture					0.032	0.124	0.033	0.124	0.019	0.124	0.023	0.126
Share of parcels with incrusted soil Affected					0.072	0.081	0.073	0.081	0.053	0.083	0.038	0.083
by soil erosion					-0.138***	0.043	-0.138***	0.043	-0.146***	0.044	-0.147***	0.044
Soil nitrogen content (g/kg)					-0.034	0.193	-0.040	0.195	-0.099	0.201	-0.142	0.256
Change in district population (2010-2000)							-0.004	0.009	-0.007	0.009	-0.010	0.009
Change in regional poverty rate (2012-1998)									-0.289	0.182	0.229	0.828
District population in 2000 ('0000 census)											-0.005	0.005
Region poverty rate in 1998 (GLSS)											0.799	1.547
Travel time to nearest town of 50K (minutes)											-0.000	0.000
Elevation of household's residence (meters)											-0.001	0.002
Constant	0.380***	0.096	0.271**	0.118	0.244	0.214	0.260	0.223	0.356	0.232	0.432	0.690
/rho	0.249***	0.070	0.246***	0.068	0.225***	0.067	0.223***	0.067	`	0.067	0.217***	0.068
/sigma	0.681***	0.053	0.667***	0.052	0.663***	0.050	0.663***	0.051	0.662***	0.050	0.661***	0.050
Number of observations	1,132											
Log-Likelihood	-1,172.9		-1,150.7		-1,142.4		-1,142.3		-1,141.5		-1,138.7	
chi2	3 17.091		4 42.364		7 53.032		9 59.403		1 60.933		6 72.073	
p	0.072		0.001		0.000		0.000		0.000		0.000	
Wald	12.756		12.954		11.360		10.959		11.118		10.122	

*** p<0.01, ** p<0.05, * p<0.1. Reported are heteroscedasticity-robust standard errors. Coefficient estimates of lagged land cover change variables not shown.

6. Conclusion

The livelihoods of households living in northern Ghana are strongly interdependent with landscape characteristics. Population and welfare dynamics in these regions are affected by the changes in land cover that modify availability and ecosystem services of natural capital, while in turn exerting pressure on the natural resource base. Therefore, understanding these linkages is crucial to design welfare-improving policies for local communities aimed at restoring the environment over the long term.

By combining remote sensing data with geo-referenced household surveys we propose an innovative methodology to observe the interlinkages between changes in landscape and household livelihoods. We show how GPS information on parcels' location collected in household surveys can contribute to refine land cover classification procedure compared to more traditional ground-truthing approaches. In addition, we demonstrate how unsupervised classification methods can be used to map land cover in northern Ghana in 1994, bypassing the need of historical ground-truthing points. Finally, we employ a spatial regression analysis to examine the links between historical land cover change and current rural livelihoods, as proxied by maize yield and harvest value, while controlling for spatial correlation.

Through mapping of land cover distribution across northern Ghana in both 1994 and 2014, we observe a large expansion of land devoted to crop cultivation over the last twenty years, which mainly replaced natural vegetation areas. Bare land has also increased, even though at a lower extent than cultivated areas. This is likely caused by practices of agricultural extensification rather than intensification. Regression results show how households located in areas that turned from natural (forest, shrubs, savannah, or water bodies) to productive covers (cropland and urban areas) over the last twenty years are associated higher crop production and productivity today, relative to those living in current productive areas that were previously degraded (or bare land). These findings suggest that land initial conditions matter for agricultural production and livelihoods, and that the cover type twenty years ago seems to be a good proxy for soil fertility today. Our study confirms that degraded bare soils are very difficult to restore as well as render fertile and productive again. Therefore, our findings call for effective conservation practices aimed at restoration of the soil nutrient content that prevents land degradation.

It is worth noting that the observed positive impact of the natural-productive change may vanish in the long term, when the increased scarcity of natural resources will begin to play a detrimental role for local livelihoods. Furthermore, the overexploitation of cultivated areas that prevent the regeneration of soil nutrients will lead to additional degradation over the long run. In recent years these concerns are indeed the driving force behind the increased focus on the need to sustainably intensify the smallholder agricultural sector, in order to balance the trade-off between productive land and natural stock, allowing a self-regenerating system. The medium-to-long term effects of different land cover changes merit further consideration beyond the scope of this study, spurring further research.

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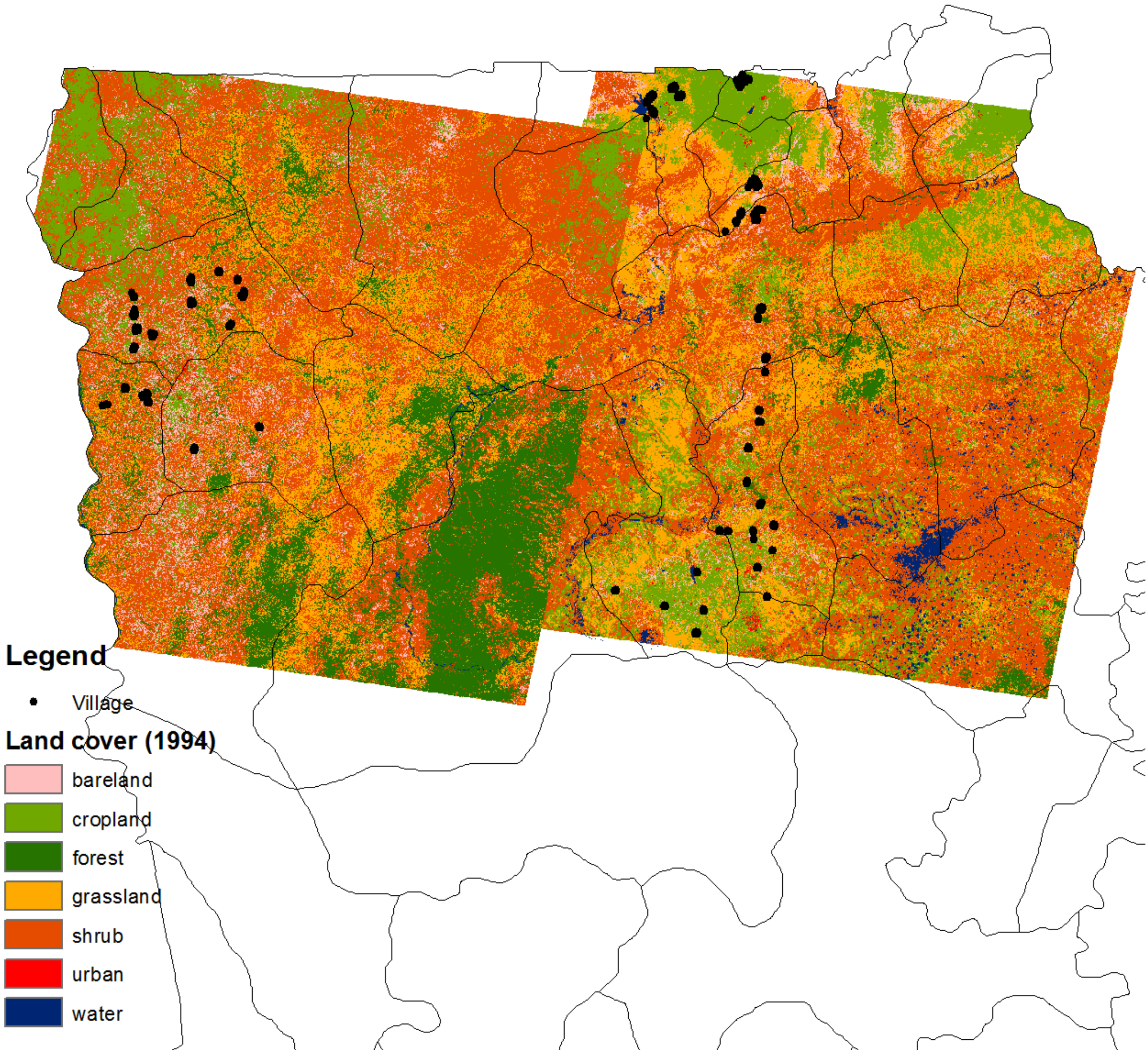
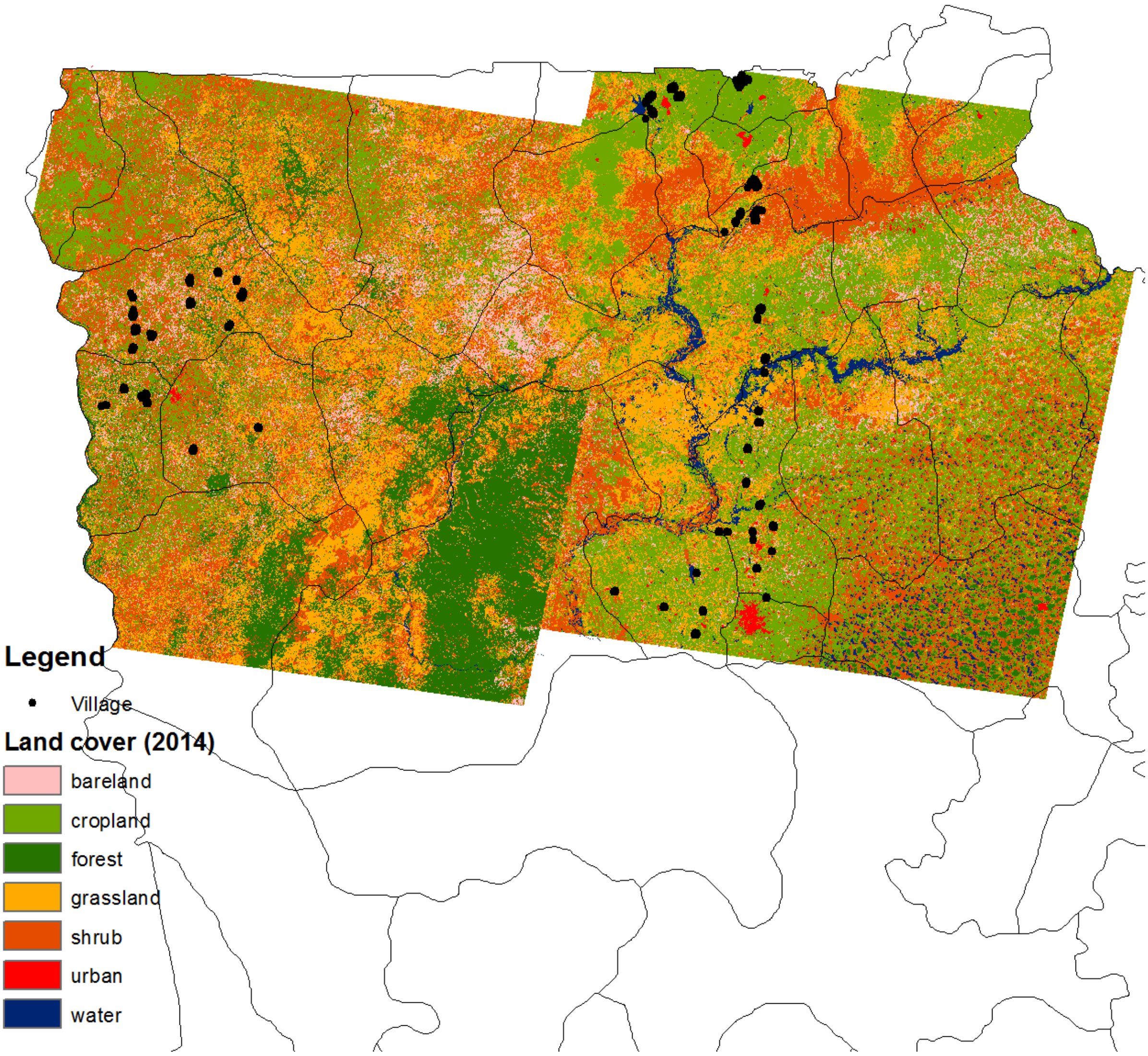
APPENDIX

Figure A1: *Land Cover in Northern Ghana, 1994*



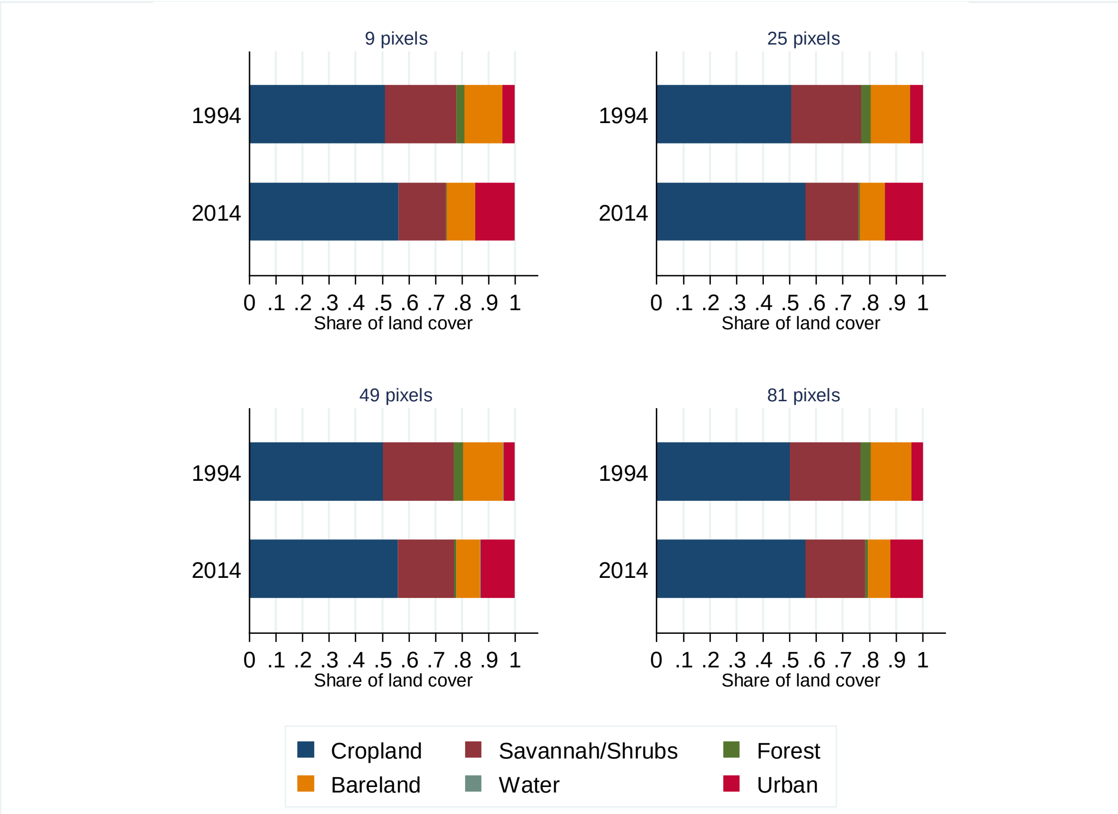
Source: Authors' calculation based on data from Landsat 5, Ghana Africa RISING Baseline Survey (GARBES), and Google Earth.

Figure A2: *Land Cover in Northern Ghana, 2014*



Source: Authors' calculation based on data from Landsat 8, Ghana Africa RISING Baseline Survey (GARBES), and Google Earth.

Figure A3: *Share of land cover (by year and buffer zone)*



Note: For each buffer zone, the share of a given land cover is computed as the ratio of the number of pixels represented by the cover and the total number of pixels in the buffer zone.

Figure A4: *Summary of Moran's I tests of spatial autocorrelation in the outcome variables*

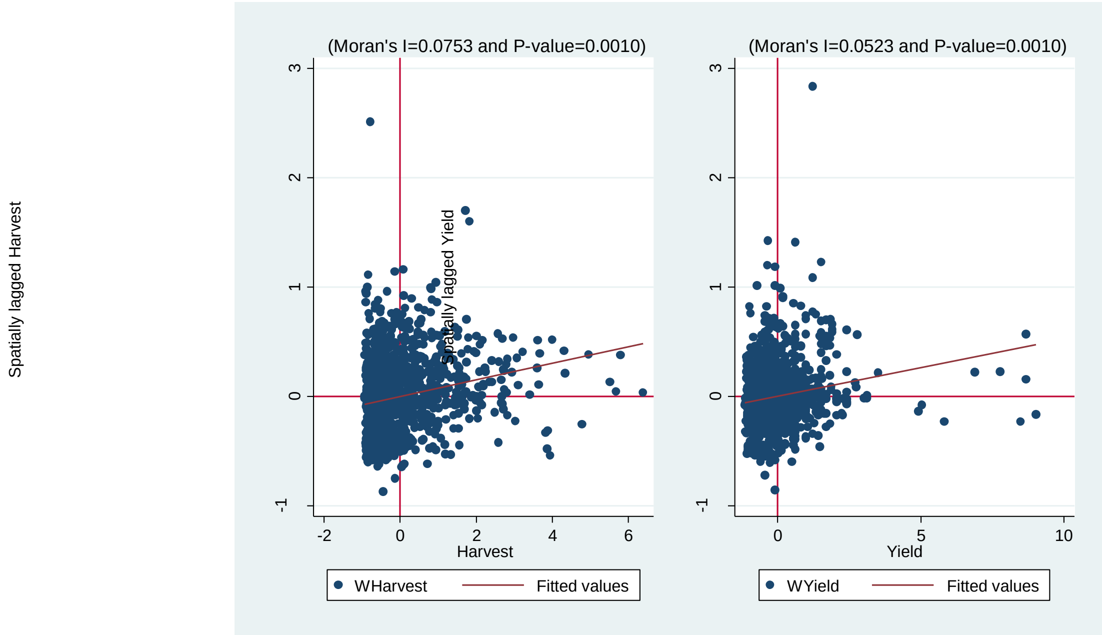


Figure A5a: *Summary of Moran's I tests of spatial autocorrelation in land cover trajectories*

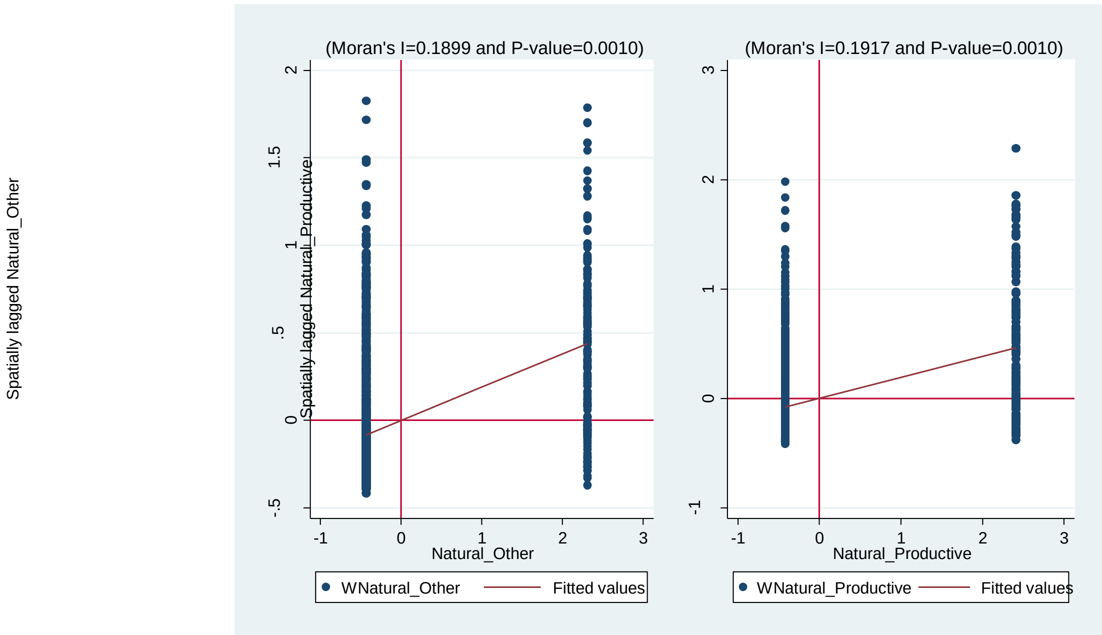


Figure A5b: *Summary of Moran's I tests of spatial autocorrelation in land cover trajectories (Cont'd)*

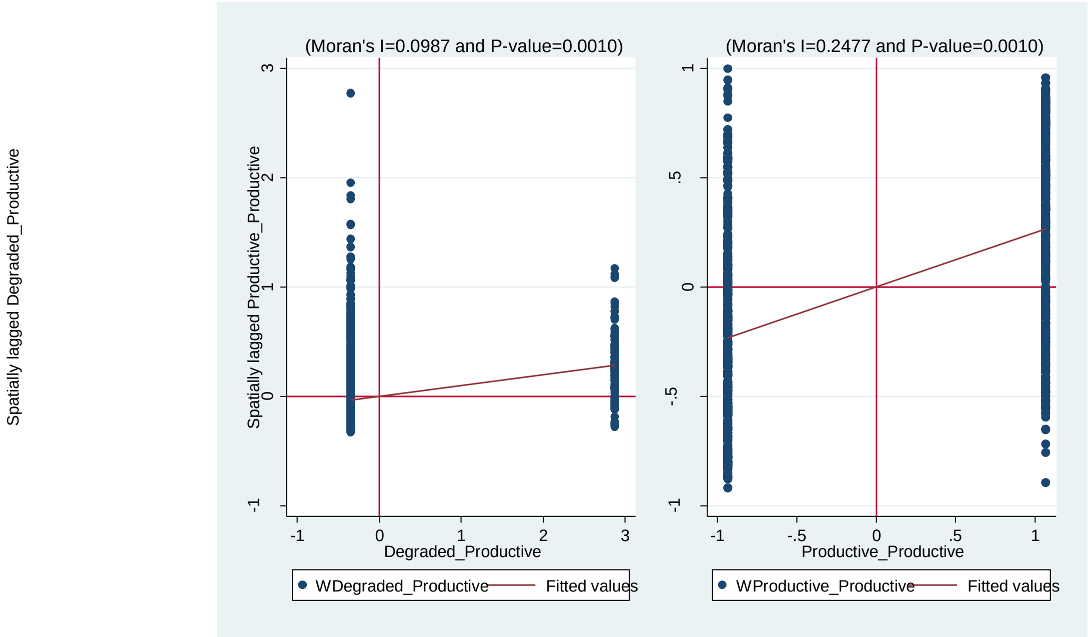


Figure A5c: *Summary of Moran's I tests of spatial autocorrelation in land cover trajectories (Cont'd)*

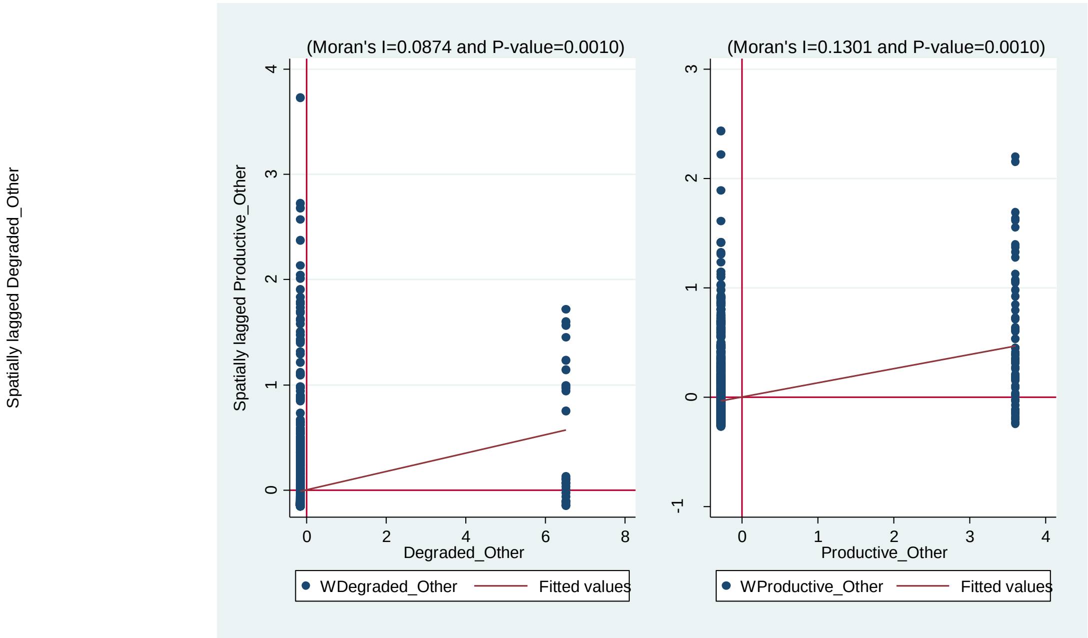


Table A1: *Descriptive summary*

	(1) Degraded-Productive	(2) Natural-Other	(3) Natural-Productive	(4) Productive-Productive	(5) Productive-Other	(6) Degraded-Other	(7) 1 vs 2	(8) 1 vs 3	(9) 1 vs 4	(10) 1 vs 5	(11) 1 vs 6
Maize yield (ton/ha)	0.69	0.89	0.92	0.78	0.74	0.63					
Total harvest ('000 GHC)	5.10	4.15	4.37	2.71	3.48	2.26			***	*	***
Household size	7.69	8.74	9.28	7.50	8.36	7.24		*			
Female head (%)	0.24	0.068	0.11	0.19	0.13	0.16	***	*			
Mean years of education in the household	1.91	2.09	2.92	3.46	2.63	2.75		**	***		*
Total dependency ratio	1.23	1.17	1.09	1.09	1.15	1.09					
Total operated land (ha)	2.46	3.82	3.64	2.53	3.12	2.51	***	***			
Non-agricultural wealth (index)	-0.13	0.19	-0.0098	-0.0062	-0.16	-0.066					
Distance to basic services (index)	-0.15	-0.25	0.016	0.11	-0.057	-0.031					
Use irrigation (%)	0	0.011	0.011	0.050	0.047	0.0071					
Use hired labor (%)	0.59	0.47	0.47	0.56	0.41	0.57				*	
Practice mixed (crop-livestock) agriculture	0.97	0.97	0.97	0.98	0.98	0.99					
Household parcels with incrusted soil (%)	0.16	0.19	0.15	0.12	0.14	0.052					***
Affected by soil erosion (%)	0.14	0.27	0.26	0.24	0.21	0.13					
Soil nitrogen content (g/kg)	0.70	0.72	0.69	0.60	0.70	0.58			***		***
Travel time to nearest town of 50K (minutes)	118.0	111.2	91.2	105.0	71.2	139		**		***	
Elevation of household's residence (meters)	263.9	143.2	177.2	218.6	186.5	279.5	***	***	***	***	*
District population in 2000 ('0000	18.2	9.76	11.9	12.6	11.3	14.3	***	***	**	**	
census) Change in district population	2.90	4.75	4.14	1.88	1.45	2.51	***	***		***	*
(2010-2000) Region poverty rate in	0.69	0.58	0.60	0.68	0.62	0.68	***	***	***	***	
1998 (GLSS) Change in regional poverty rate (2012-1998)		-0.074	-0.061	-0.13	-0.066	0.010					
-0.0056 Observations		190	175	626	86	140	365	816	276	330	219

29*** p<0.01, ** p<0.05, * p<0.1.

Significance tests are for pair-wise mean comparison between Degrade-Productive trajectory (omitted category in the regression analysis) and each one of the five other land cover trajectories.

Area estimation by integration of line transect sampling and multi-source remote sensing data

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Keywords: Crop area estimation, line transect sampling, multi-source remote sensing

DOI: 10.1481/icasVII.2016.g42e

Abstract:

Background and methodology:

Crop area estimation is one of the key components for agricultural statistics. Crop identification is a basis for area estimation for long time. Plenty of methods and algorithms for crop classification have been developed or improved during the last three decades. However, Pixels in remote sensing data do not always correspond to a single crop type or field. Mixed pixels are commonly found in agriculture regions with small crop fields and always impact crop classification accuracy. Therefore, remote sensing based crop classification without ground survey is not sufficient.

To overcome the shortcomings of area estimation based on classification, a crop planting and type proportion method (CPTP) (Wu and Li) was developed for CropWatch to estimate crop acreage, which crop planting proportion was derived from optical satellite data and crop type proportion was derived from GVG transact sampling survey. GVG surveying system which integrated a GPS receiver, a video camera, and a GIS analysis system was invented and developed to survey the crop type proportion along transact sampling lines. Crop area for each crop type can be calculated using the following equation:

Crop area = Arable land area * cropped arable land fraction * crop type proportion

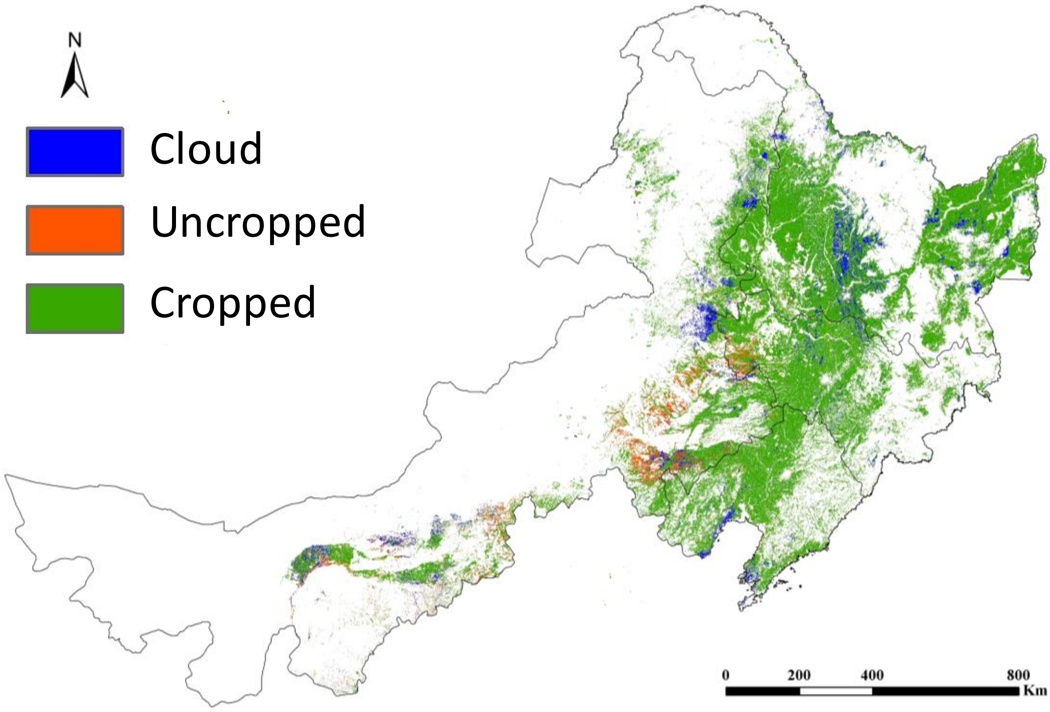
The four provinces – Heilongjiang, Jilin, Liaoning, and Inner Mongolia were selected as the study area. Field sampling was carried out from August 1st to 15th according to the sampling frame. Arable land area was derived from the arable land mask extracted from ChinaCover 2010 (a 30m resolution land cover dataset for whole China). The objective of this research is to use multi-source satellite data to overcome the impacts by cloud covers to improve the accuracy of cropped arable land fraction.

Images from China High resolution Earth Observation satellite (GF-1), China Environmental Satellite (HJ-1), Landsat 8 as well as Sentinel-2 Satellites were acquired during the summer crop growing season. Decision tree was applied to all the images for cloud extraction, cropped and uncropped arable land separation. Independent field samples were used for classification accuracy assessment based on the derived confusion metrics.

Results:

1.Cropped and uncropped arable land separation

Classification results showed that total arable land area is 35617.3kha, of which 94.2% is cropped; 93.5% of upland and 99.3% of paddy fields in the study area are under cultivated. Uncropped fields mainly locates at southeastern Inner Mongolia, Chifeng and Tongliao.



The independent validation results show high accuracy in separating cropped and uncropped arable land. Accuracy assessment in Inner Mongolia presents slightly lower than that in Heilongjiang province. The overall classification accuracy for Inner Mongolia and Heilongjiang was 97.8% and 99.3%, respectively.

Table 1 Accuracy of cropped and uncropped arable land mapping from confusion metrics

Province	Cropped arable land		Uncropped arable land	
	Producers' accuracy	User's Accuracy	Producers' accuracy	User's Accuracy
Inner Mongolia	97.3%	99.8%	99.3%	92.9%
Heilongjiang	99.2%	99.9%	99.6%	97.6%

2.Cropped arable land fraction

Crop type proportion for each county was estimated based the 39025 collected field photos, and was then interpolated and aggregated to crop type proportion zone, and provinces. Crop type proportion for the four provinces in 2015 and 2016 was compared. (Table 2). The proportion of maize in Inner Mongolia and Heilongjiang in 2016 is lower than that in 2015, while that in Liaoning and Jilin is slightly higher. The proportion of maize in Inner Mongolia was 40.99%, down by 3.12% compared with the same period of last year. Correspondingly, the proportion of soybean increased by 2.2% and that of spring wheat increased by 0.94% in Inner Mongolia. The proportion of maize in Heilongjiang was 45.61%, down by 0.42% and the planted proportion of rice, soybean and spring wheat was increased by 0.57%, 0.25% and 0.06%, respectively. The proportion of maize in Liaoning Province (54.84%) increased by 1.93%, while that of rice and soybean decreased by 12.23% and 3.52%, respectively. The proportion of maize in Jilin province increased by 0.5%.

Table 2 Crop type proportion for the four provinces in 2015-2016 (%)

Province	Maize		Rice		Soybean		Spring wheat		Other crops	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016

Inner Mongolia	44.11	40.99			8.41	10.61	9.21	10.15	38.27	38.25
Liaoning	52.91	54.84	13.42	12.23	4.47	3.52			29.21	29.41
Jilin	62.64	63.14	13.06	14.29	5.62	5.78			18.68	16.78
Heilongjiang	46.03	45.61	26.55	27.12	22.53	22.78	1.28	1.34	3.61	3.15

3.Crop area inter-annual variation

Table 3 Estimated crop area for the four provinces in 2015-2016 (Kha)

Province	Maize		Rice		Soybean		Spring wheat	
	2015	2016	2015	2016	2015	2016	2015	2016
Inner Mongolia	3258.6	3036.5			621.2	786.1	680.7	751.7
Liaoning	2572.5	2587.2	652.3	577.1	217.2	166.0		
Jilin	3446.6	3494.4	718.7	790.9	309.3	320.1		
Heilongjiang	5180.6	5077.2	2987.7	3019.1	2536.2	2535.8	144.3	149.6
Sub total	14458.3	14195.3	4358.7	4387.1	3683.9	3808.0	825.0	901.3

In terms of planted area, maize in Inner Mongolia decreased by 222.1 thousand hectares, and maize area in Heilongjiang Province was down by 103.4 thousand hectares from 2015. At the same time, maize area in Liaoning Province and Jilin Province increased by 14.7 and 47.8 thousand hectares, respectively. In total, 262.9 thousand hectares (about 394.4 million mu) decrease of maize area in the four provinces was observed.

Soybean acreage in the four provinces totaled at 3808.0 thousand hectares, an increase of 124.2 thousand hectares, of which Inner Mongolia soybean acreage increased by 164.9 thousand hectares, while soybean acreage in Liaoning Province decreased by 51.2 thousand hectares. Soybean planted area in Jilin increased by 10.8 thousand hectares, while Heilongjiang soybean area in Heilongjiang is almost same as the 2015.

Discussion and conclusions:

The changes in decreased maize area are mainly due to the policy changes released by China Ministry of Agriculture which reduce the subsidy for maize cultivation. It is expected that maize area in the four provinces will decreased by about 700 thousand hectors. However, the decreased maize area in 2016 is estimated at 262.9 thousand hectors, indicating that only 40% of expected reduction of maize planted area was achieved. Soybean area increased by 76.3 kha in the four provinces which leads to a slightly increase of soybean planted area nationally in 2016, the first inter-annual increase in more than a decade.

By integration of images from multiple wide swath sensors, sufficient data source can be acquired for cropped and uncropped arable land mapping. Even though, there are still some pixels invalid due to the continuous cloudy weather over the area. In the future, the integration of optical and SAR data could potentially improve cropped and uncropped arable land mapping accuracy.

Crop type proportion sampling used in this research is still time-consuming, labor intensive and costly. Crowd Sourcing Geographic Data will dramatically improve the efficiency and the GVG APP will be upgraded to allow any user to upload the field photos.

THEMATIC SET

G43

MODELLING FOOD, NUTRITION AND AGRICULTURAL MARKETS: UNDERSTANDING DATA NEEDS AND DISCOVERING NEW OPTIONS TO MEET THEM

Session Organizer
B. Schmidhuber | FAO | Rome | Italy

ABSTRACT

This session will be organized around two major streams of interest. The first will focus on needs and challenges, the second will try to identify efficient solutions that allow data practitioners to live up to these challenges. 1. What are the needs? Analysts and model builders in the area of food , agriculture and nutrition have long been struggling with a number of large and persistent challenges. These challenges arise from the ever greater data needs for ever more complex modelling tasks, the need to combine data of different provenances into a consistent overall framework, to update existing series fast and efficiently, to document their specificities and, more generally, to maintain a comprehensive metadata archive. Without finding practical solutions to these challenges, modelling and data analysis more generally, will become increasingly burdensome and the associated costs may put valid and important modelling tasks into jeopardy. Eventually, this could undermine the general commitment to evidence-based decision making. 2. How can we live up to the challenges? The second part of the session will focus on concrete solutions and specific tools to address the challenges. It will take stock of existing tools and solutions and focus on synergies, "share-ability" and interoperability to address the needs of a broader community of data analysts and modellers. It will look at communalities between solutions, present platforms to share data and modelling code and, if and where possible, identify common solutions to common problems. Importantly, it will try to match the supply from data providers with the demand from data users. Contributions will be sought from practitioners in the following area: Partial (agricultural) and general equilibrium modellers, designers of statistical data warehouses, developers of apps, tools, and software sharing platforms. On the supply side, contributions will be sought from FAOSTAT, the FAO Statistical Data Warehouse (SDW), the UN, the World Bank, the IMF, and selected national authorities such as USDA. On the demand side, modellers and data analysts will present both their demands and their own solutions, which often reflect a lack of relevant supply. These include, inter alia, contributions from GTAP, AGLINK/COSIMO, ENVISAGE and MIRAGE.

LIST OF PAPERS

The study of prediction of hog price in China

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DOI: 10.1481/icasVII.2016.g43

Challenges for Indian agriculture and non - Gaussian time series models for agricultural crop prices

K. K. Jose | Central University of Rajasthan | Ajmer | India

DOI: 10.1481/icasVII.2016.g43b

Computation of agriculture: analytics for agriculture

C. Pramanik | e-Rural Services | Hafeezpet |Hyderabad | India
A. Sengupta | BuildFusion, Inc| Kolkata | India
A. Haque | Indian Agricultural Statistics Research Institute | New Delhi | India
S. Das | Cognizant Technology Solutions India Pvt. Ltd | Kolkata | India
N. Sahi | BuildFusion, Inc. | Kolkata | India

DOI: 10.1481/icasVII.2016.g43c

G43

Canada – crop yield modelling using remote sensing, agroclimatic data and statistical survey data

G. Reichert | Statistics Canada | Ottawa | Canada
F. Bédard |Statistics Canada | Ottawa | Canada
C. Mohl | Statistics Canada | Ottawa | Canada
W. Benjamin | Statistics Canada | Ottawa | Canada
V. Dongmo Jiongo | Statistics Canada | Ottawa | Canada
A. Chipanshi | Agriculture and Agri-Food Canada | Ottawa | Canada
Y. Zhang | Agriculture and Agri-Food Canada | Ottawa | Canada
DOI: 10.1481/icasVII.2016.g43d

Modelling macronutrients trajectories: dynamics patterns and much more

M. Vassallo | CREA | Rome | Italy
M. Serafini | CREA | Rome | Italy
DOI: 10.1481/icasVII.2016.g43e

The Study of Prediction of Hog Price in China

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DOI: 10.1481/icasVII.2016.g43

ABSTRACT

Pork is the main meat for Chinese consumer, the price of hogs has a significant impact on the price of agricultural products and the Consumer Price Index(CPI), and it has always been the focus of the government and the academic community to stabilize the price of hogs. In this paper, we use the intermediate consumption survey data from National Bureau of Statistics of China, by using the machine learning algorithm, to predict the price of hogs in each provinces in the first half of year 2016.The result of this research would be used to lay the foundation for more accurate and efficient policy control and market regulation.

Keywords: hog prices, intermediate consumption survey, machine learning algorithm

1. INTRODUCTION

Pork is the main meat for Chinese consumers. In 2015, The production of pork reached 54.87 million tons, about 41 kg per person ,accounting for about 65% of the total output of meat. In recent years, The hog price fluctuates frequently. On the one hand ,the producers may face more risks in the market, on the other hand, the quality of people's lives would be affected. Therefore, The hog price controlling mechanism for stabling the hog prices and reducing the volatility of the hog prices become a hot topic for government, the society and the scholars.

Most studies on the mechanism for producing hog price at home and abroad focus on: Effects between supply and demand, Production costs, the level of money supply, the international market price transmission, the scale of production and epidemic disease etc. The main research methods include Cobweb Theorem, Vector Autoregression (VAR) ,Neural Networks(NN), Grey System etc., based on the analysis of the seasonal, cyclical and trend fluctuations in the price of Hogs. For example, Ying Qi, Jie Li (2007) considered that the relationship between supply and demand, the deviation of production decisions, the cycle of hog production, Consumption habits of the residents are the main causes of hog price volatility. By using the method of Co integration analysis, with the monthly data from 2002 to 2006,Fang Wang (2009) found out that the long term influence factors of pork price, sorted by impact strength, are the price of corn, piglet, hogs and pork. Feng Luo et al. (2009) indicated the long-term equilibrium relationship between the Chinese and the international prices of agricultural products by using the Co-integration Analysis and Impulse Response Function ,with the data from 2003 to 2008 . LiXiang Zhang et al. (2011) found the high degree of integration in the hog chain market by using the Co integration Analysis to study the price data of corn, feed, piglets, pig and pork, from January 2003 to July 2010, and the prices of Piglets and hogs are the core of the whole chain by the Granger Causal Relation Test. YongBo Ma (2011) considered the price volatility of agricultural products mainly came from the supply, cost-push, the money supply and international agricultural price transmission and so on. GuoChang Xin(2013) found the supply of cattle products can provide a stronger affect on the prices than the demand did, and the supply, demand, production costs, the price of alternatives, macro-control can cause significant different affect on the hog price by path, intensity and period.

Since the 1990s, the scale production of poultry breeding industry have developed rapidly in China, the marketable fattened stock from the scale-producing units(units that have the size of the marketable fattened stock more than 1000) accounts for about 17% of the total amount of the marketable fattened stock. In recent years, the yield of Chinese pork goes up periodically , there were inflection points once every 5-8 years. In the last 15 years, the inflections occurred in the year of 2007,2011 and 2015.

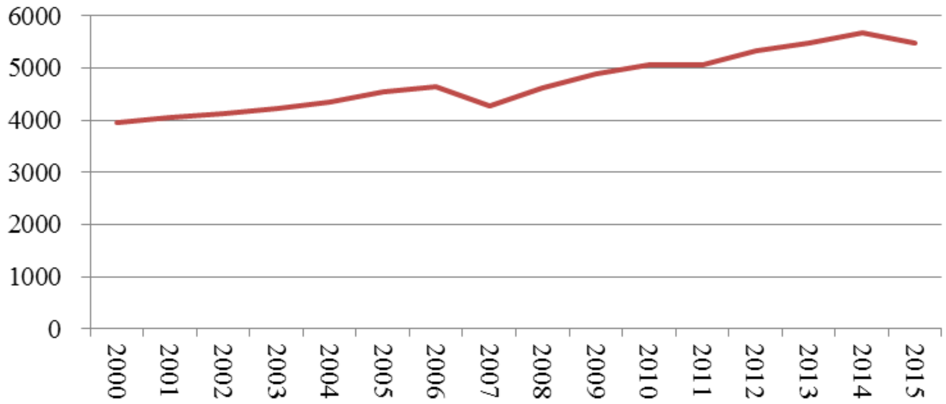


Figure 1: *The yield of Chinese pork,2000-2015 (Unit: 10,000 tons)*

The hog price presents the obvious periodicity and seasonality. From a monthly point of view, the price is usually lower from April to May and higher from January to February. Viewed annually the hog market price has a fluctuation cycle of 3-5 years, and recently the cycle became shorter.

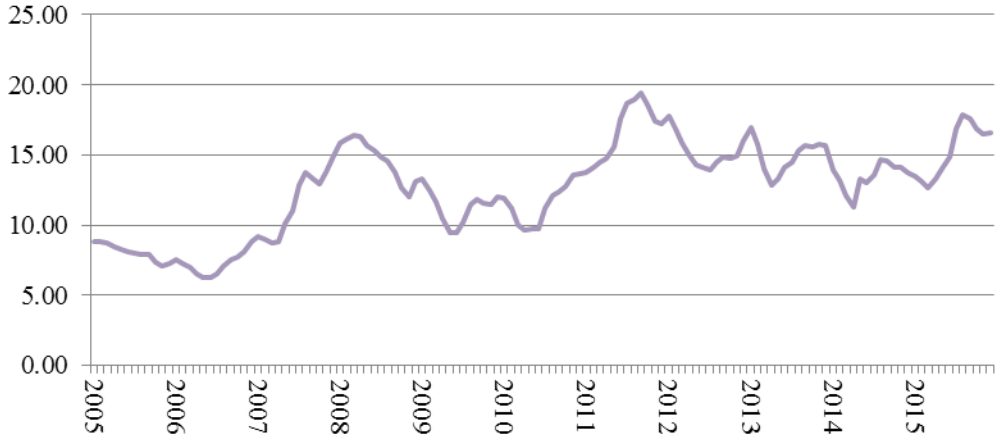


Figure 2: *The Chinese Hog market price,2005-2015 (unit: yuan / kg)*

There are four surveys related to hog in the Rural Division of the National Bureau of Statistics of China including the animal husbandry production survey (quarterly), the agriculture, forestry, animal husbandry and fishery output survey (quarterly), the agricultural products price survey (quarterly or monthly) and the intermediate consumption survey (semiannually). The relevant statistical indicators include the amount of output, slaughter and feeding; the output value and added value; the producer price and the market prices; the feeding costs, costs of piglets, labor costs, operating expenses and so on. In order to adapt to the industrial development of the hog production ,the National Bureau of Statistics continually reforms and improves the statistical investigation system and sampling methods to better reflect the production and development of hog.

2. EMPIRICAL ANALYSIS

2.1 Model Selection

In the study of forming mechanism of the agricultural products prices, the methods of Cobweb Theorem, the VAR model, the neural networks and the grey system all have been widely used and achieved fruitful results. In the empirical study, the quality of data has a significant impact on the results. The study of the hog price has its special difficulties: firstly, with the rapid development of industrialization and the necessity of environmental protection, the picture of hog producing changes rapidly, which makes the analysis of the long-term hog prices become difficult. Secondly, Since the producing and consuming of hogs have the attribute of periodic and seasonal characteristics, the relationships between the hog price and its influencing factors are relatively complex, meanwhile, the function between the hog price and its influencing factors are different on path, intensity and cycle ,there are both the positive and reverse conduction between the hog price and its influencing factors and the transmission intensity is also different. Thirdly, the quality of the data itself affects the results. With the different sources of data and differently processing methods, the scholars may draw different conclusions from the same object. There are a large number of high quality data in NBS. To develop and utilize these data has always been an important issue of our work. There are about 2000 sample units in the intermediate consumption survey of hogs nationwide in China, Each year about 1/5 of the sample units are rotated. There are two surveys for one year, one is held in the first half of the year and the other held in the second half. The interview of the survey covers the main information of each sample unit, including address, the hog slaughter, the sale price ,the piglets cost ,the feeding cost, the fuel cost, the water cost, the electricity cost, the labor costs and so on. It could be theoretically and practically instructive to predict hog price movements by using these data.

On the basis of the represent above, this study based on samples which have many variables and been observed in a short-term period. Considering the characteristics of the data and the applicability of the model ,we decide the research method of this paper is using the data of the intermediate consumption survey, applying the machine learning method (the four models of Decision Tree, Support Vector Machine ,Neural Networks and Random Forest) to construct the forecast model to forecast the price movements of hogs, and then put forward some specific suggestions.

2.2 Variables Selection and Data Processing

To form the index system from the intermediate consumption survey data we preliminarily select the price of hog as the explained variables, and the explanatory variables include the price of purchased piglets, the price of since numerous bred piglet, the price of concentrated feed, the price of crude feed, the price of water fees, the price of electricity fees, the price of gasoline, the price of diesel, the price of coal, the price of hired worker, the price of family labor and the cost of the epidemic prevention.

Table 1: *preliminary selection of variables*

Name	Shortcut	Type
the price of hog	y	explained
the price of purchased piglets	gzx	explanatory
the price of since numerous bred piglet	zfzx	explanatory
the price of concentrated feed	jsl	explanatory
the price of crude feed	csl	explanatory
the price of water fees	sf	explanatory
the price of electricity fees	df	explanatory
the price of hired worker	gg	explanatory
the price of family labor	jg	explanatory
the cost of the epidemic prevention	Fy	explanatory

the price of gasoline	qy	explanatory
the price of diesel	cy	explanatory
the price of coal	m	explanatory

The intermediate consumption survey began in 2002 in the Rural Survey of the National Bureau of Statistics. Taking into account the sample rotation and the characteristics of the hog production in different periods, we selected the data from 2011 to 2015 into the analysis. The objects of the intermediate consumption survey are households or units, considering the sample rotation and the different characteristic of hog production in different regions, we selected the provincial average prices into analysis after comparison. Therefore we get the final analysis data of a total of 10 cycles from 2011 to 2015 and the provincial average prices.

Before carrying out the machine learning method, we need to translate the time series data into the panel data. We tested for the correlation coefficients between the hog prices and all the influential factors in the cycles (T-4,T+4) by applying the Pearson Correlation Coefficient Test. Then we get to a conclusion that the price of purchased piglets, the price of concentrated feed, the price of water fees, the price of electricity fees, the price of hired worker in the period of T-1 have the biggest correlation with the price of hog, while the correlation between the price of self breeding piglets, the price of crude feed, the price of gasoline, the price of diesel, the price of coal, the price of family labor in period T-1 did not correlate significantly with the price of hog. Hence we put a one-cycle-advance on each influencing factor then matched with the hog price to make up the training and testing samples for the machine learning model , and impact factor data of the last cycle was used to predict the hog prices of the coming cycle.

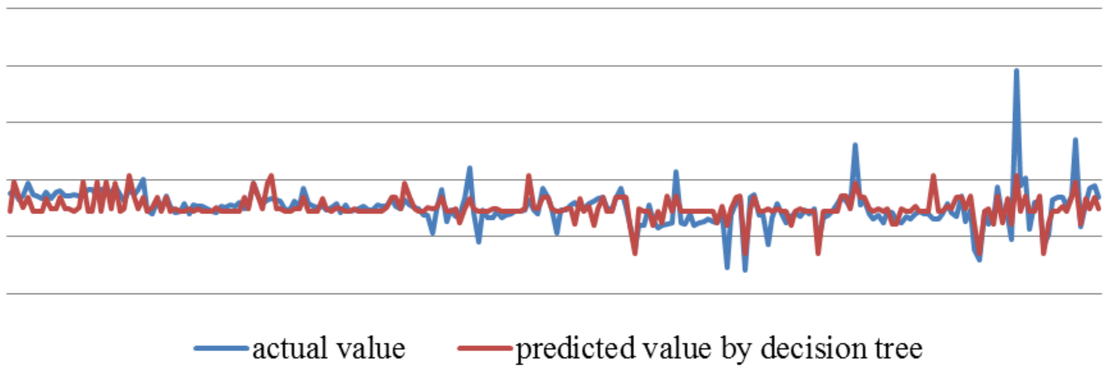
Table 2: *The correlation test between the price of hogs and the T-1 influencing factors*

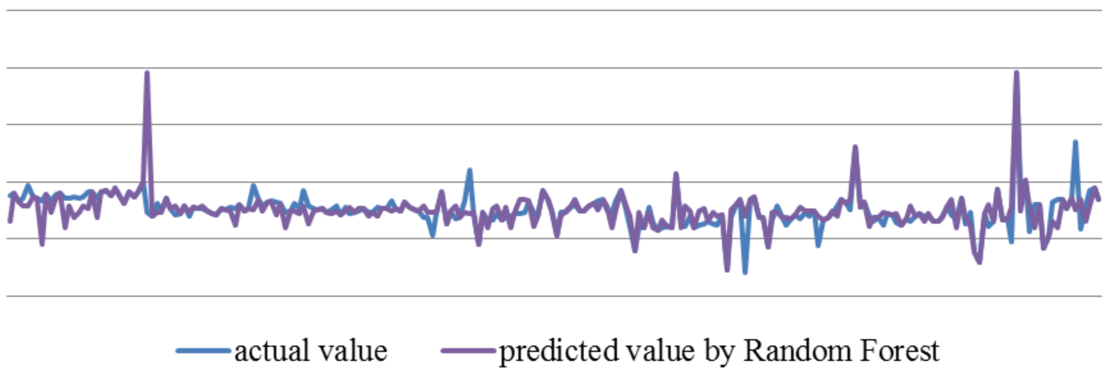
Name	Coefficient	P Value
the price of purchased piglets	0.837	0.0000
the price of concentrated feed	0.867	0.0002
the price of water fees	0.513	0.0307
the price of electricity fees	0.551	0.0312
the price of hired worker	0.732	0.0237
the price of since numerous bred piglet	0.637	0.1017
the price of crude feed	0.523	0.0749
the price of gasoline	0.314	0.2022
the price of diesel	0.350	0.2812
the price of coal	0.211	0.3714
the price of family labor	0.273	0.0747

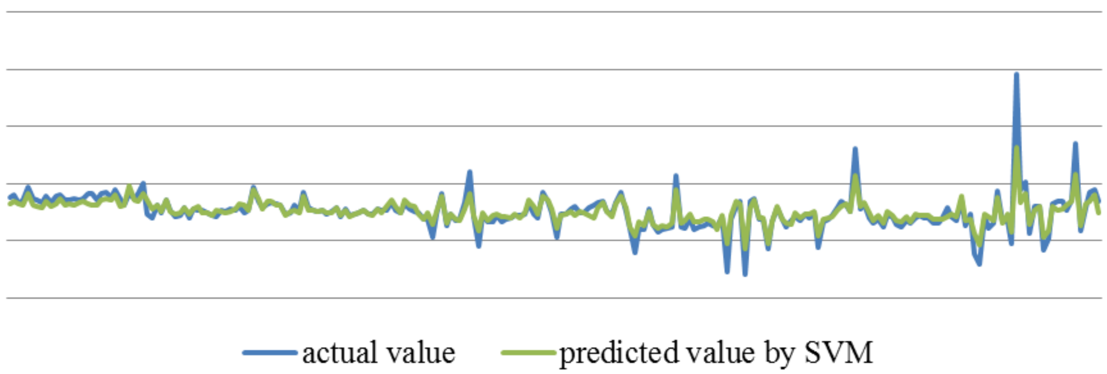
the cost of the epidemic prevention	0.416	0.0814

2.3 Model Implementation

The training and test data are used to model in R3.2.4 by the models of the Decision Tree, Random Forest, Support Vector Machine and BP Neural Networks. The program code is shown in the Appendices. The fitting curves of the four models are shown below.







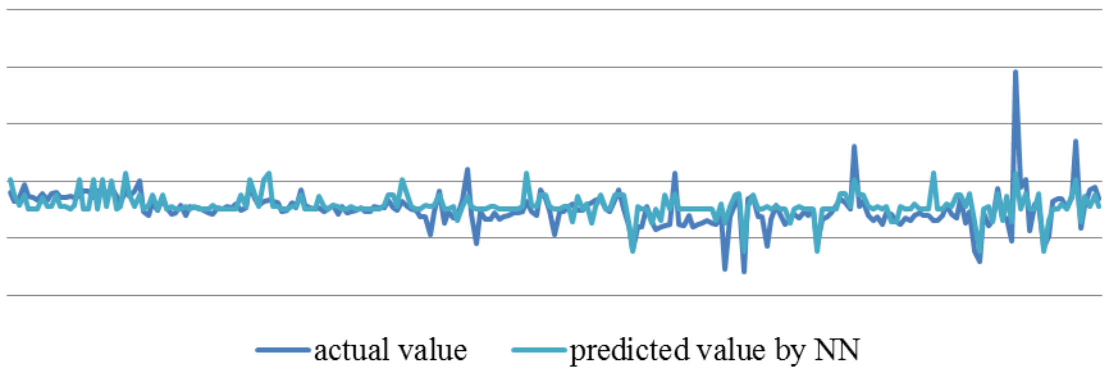


Figure 3: *The fitting curves of the four models*

By applying the 10-fold cross validation, we get the Root Mean Square Errors (RMSE) of the four models decision tree, random forest, support vector machine and BP neural network are respectively 0.2214, 0.0125, 0.3756 and 0.3392.This shows that the four models have good fitting effects and it is feasible by using these models to predict the hog prices, By comparison of the values of RMSE, in these four models, the Random Forest model is relatively better. Finally, we used the 10th period data of the influential factors to predict provincial hog prices in the first half of 2016,then calculated the national price index of the hog which was about 113.7.

3.CONCLUSIONS AND RECOMMENDATIONS

Firstly, this paper shows that it is feasible to use the intermediate consumption survey data such as the cost of piglets, feed, operating and labor etc. to predict the price of live pigs by applying the machine learning algorithm.

Secondly, this paper provides a reference of building a price forecasting model in multi regions and shorter periods with the exploration of forecasting the price of hogs in many provinces and the semiannual.

Thirdly, since the obtainable data is limited, this article has not yet taken the effect of market demand, money supply level, international market price transmission, alternative goods prices, the macro-control policy etc. into scope of study. we will continue to explore the impact of these factors on the price of hog in the next stage.

Finally, by looking into the leading indicators we can forecast the price movements of hogs in advance of one or several cycles. In addition, analysis on the price movements of the different regions with the leading indicators could help to make more accurate and sensitive policy and market regulation.

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Challenges for Indian Agriculture and Non - Gaussian Time Series Models for Agricultural Crop Prices

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ABSTRACT

India being a pre-dominantly agricultural country, agricultural crops form the major factors contributing to the Gross Domestic Product (GDP). The author reviews and develops various non-Gaussian as well as non-linear time series models for prices of agricultural crops. The study also aims at predicting future prices, so as to enable the scope of agricultural crops as profitable means of cultivation. Another aspect is to assess the global threats and reasons for the decline in prices in the post liberalization period in India. We also give special emphasis on the external factors consequent to India's adherence to the W.T.O. agreement and suggest some remedial measures to make Indian agricultural sector profitable to the farmers as well as the nation.

In Part1, a detailed analysis of the GATT rules and multilateral agreements, which are relevant to natural rubber and coconut, is done. An insight into the developments in the international market and various policy initiatives during the last decade is done. The need for productivity enhancement, effective production, quality improvement for export competitiveness, steps to be taken for value addition of rubber, etc are pointed out. It is found that the price of coconut oil depends on the prices of other vegetable oils. The coconut industry in the world is always susceptible to the pressure from low oil seed prices and increased availability of cheap oils like palm oil, soybean oil etc. The widespread incidence of coconut mite and root wilt disease as well as recurring drought during recent years affected coconut sector to a great extent. Rather than W.T.O. effects, lack of productivity and adequate market connectivity, outdated trading practices, etc caused havoc in this sector. However, the tea, coffee, pepper, cardamom etc are facing serious problems.

In Part 2, we have developed some non-Gaussian time series models. It was found that most data on agricultural crop prices/indices are marginally non-Gaussian and hence time series models

with non-Gaussian marginal distributions are to be developed for proper modeling. First order autoregressive models are sufficient and parsimonious in modeling agricultural crop prices/indices. Models with marginal distributions like Cauchy, Stable, Linnik, Geometric Linnik, Generalized Laplace, Marshall-Olkin Exponential and Weibull distribution are appropriate in this regard. Non-linear models like AR(p)–ARCH(q) models can best reflect the volatility and changing conditional variances. The best non-Gaussian time series model for agricultural crop prices is one with Generalized Laplacian marginals. Cauchy and Linnik autoregressive models are also satisfactory. With regard to modeling volatility and varying conditional variances with regard to time, ARCH models are more suitable. Only short term forecasts are meaningful as prices depend on various non-random extraneous factors like govt. policies at national and international levels. Also some computer programs are developed for simulating the models and estimating the parameters. In the concluding section, the findings and conclusions are summarized.

Keywords: ARCH Models, ARMA Models, WTO regime, Natural Rubber, Coconut.

1. Introduction

The changed economic order in the context of globalization and liberalization of world trade in agriculture has opened up new vistas of growth. Spices sector is one of the key areas in which India has an inherent strength to dominate the global markets. The world's romance with Indian spices continues unabated. India is the largest producer, consumer and exporter of spices in the world. The present annual production of spices in India is 3.0 million tons from over 2.5 million hectors. About 8.5% of India's export earnings from agricultural and allied products come from spices. India is a significant exporter of spices and plantation produces.

India occupies the 3rd position in production and 4th in consumption and 1st in terms of productivity of Natural Rubber (NR). Of the global production of 71.1 lakh MT India's share is only 6.4 lakh MT in 2002. The annual growth is at the lowest at 0.08%. Kerala accounts for 84% of the rubber production in India. In India about 1.89 million hector of land is under coconut cultivation. At the rate of 6776 nuts per hector India produces about 12822 million nuts a year. Though the share of Kerala state was 56% in 91-92 the share has come down to 48% in 2001 and 2002. The productivity has also come down to 5895 nuts per hector. The major products are coconut oil and coir products. India contributes 25% of the world pepper production with about 3.2 lakh million tons in 2002.

Since agriculture is always at a loss, the area under cultivation of many crops is declining. The productivity of all the crops is showing a slowing trend. It's also a fact that we produce comparatively more but do not realize proportionate revenue from these commodities in the international market. In view of the existing open market approach under the provisions of World Trade Organisation rules coupled with the Regional Trade Agreements it is apprehended that free flow of these commodities from international markets would badly affect the farm economy of the country. Though market access for our commodities to international markets is technically feasible, technical barriers to trade might become an impediment unless they are professionally addressed to at the right time through appropriate mode. Though all these commodities are not covered under the Agreement on Agriculture of WTO, there are GATT negotiations on these.

2. WTO and Agricultural Crops in India: Challenges and Opportunities

The rigorousness of the applicable WTO disciplines increase manifold if they are agricultural products as compared to the 'non-agricultural'. Non-agricultural products in the WTO, are not the same as industrial products and include products and product groups which traditionally or in context of other international agreements/ understandings are agricultural. The prime examples being products like natural rubber, coir, jute and even fishery or marine products. This is so because the WTO Agreement on Agriculture (AOA) applies on a list of products specifically mentioned in the Annex to that Agreement. By default therefore, any product that is not included in the Annex to the AOA, such as those mentioned above, fall within the ambit of the 'general' provisions of GATT and related WTO agreements.

The main agricultural products of concern in this study are: (i)Coconut & products such as copra and coir, (ii)Natural Rubber; (iii)Spices – pepper, cloves and cardamom; (iv)Cashew; (v)Tea; (vi) Coffee.Here we attempt to raise certain issues of concern to India's negotiating position/ options in WTO for these products/ product groups. Identification of possible developmental mechanisms and their examination under applicable WTO disciplines is necessary to throw up crucial development issues that need to be examined and debated. Formulation of a coherent and comprehensive policy structure for the long-term development of supply capacities in India of these products is only possible through such a structured approach.

2.1 Natural Rubber

Kerala holds a share of 92% in Natural Rubber production in India. World trade in natural rubber both in terms of the main suppliers and the main importers or users is very well defined and limited.Thailand, Indonesia,Malayasia, Singapore,Ivory Coast,USA, India constitute the principal suppliers of natural rubber.The principal importers are USA,China,Japan,Malayasia and Korea. Of these China imposes 20% MFN applied Tariffs where as USA, Japan and Malayasia do not impose this tariff.

Other than tariffs, the important WTO disciplines that apply to the trade of natural rubber are the possible non-tariff barriers – in terms of standards and other technical requirements - and the subsidies that may be provided by other exporting countries. Finally, an issue for discussion would be the implications under WTO agreements of possible development measures that the States and Central Government in India may put in place for the development of the industry. It may be verified that tariffs are not the most significant barriers to trade, the applied tariffs in the main markets are fairly low, ranging from 0% to 20%. Since this is also the range for the bound tariffs in these countries, the scope for negotiating the reduction of these tariffs for further improvement in the market access is limited. The present applied tariffs in India, which are amongst the highest in the main producing and exporting countries, is affording the needed protection in the domestic market for the present.

The main issue concerning Natural Rubber in India is the volatility of the international price of rubber, making it difficult to formulate a steady and long term policy. Unlike other major producers like Malaysia, Indonesia and Vietnam, where substantial state support for exports are provided no such structured incentive is provided for rubber exports from India. Governmental attempts at price stabilization has also at best had mixed results and difficult to justify as a continuous policy support mechanism, particularly when the international prices move up. The alternative to market interventions is a sustained and long term WTO compatible development policy for the sector without a specific focus on exports. This would promote a competitive industry in general.

2.2 Issues of concern

Natural Rubber in India is treated as an agricultural product, but in the WTO it is not covered by the disciplines of the Agreement on Agriculture (AOA). A move seeking renegotiation in product coverage will require significant negotiating capital – and just re-designating Rubber as an agricultural product will not allow India the right to enhance the present bound rates. For enhancing the bound rates on several agricultural tariff lines including rice and wheat, India had to negotiate under the Article XXVIII of GATT 1994 and pay significant compensation to the affected countries. This intervention is urgently needed since rubber prices had reached the lowest level of Rs.90/- per kg in the global as well as Indian markets in January 2016.

There is a need for balancing the consumer interest of NR users in India with that of the producers. Therefore, prohibitive import duties will not be supportable in the long run. The solution has to be targeted towards the sustained development of the Rubber industry. In addition to W.T.O. effects, there are various external factors, which influenced the prices of agricultural crops in recent years. As far as rubber sector is concerned the main factors are low productivity and lack of value addition. Non-exposure to export market, devaluation of Indian rupee during 1991 and Asian economic turmoil caused decline in prices. Demise of INRA (International Natural Rubber Agreement), removal of port restrictions and quantity restrictions, accumulated surplus, decline in international price, non-inclusion under AoA and treating NR as a non-agricultural crop, treating NR as an industrial raw material, lack of cost efficiency, slow down in the internal demand of NR since 1996-97 etc had their impacts.

Measures to reduce adverse effects in the rubber sector are inclusion under AoA, enhancing bound rate of tariff and infrastructure strengthening for quality improvement. Promotion of rubber wood, as an eco-friendly plant, giving subsidy for rubber export, providing a level playing field for NR growers, re-categorization of rubber as an agricultural product, imposing antidumping duty etc are some other measures. Procurement and buffer stocking through STC, NAFED etc, Promoting group action through Rubber Producers Societies (RPS), avoiding import of rubber products, providing strategic market information support, enhancing productivity, investment for productivity increase and cost effective production, promoting rubberization of roads, using rubber wood as construction timber, developing value addition techniques, incentives for quality improvement, certification and packaging and transportation and periodic review of market situations are needed.

In the case of coconut, low price of other vegetable oils, minimum level of demand, recurring drought, endemic and epidemic outbreak of pests and diseases etc are the various external factors, which caused the havoc. Dependence on coconut oil driven market alone, middle level trade practices, coconut mite infestation, drastic decline in production and lack of oil market connectivity affected this sector to a large extent. Non-inclusion under AoA and fear of cholesterol in coconut oil had adverse effects.

As remedial measures we should evolve policies focused on competitiveness through higher productivity, reduction in cost of production and better adoption of cultivation practices at farmer's level. It is necessary to find ways and means to put coconut into other alternative uses like tender coconut as soft drink, edible copra, desiccated coconut, coconut cream etc. Value addition and by-product utilization, effective utilization of land through mixed cropping in order to increase productivity and net return, integrated disease management for effective controlling of eriophyid, mite, root wilt disease, leaf rot disease, bud rot disease, stem bleeding disease etc. can help a lot. Post harvest processing methods are to be modernized for ensuring quality. The full economic potential of coconut and related products like coir, shell based handicrafts, etc are to be explored. Regulation of import, readjustment in tariff, promotion of coconut oil as an edible oil, diversification of products, promotion of sweet toddy as a health drink and jaggery making, promotion of tender coconut water as a soft drink, using coconut oil as a lubricant oil are some other steps. Coconut development projects, continuation of minimum support, price stabilization and productivity, enhancing production and productivity, expansion of area under coconut, integrated farming, new technologies for food and beverage industries etc are necessary.

Thus to achieve competitiveness in the liberalized era we have to reorient the production process towards global market rather than domestic market. One has to be proactive with the changing consumer preferences and market conditions in the global market. We have to attain global competitiveness in cost of production and value chain process and create a brand image by supplying only quality products. We have to boost spices production and ensure quality. Import of low-grade spices to India and re-export of mixed (Indian and foreign) under the Indian label should be banned.

3. Non-Gaussian Time Series Models for Crop Prices Data

Now we develop time series models for modeling time series data on agricultural crop prices. We develop non-Gaussian AR(1) time series models in Cauchy and Generalized Laplacian variables. Usual normal ARMA models are also developed. Since observed prices arise in a time sequence, it is possible that the consecutive observations are dependent. Therefore a time series model based approach has been tried to explain the fluctuations other than trend and seasonal variations. A fairly good estimate of the parameters of the series is obtained only if the series is stationary. Plotting of the original data shows that it is not stationary. Therefore, for further analysis, we take a first order difference of the prices given by $Z_n = X_n - X_{n-1.}$

Firstly we try to model the prices using the Box Jenkin's (BJ) method. In this technique a model can be fitted to data by studying the behavior of the characteristics such as ACF and PACF or by using some Information criteria like AIC. After identifying order and nature of the relationships, the model parameters are to be estimated. These models can be used for short term forecasting, because most of the autoregressive models place emphasis on recent past rather than its distant past.

As part of this study we will construct ARMA models and in special Auto Regressive (AR) Processes. An ARMA (p, q) model has the general form

$$X_t = a_0 + a_1 X_{t-1} + \ldots + a_p X_{t-p} + \varepsilon_t + b_1 \varepsilon_{t-1} + \ldots + b_q \varepsilon_{t-q}$$

The simplest AR process is the AR(1) model having the structural equation

$$X_n = a X_{n-1} + \varepsilon_n \ ; \ |a| < 1.$$

where $\{\varepsilon_n\}$ is a sequence of independent identically distributed (i.i.d.) random variables, independent of distributed (i.i.d.) random variables, independent of $X_0, X_1, \ldots, X_{n-1}$. We can obtain the structure of the innovation process $\{\varepsilon_n\}$.More details including the properties of are available in Brockwell & Davis (2002).

As part of this study we have developed different non-Gaussian Auto Regressive processes. The autocorrelation function and partial autocorrelation function along with Akaike Information Criterion (AIC) led to the conclusion that AR(1) models are sufficient to model the data on crop prices to a satisfactory level.

ARCH models

In conventional econometric models the variance of the disturbance term is assumed to be constant. However, most economic time series like price data exhibit periods of unusually large volatility followed by periods of relative tranquility. We assume a time dependence on conditional variances through an autoregressive equation for the squared innovations. This led us to construct Auto-Regressive Conditionally Hetroscedastic models.

An AR(p)–ARCH(q) model has the general form given by the structural equation

$$X_n = a_0 + a_1 X_{n-1} + \ldots + a_p X_{n-p} + \varepsilon_n$$

where $\{\varepsilon_n\}$are distributed as normal with means zero and conditional variances given by

$$h_n = b_0 + b_1 \varepsilon^2_{n-1} + \ldots + b_q \varepsilon^2_{n-q} + \nu_n$$

where $\{\nu_n\}$ is a white noise process.

The details are summarized as follows.

3.1 Some non-Gaussian Time series models

(i) An Auto-regressive Model with Cauchy innovations

Consider the AR(1) model

$$X_n = aX_{n-1} + \varepsilon_n \; ; \;\; |a|<1 \qquad (1)$$

where $\{\varepsilon_n\}$ is i.i.d. and independent of $\{X_{n-1}\}$. In terms of characteristic functions, equation (1) can be rewritten under the stationary case as

$$\varphi_X(t) = \varphi_X(at)\, \varphi_\varepsilon(t)$$

$$\therefore \;\; \varphi_\varepsilon(t) = \varphi_X(t)/\varphi_X(at) \qquad (2)$$

Consider the Cauchy distribution whose characteristic function is

$$\varphi_X(t) = e^{-|t|}$$

Substituting in (2), we get the characteristic function of the innovation process as

$$\varphi_\varepsilon(t) = e^{-(1-|a|)t}$$

Hence the p.d.f. of $\{\varepsilon_n\}$ is another Cauchy density.

(ii) etric Stable Processes

In this case also the innovations are also distributed as symmetric stable.

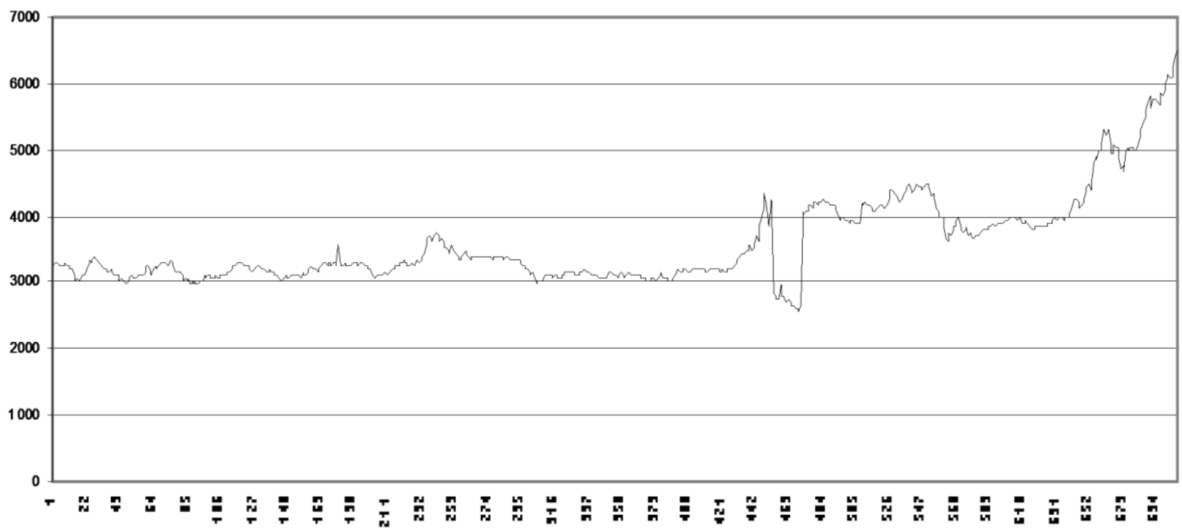
(iii) Generalized Laplacian Processes

The generalized Laplacian random variable being the difference of Gamma random variables is the sum and difference of a number of exponential random variables. It has wide flexibility and can model data from various contexts having a growth-decay structure. Agricultural crop prices can be regarded as the net effect a number of positive and negative factors. Hence a generalized Laplacian autoregressive process may be most appropriate in this context. The innovation distribution can be derived easily as before.

3.2 A Cauchy model for Coconut prices

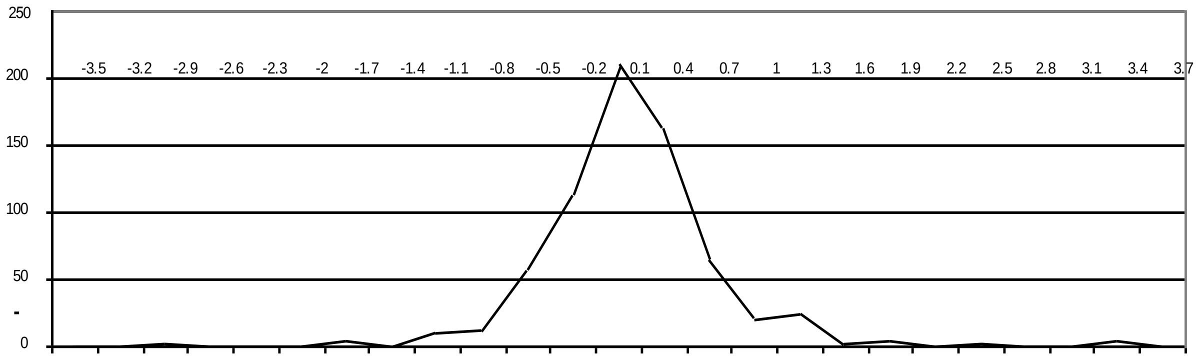
We apply the Cauchy model developed above to model a set of data consisting of daily coconut oil prices (in Indian Rupees per quintal) at Cochin market for a period from January 1994 to December 1996. The analysis is mainly concerned with the price recorded on each trading day.

Time series plot of Coconut Oil Prices (1993-96)



The time series plot of the original data shows an increasing trend while the differenced series is stationary. So it is convenient to analyze the changes in the successive prices. Let X_n be the original price on the day 'n', then we make the transformation $Z_n = (X_n - X_{n-1}) / \sigma (X_n - X_{n-1})$, where $\sigma (X_n - X_{n-1})$ is the standard deviation. For testing normality, we use Geary's (Cooper and Weeks (1988)) test statistic G, which is the ratio of the mean deviation to the standard deviation. The G-statistic for the transformed values of the coconut oil prices is G = 0.4956 and hence we reject the hypothesis that the underlying distribution is normal.

Frequency curve of the transformed coconut oil prices



The figure suggests that the other possible distributions may be Cauchy, generalized Laplace, Linnik etc as we are dealing with the price data. To confirm the applicability of the distribution we have to test the goodness of fit. The transformed data is symmetric about zero. Goodness of fit test concludes that the transformed sequence follows a Cauchy distribution.

Finally we get the model $Z_n = 0.033277\, Z_{n-1} + \varepsilon_n$, where $\{\varepsilon_n\}$ is a sequence of independent and identically distributed random variables which follows Cauchy C(0.966723,0) distribution .

3.3 ARMA and ARCH Models for Coconut Oil Prices

In this section we develop various time series models for coconut prices/indices. In order to achieve stationarity we make the following transformation. If X_t is the price at time t, the first order difference is $Z_t = X_t - X_{t-1}$. The first order differences are labeled as 'dprice'. In the case of coconut and rubber we analyze both prices and wholesale price indices. The data on prices is monthly prices of coconut at Cochin market.

Since the AIC and RSS for all the models are not much different the most parsimonious model is the AR(1) model given by

$$Z_t = 22.921 + 0.3088\, Z_{t-1} + \varepsilon_t$$

where $Z_t = X_t - X_{t-1}$ and $\{\varepsilon_t\}$ is the innovation process. The innovations may be assumed as following distributions like Linnik, stable, Cauchy, Laplacian, generalized Laplacian etc.

In a similar manner AR(2), ARMA (1,1), ARMA (2,1), ARMA (2,2) models can be constructed. The fitted ARMA model is

$$Z_t = 19.509 + 1.736\, Z_{t-1} - 0.9976\, Z_{t-2} + \varepsilon_t + 1.70224\, \varepsilon_{t-1} - 0.9976\, \varepsilon_{t-2}$$

Since the AIC and RSS for all the models are not varying much we conclude that the most parsimonious model is the AR(1) model given by

$$Z_t = 1.19964 + 0.34036\, Z_{t-1} + \varepsilon_t .$$

For the coconut oil prices data, we get the AR(1) – ARCH (1) model given by

$Z_t = 22.921 + 0.3088\ Z_{t-1} + \varepsilon_t$

where $\{\varepsilon_t\}$ are distributed as normal with mean zero an conditional variances given by

$h_t = 19.4308 + 3.2083\ \varepsilon^2_t + 0.2122\ \varepsilon^2_{t-1} + \nu_t$

where $\{ \nu_t \}$ is a white noise process. Using the models developed we can predict the future values of the process. This method can be used for obtaining forecast and confidence limits for the future values of the series. Similarly we can develop AR-ARCH models for pepper, tea, and cashew prices as follows.

The AR(1) – ARCH (3) model for pepper price indices is $Z_t = 7.1813 - 0.3880\ Z_{t-1} + \varepsilon_t$ where $\{\varepsilon_t\}$ are distributed as normal with mean zero an conditional variances given by

$h_t = 3.1435 + 326.0578\varepsilon^2_t + 0.6210\ \varepsilon^2_{t-1} + 0.2143\ \varepsilon^2_{t-3} + \nu_t$ where $\{ \nu_t \}$ is a white noise process.

The AR(1) – ARCH (3) model for tea price indices is $Z_t = 1.15963 + 0.19433\ Z_{t-1} + \varepsilon_t$

where $\{\varepsilon_t\}$ are distributed as normal with mean zero an conditional variances given by

$h_t = 2.7698 + 285.4655\varepsilon^2_t + 0.5540\ \varepsilon^2_{t-1} + 0.2844\ \varepsilon^2_{t-3} + \nu_t$ where $\{ \nu_t \}$ is a white noise process.

The AR(1) – ARCH (3) model for cashew price indices is $Z_t = 1.30989 + 0.19557\ Z_{t-1} + \varepsilon_t$

where $\{\varepsilon_t\}$ are distributed as normal with mean zero and conditional variances given by

$h_t = 1.1594 + 47.6680\ \varepsilon^2_t + 0.3887\ \varepsilon^2_{t-1} + 0.0791\ \varepsilon^2_{t-3} + \nu_t$ where $\{ \nu_t \}$ is a white noise process.

4. Conclusions

The paper makes a detailed analysis of the various problems faced by Indian agriculture in the new liberalized era under W.T.O. regime and points out the challenges ahead. The economics of globalization is based on Ricardo's principle of comparative advantages. Our comparative advantage is mainly in the field of agriculture. It should always be remembered that the only means of success under the W.T.O. regime of liberalization are increased productivity, high quality and value addition.

The new time series models developed can be used for short-term predictions only since agricultural prices depend on government policies and various other factors. Problems like proper data warehousing and management, developing advanced statistical tools, diagnostic checking, statistical inference, developing more efficient algorithms etc are problems for further research

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Computation of Agriculture: Analytics for Agriculture

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ABSTRACT

Computation of Agriculture is a concept to encourage sustainable growth of agriculture and rural development. The concept is anticipated through an analytically enabled digital platform, "e-Rural Services". The platform helps to capture data through digital means and process through advanced analytical models to provide valuable insights from the data. It helps to reduce uncertainty in farming business and enhance productivity. The agri-business services through analytical tools and engaging multiple corporations make the application economically viable and encouraging. The public and policy making institutes will be interested to monitor periodic developmental metrics and suggest strategies for sustainable growth. Thus the stakeholders of entire eco-system are encouraged to be participated in the developmental process through this analytical platform, modernizing the farming systems and encouraging the youths in agriculture.

Keywords: Analytical Models, Digital applications, Developmental Goals

1. Introduction

Agriculture is the noblest profession in the world. The livelihood feeds the world. The farmers are the key contributors for the food securities of nations and the world. Technological innovations have changed the urban livelihood and business. But the countryside life has been enriched but not at the pace of urban world. The discrepancies in the standards of living have given birth of multiple problems, including shift from agriculture profession. This has direct bearing to the food security. The situation is more miserable in under-developed and developing countries, where farmers have limited resource and small and marginal land size. It is very difficult for them to combat against modern challenges in agriculture; climate change, increase in disease and insect pests incidences, decrease in soil fertility, water scarcity and market dynamics. The rural youth feel very much discouraged to have agriculture as their future profession. This is a matter of concern for all of ours existence.

Agriculture business needs to be modernized.The data science and digital technologies can revolutionize the ways of business in agriculture as it is observed in urban space. With increase in population and decrease in resources it is needed to adopt precision farming tools and optimize farming through scientific means. The modern technologies being cost effective, it is challenging to adopt for the small and marginal farmers. The farmer cooperatives and groups are not even successful due to various socio-economic and political issues. Considering the challenges it is very likely that the data science can group probable friendly farmers through a virtual platform, to facilitate in agri-business activities.

It has been envisioned to modernize the living standards of the rural world through computation of agriculture data and provide analytical insights on farming business strategies through e-Rural Services platform.The metrics measured on farming livelihood development is targeted to address the indicators of United Nations developmental goals. This helps the regional and national institutes to reap the benefit of the farmers' data. The agri-business information can be suitable for the corporations in agriculture to improve their sales with useful insights on demand and supply. The farmers the key beneficiaries will be provided with basic agricultural productivity information; crop selection based on soil, weather and available resources, disease and insect pests alerts through weather modelling, weather forecast alerts and market information. Each of the stakeholders' participation in the platform will make the digital eco-system economically viable and sustainable. The periodic self-initiated updates on the farmers' data will be helpful to monitor, identify and uplift the weaker zones of the society. The data collection is facilitated through mobile phone technologies which is mostly accessible.

2. e-Rural Services Platform

The "e-Rural Services" is a digital platform for agricultural and rural development. It is an integrated platform to collect sanitizes and store data, analyses and disseminates information. The services related to the initiative aredesigned for the major stakeholders of the agri-business. The farmers are the key beneficiaries with basic agriculture information, livelihood developmental support from institutes and farming business support from corporations.The platform is believed to be economically self-sufficient and sustainable with more data and information related services.

The platform is divided in three components; Data Collection, Data mining through Analytical models and Reporting (Figure 1).

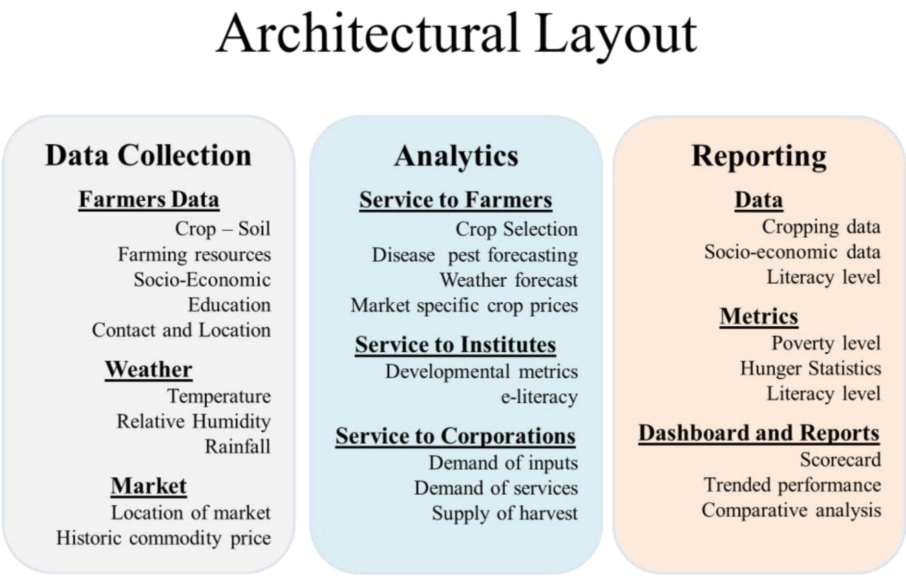

Figure 1: *Architectural Components of e-Rural Services*

The platform is a web-based application. It facilitates the users and operators to function irrespective of location and time.This helps in improvement of the services and penetrates to the remote locations. The internet connectivity and smart phone technologies may not be affordable to all the farmers. It is being bridged through farmer- agents, who can enrol multiple farmers in the application. The information on cropping practises and weather are facilitated through SMS and voice calls. It eliminates the immediate requirement of IT gadgets and subscriptions.

The initial services on agri-business prompt the farmers to enrol and update in the digital platform. Information related to agricultural activities and resources and weather data will abreast to build the models to provide precision services for cropping practises. The market location and trended crop-prices will help to locate best revenue of the harvests. The input requirements (seed, fertilizer, pesticides, farm machineries etc.) for cropping practises will help the corporations to assist the farmers with competitive prices and in right time. It will help the agri-input companies to maintain the customer loyalty and the farmers to be advanced in their farming productivity with new products. The available harvests can trigger the output agriculture services to procure harvests at field with best prices. It will eliminate the intermediate business exchanges, thus providing improved pay-off.

The information related tocropping practises, socio-economic and education will help to derive useful insights related to the livelihood development of the location. It will be an interest of the policy making institutes to improve the metrics, which contribute to the overall development of the Nation.

The digital platform is operated seamlessly with the support of advanced analytical models and modern tools on information technologies which enable to provide useful insights and presentable automated reports. The information for the farmers through SMS, voice call, mobile app messages are very simple to understand and executable. They are encouraged to connect with system for further clarification and information.

3. Description of components of e-Rural Services Platform

The components of the digital platform are represented as Data Collection, Analytical processing of the data and Reporting (Figure 1). The components are enabled to be connected with each other for automated processing, real time output generation and information dissemination. Each of the modules is depicted in details in the following sub-headings.

3.1 Data Collection

The data collection and periodic updates on data from the users are the fuel for analytical engine of the platform to be functional. The good data collection is one of the major challenge for operation of the functionalities. The digital means of data collection will facilitate to reduce costs and with increase data quality. The data assortment is done under following heads –

a) Farmers'Data –The farmers' data are collected through the mobile application. Farmers' friend and agents in fields helps for initial registration process. The registered farmers are being connected with the system through voice calls and SMS. Since most of the data fields are pre-defined and selective there are less chances of data entry errors.

b) Weather Data – The historic and predicted weather information are being pulled from government sources and transmitted through the system. The weather information are required for model building exercises for recommendation on agricultural services. With growth of services and farmers' empowerment automated weather stations can be installed for more precise forecasting services.

c) Market Data – The regional level local market locations and crop prices data are being fetched through farmers' network. The recognized market places and the prices are recorded in government websites. Those data are pulled for analysis and transmission to the respective location specific farmers. Online markets can be linked to the platform to provide best bid to the farmers.

The mobile application has been explored for data collection from the farmers. The application can be operated as Farmer, as Agent and as Administrator (Figure 2), demonstrating different data requirements. The operational hierarchies are needed for effective communication management enabling good data collection and viability (Figure 3).

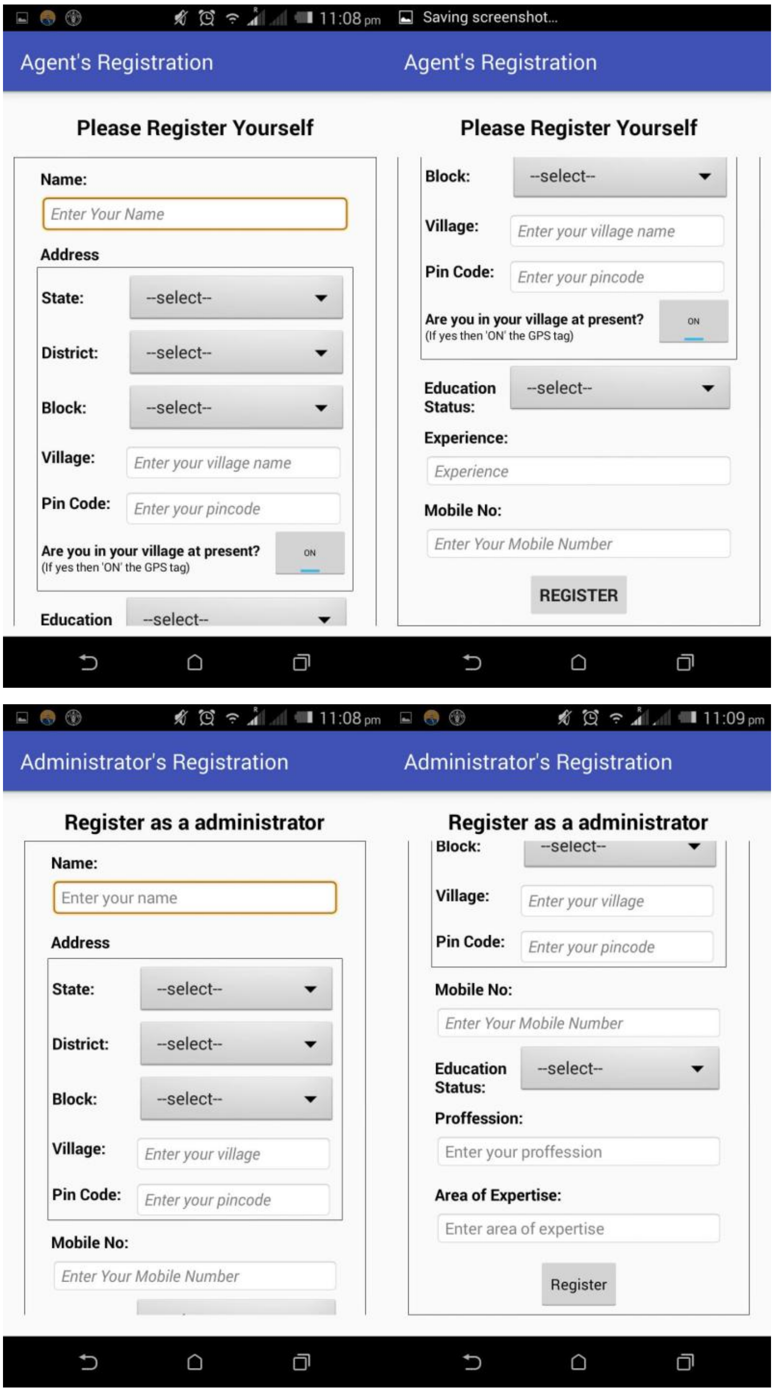

Figure 2: *Mobile Application screen shots for registration of different operators*

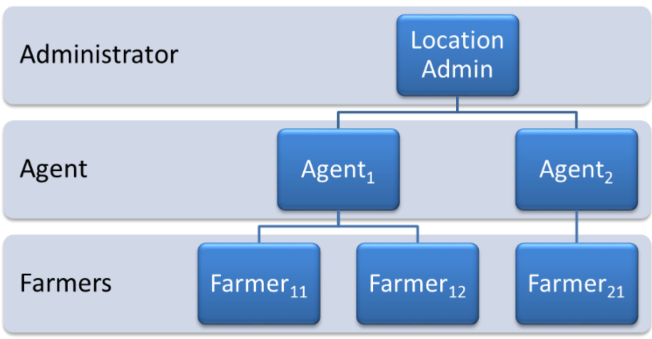

Figure 3: *Operational hierarchy for communication management*

3.2Analytics

The services provided to the different stakeholders are based on data analytics. This enables the farming business eco-system to be viable and transparent. Following are the brief description on the analytical modules based on the stakeholders.

a) Service to Farmers –The analytical infrastructureisdesigned to process varieties of services through data modelling. The data being gathered are subject to undergone through sanity checks (through trend and growth analysis) and cross-validation for exceptional entries. It is then processed for further inferential operations. Following are the current focus points –
   i. Crop Selection:Crop selection is done based on the available resource information and probable weather conditions. Linear programming and regression based models are being explored to determine best profitable crop for the cultivator.
   ii. Disease and insect pests forecasting: The weather based models are developed to forecast incidences of crop specific disease and insect pests and strategies to control them. The machine learning (Logistic regression and Artificial Neural Network) and differential equation based techniques are explored for model building.
   iii. Weather Forecast: Forecast for weather parameters like temperature, relative humidity and rainfall are subscribed through weather portals of government and other agencies.
   iv. Market specific crop prices: The right market search and price forecasting are one of the important services for the farmers. The time series forecasting mechanism (ARIMA and Spline regression) approach is being explored. The best market search is based on distance of the field to farm and profit margins.

b) Service to Institutes – The rural and agriculture development institutes comprising of public and private domains will be interested to know the performance metrics for the group of the farmers. The data being updated periodically will help to gauge the developmental trends.The developmental metrics focussed on first two goals of Millennium Development Gaols; Eradicate Extreme Poverty and Hunger (Goal 1) and Achieve Universal Primary Education (Gaol 2). The goals are followed as No Poverty (Goal 1), Zero Hunger (Goal 2) and Quality Education (Goal 4) under Sustainable Development Goals (SDGs). –
   i. Developmental Metrics:
      a. Proportion of population below \$1.25 (PPP) per day

$$P_0 = \frac{1}{N} \quad {}_{i=1}^{n} I \quad y_i \leq z \quad = \frac{N_p}{N} \qquad (1)$$

where I(.) is an indicator function that takes on a value of 1 if the bracketed expression is true, and 0 otherwise. If individual consumption or income (yi) is less than the poverty line (z), then I(.) is equal to 1 and the individual is counted as poor. Np is the total number of the poor. N is the total population. As followed in MDGs indictor definition.

      b. Poverty gap ratio

$$P_1 = \frac{1}{N} \sum_{i=1}^{N} \left(\frac{G_n}{z} \right), G_n = (z - y_i).I(y_i \leq z) \qquad (2)$$

where the poverty gap (Gn) is the difference between the poverty line (z) and income or consumption for those who are poor (the non-poor have a poverty gap of zero). I(.) is an indicator function that equals 1 if the bracketed expression is true, and 0 otherwise. N is the total population. As followed in MDGs indictor definition.

      c. Proportion of population below minimum level of dietary energy consumption

This indicator has been defined within a probability distribution framework. As followed in MDGs indictor definition.

$$P(U) = P(x < r_L) = \int_{x<r_L} f(x)dx = F_x(r_L) \qquad (3)$$

where,

P(U) is the proportion of undernourished in total population;

(x) efers to the dietary energy consumption or intake;

r_L is a cut-off point reflecting the minimum acceptable dietary energy consumption;

f(x) is the density function of dietary energy intake; and,

Fx is the cumulative distribution function.

d. Literacy rate of 15-24 year-olds, women and men

Literacy rates are computed by dividing the number of people aged 15–24 years who are literate by the total population in the same age group, the result is then multiplied by 100. As followed in MDGs indictor definition.

$$LR_a^t = \frac{L_a^t}{P_a^t} \times 100 \qquad (4)$$

LR_a^t= Literacy rate of age group “a” in year “t”

L_a^t = Literate population of age group “a” in year “t”

P_a^t= Population of age group “a” in year “t”

ii. e-Literacy:The metrics defined to measure the level of e-Literacy for sharing of knowledge for agri-business. It is the ratio the farmers registered did self-registration and maintains smart phone and internet to the total no. of registered farmers. It is also a measure of economic prosperity to avail advance knowledge through modern tools.

c) Service to Corporations

The corporations can explore the experience of direct trading with the end consumers through the digital platform. Following metrics can be useful for managers of the corporations.

i. Demand of Inputs:The farmers’ agricultural input requirements can be based on forecasted models for the crop section and pesticide requirements. Fertilizer module being integrated can be an area of interest. Agricultural machineries can be placed at farmers’ utilities based on the crop stages information.

ii. Demand of Services: Various services can be explored for the farmers to improve the crop productivity and financial improvement. It can be the initiatives of various input companies to place their product and improve farmers’ loyalty. Financial services from banks and insurance institutions can aid the farmers to advance in their agri-business.

iii. Supply of Harvest:Harvest gathering information will be interests for the retail chains and various food industries. Farmers and the food services can mutually be benefitted eliminating intermediate business exchanges.

3.3Reporting

The reporting service from the platform is one of the most important modules of the digital platform. It enables the users to take benefit of the data for their respective businesses improvement encompassing around public, private and personal sectors. The agri-businesses, mostly the personal sector, are the largest sector in terms of employment. But the sector suffers from less revenue due to uncertainties in farming business and improper management. The reporting section is aimed to provide insights and opportunities to improve the sector’s performance. It will help the farmers to increase their efficiencies. The public and private sectors contributions will enhance the improvement.

The reporting of the information has been categorized under following heads –

a) Data:The processed data on cropping activities, socio-economic informationand literacy will be helpful for the responsible authorities to perform personalized studies.
b) Metrics: The automated metrics generated on the data processing will benefit all the sectors, in particular the public sector design policies for countryside development.
c) Dashboards and Reports: The dashboards and reports are the vital to monitor the periodic progress.

4. Conclusion

The "e-Rural Services" is a platform to perform agricultural analytics and provide services to different agri-business stakeholders. The digital platform can serve as an automated monitoring system to gauge periodic agricultural development. The farmers being engaged with the system for agricultural and business services, helps to inflow of data in the platform. With the passage of time it is envisioned as a self-serviced, economically viable and sustainable analytical-digital platform for agriculture. The platform being in service for public, private and personal sectors of the rural ecosystem, the penetration of the services to maximum farmer population is highly expected. It will encourage development in every aspect of country side life. Thus stabilizes uniform sustainable growth of the Nations.

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Canada - Crop Yield Modelling Using Remote Sensing, Agroclimatic Data and Statistical Survey Data

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ABSTRACT

Statistics Canada's goal for modelled yield estimates was to produce a midseason estimate of crop yield and production based on information received as of the end of August, similar to what has been traditionally done with the September Farm Survey. The November Farm Survey estimates are considered the most accurate estimates of yield for a given year, due to the fact that the data are collected after the majority of harvesting has been completed and the sample size is the largest of the Field Crop Reporting Series. The modelled yield estimates and September Farm Survey estimates were both compared to the November Farm Survey estimates to verify the accuracy of the yield model results compared to the survey. Nineteen crops were introduced to the modelling process but published results were restricted to 15 when rules based on data availability and quality were implemented.

In 2015, the model-based yield estimates were disseminated for the first time by Statistics Canada as a supplemental publication 3 weeks in advance of the September Farm Survey and 11 weeks in advance of the November Farm Survey results.The modelled yield estimates had less deviation from the November Farm Survey than the September Farm Survey for canola, corn for grain,mixed grains, oats, rye, soybeans, and canary seed. Conversely, the September Farm Survey had less deviation from the November Farm Survey than the model for barley, flaxseed, dry peas, spring wheat, winter wheat, lentils, and mustard seed. Equal deviation was noted for durum wheat yield.

Feedback through government and industry consultation has been very positive and commencing in 2016, Statistics Canada replaced the September Farm Survey with the Model-based Principal Field Crop Estimates.

Key words: Remote Sensing, Normalized Difference Vegetation Index, Yield Model, Agriculture, Crop Statistics

1. Introduction

Innovative approaches in estimating crop yields are continuously being sought with the objective of reducing respondent burden while producing accurate, timely and reliable estimates. Statistics Canada, in cooperation with Agriculture and Agri-Food Canada, has developed a crop yield modelling approach as a non-intrusive method of producing yield forecasts that incorporates the 1 km resolution Normalized Difference Vegetation Index (NDVI) data used as part of Statistics Canada's Crop Condition Assessment Program, statistical survey data from Statistics Canada's Field Crop Reporting Series, and agroclimatic data for the agricultural regions of Canada. Although both the agroclimate and crop yield data had a longer time series, the study period was chosen according to the availability of the satellite data; a 29-year time series from 1987 to 2015.

Each year, Statistics Canada has traditionally conducted six farm surveys, in part, for estimating seeded area, harvested area,expected yield and production as part of the Field Crop Reporting Series. Like many other national statistical agencies, it is under increasing pressure to reduce response burden and cost of the traditional surveys while maintaining relevance, accuracy, timeliness, accessibility, interpretability and coherence.

Statistics Canada has therefore been researching and evaluating alternate methods of incorporatingadministrative data into its program to produce non-intrusive estimates of field crop yields and production.Agriculture and Agri-Food Canada (AAFC), has also been investigating the use of yield modelsfor the same purpose.To ensure no duplication of effort, a yield model that was being developed by AAFC using R statistical language software was transferred to Statistics Canada. The two organizations workedtogether on developing a robust yield model. Within Statistics Canada, the yield model was ported to a SAS platform.

The two departments modified the model with the goal of producing principal field crop yield estimates as of August 31.The 2015 modelled results were deemed of acceptable quality and were published by Statistics Canada3 weeks in advance of the September Farm Surveyresults and 11 weeks in advance of the November Farm Survey results.

This paper provides an overview of the background and general methods used to model reliable crop yield estimates as a preliminary estimate ofthe November Farm Survey estimates.

2. Methodology

A methodology for modelling crop yield was developed and tested in fiveCanadian provinces(Alberta, Saskatchewan, Manitoba, Ontario, and Quebec)forcrops that are typically published at the provincial and national levels by the September Farm Survey. These five provinces account for about 98% of the agricultural land in Canada and for the purpose of this paperare referred to as the national level when the yield model resultsare discussed.

2.1 Data sources used in the model

The modelling methodology used three data sources: 1) NDVI derived from coarse resolution satellite data (Latifovic et al., 2005)an integral component of Statistics Canada’s Crop Condition Assessment Program (Bédard, 2010); 2) area and yield data collected through Statistics Canada’s Field Crop Reporting Series, and 3) agroclimatic data for the agricultural regions of Canada.

2.1.1 Normalized Difference Vegetation Index (NDVI)

Since 1987, Statistics Canada has monitored crop conditions across Canada using the 1-km resolution, Advanced Very High Resolution Radiometer (AVHRR) sensor aboard the National Oceanic and Atmospheric Administration (NOAA) series of satellites. The NDVI was processed on a weekly basis throughout the growing season and used within Statistics Canada’syield model as a standardized index of vegetation health. These weekly NDVI values are available for download fromStatistics Canada’s Canadian Socio-Economic Information Management System (CANSIM), Table 001-0100.

2.1.2 Survey area and yield data

Survey estimatesfrom Statistics Canada’s Field Crop Reporting Series provided accurate and timely estimates of the seeded area, harvested area, yield and production of the principal field crops in Canada at the provincial level (Statistics Canada, Table 001-0010; Table 001-0017).

Results from the surveyswere only utilized in modelling activities when the crop wasrelatively abundant. If the crop wasabundant in a province, the yield estimates wereavailable at sub-provincial geographicunits.This finer level of geography usually correspondedto the Census Agriculture Regions (CAR) of which there are 82 across the agriculture region of the country (Statistics Canada, 2011). If the crop wasnot abundant, then yield estimateswereavailable at the provinciallevel only.

For abundant crops, CAR level crop yield estimates from the July and November Farm Surveys from 1987 to present were used as input variables for developing the model while yield estimates from the September Farm Survey and the November Farm Survey were used to validate the yield model results. For less abundant crops, the survey data and model results wereanalyzedat the provincelevel.

Area data from the June Farm Survey were used to aggregate yield estimates to larger geographic regions as described in Section 3.2. This area data along with yield data from the July and November Farm Surveys were used as part of the publication rules to determine which of the modelled yields were of acceptable quality for publication. The publication rules are described in Section 4.1.

2.1.3 Agroclimatic data

Climate data from 416 climate stations throughout the agriculture region of the five provinces was the third data source used as part of the crop yield modelling process. The station-based daily temperature and precipitation data provided by Environment and Climate Change Canada and other partner institutions were re-analyzedby AAFC to generate the climate-based predictors which amongst others included crop moisture stress, cumulative precipitation and growing degree days(Newlands et al. 2014, Chipanshi et. al. 2015). These data were provided to Statistics Canada by AAFC.

3. Modelling survey yields

3.1 Development of Statistics Canada'syield model

AAFC has an extensive history in developing field crop yield models. The most recent were documented in Newlands et al. (2014), and Chipanshi et al. (2015). These models incorporated non-Bayesian and Bayesian methods at different steps. The variable selection step used a non-Bayesian approach by the least-angle robust regression algorithm. Yields were then estimated using a Bayesian approach.

Statistics Canada had different modelling needs than AAFC. The AAFC model used Bayesian methods in order to estimate yields throughout the growing season at monthly intervals. Early season estimates were produced when data for the current year were not available. Unavailable data for the rest of the growing season were generated using a random forest method (Liaw and Wiener, 2002) which allowed crop yield results to be displayed as a probability.The Statistics Canada model was to be used in the middle of the growing season when the majority of thedata forthe current season werealready available, thereforethe Bayesian approach was not required. Statistics Canada also required that the model run on a SAS platform which is the standard programming tool used at the Agency. The AAFC models were programmed using Rstatistical language software.

Statistics Canada'smodelling goalwas to predict the final crop yield, therefore, the dependent variable of the model was the crop yield estimate from the November Farm Survey. There were 80 potential explanatory variables derived from the three data sources described in Section 2. Thus it was necessary to implement an appropriate method of selecting the model's explanatory variables. Bédard and Reichert (2013), established that the optimal number of explanatory variables to be selected for modelling was five. Khan et al., (2007), emphasized the importance of using robust modelling methods for selecting the explanatory variables for the model and estimating the yields. As there was no robust variable selection procedure in the SAS software it was necessary to use non-robust algorithms as an alternative at the selection step and then to estimate the model in a robust way. The Least Absolute Shrinkage and Selection Operator (LASSO) method was selected from the five variable selection algorithms available in SAS. The MM method (Yohai, 1987) was chosen from the robust regression methods available in SAS due to its ability to effectively treat outliers (Copt et al. 2006).

Preliminary evaluations were conducted using the data from 1987 to 2014. The median absolute differences in yield at the national level between the AAFC and Statistics Canada models for the seven largest crops in Canada were all between 0.9% and 2.4% (barley, 0.9%; canola, 1.0%;

corn for grain, 1.4%; durum wheat, 1.3%; oats, 0.9%; soybeans, 2.4%; and spring wheat, 0.9%)(Statistics Canada 2015). Since the two methods produced similar results, Statistics Canada made the decision to adopt a model using LASSO variable selection and the MM robust regression estimation in SAS.Throughout the remainder of the paper, results will only be discussed for this model used by Statistics Canada and will be referred to as the “yield model”.

3.2 Aggregating modelled yield estimates

For the majority of the crops, modelling was done at the CAR level, the smallest geographic unitfor which historical survey data were available, or, for less abundant crops, the provincial level. The CAR level yield estimates are weighted based on seeded area estimates from the June Farm Survey and aggregated to produce a provincial estimate. For crops that are less common in a province, the model estimates werebuiltat only the provincial level. A similar weighting approach was used to aggregate provincial and the national yield estimates.

3.3 Model evaluation method

The November Farm Survey estimatesare considered the most accurate estimate of yield for a given year, due to the fact that the data are collected after the majority of harvesting is completed and the sample size is the largest of all six of the survey occasions. The results of the September Farm Survey can be considered a preliminary estimate of the November results. Therefore, Statistics Canada’sgoal for the yield model wasnot to replicate the results of the September Farm Survey but rather to obtain a sufficiently accurate yield estimate in advance of the November Farm Survey results.

The relative difference (presented as a percentage) between the yield estimate of a given method (i.e., September Farm Survey or the yieldmodel) and the November Farm Survey yield estimate was the measure of accuracy.A negative relative difference indicated that the given yield estimate was smaller than the November Farm Survey estimate, while a positive relative difference indicated that the given yield estimate was larger than the November Farm Survey estimate.

$$Relative\ difference = 100 * \frac{Given\ yield\ estimate - November\ Farm\ Survey\ yield\ estimate}{November\ Farm\ Survey\ yield\ estimate}$$

4. Publishing the yield estimates

Modelled crop yield estimates wereproduced at the CARlevel whenever possible and then rolled-upto the provincial and national levels.Statistics Canada has established three criteria based on data availability and quality that must be met to ensure the statistical integrity of the estimates and to determine which of the modelled crop yields were of acceptable quality for publication. Each year, the yield model estimates for individualcropsmust be evaluated to determine whether there is sufficient quality to warrant publication.

4.1 Publication rules for modelled yields

A minimum of 12 years of historical survey yield data for both theJuly and November Farm Surveys must be available as well as area and yield estimates for the current year from the June and July Farm Surveys, respectively. If these conditions are not met, then a modelled yield estimate will not be produced for that CAR or province.

The provincial yield estimate for a crop will not be published if the total cultivated area estimated by the June Farm Survey from suppressed regions (based on the previous set of conditions) exceeds 10% of the provincial area for the crop. Similarly, if provincial yield estimates for a crop were not published, the national level estimate will not be published if the total cultivated area for the suppressed provinces exceeds 10% of the national area.

Finally, if the coefficient of variation (CV) of the provincial or national estimate from the model was greater than 10%, the estimate was not published at that level. Model based CVs are calculated differently than those for survey estimates. Different CV thresholds are used to determine which estimates are suitable for publication than those used in the Field Crop Reporting Series. The 10% CV threshold for the model is the approximate equivalent to allowing a maximum absolute relative difference of 25% between the modelled yield and the November Farm Survey yield estimate.

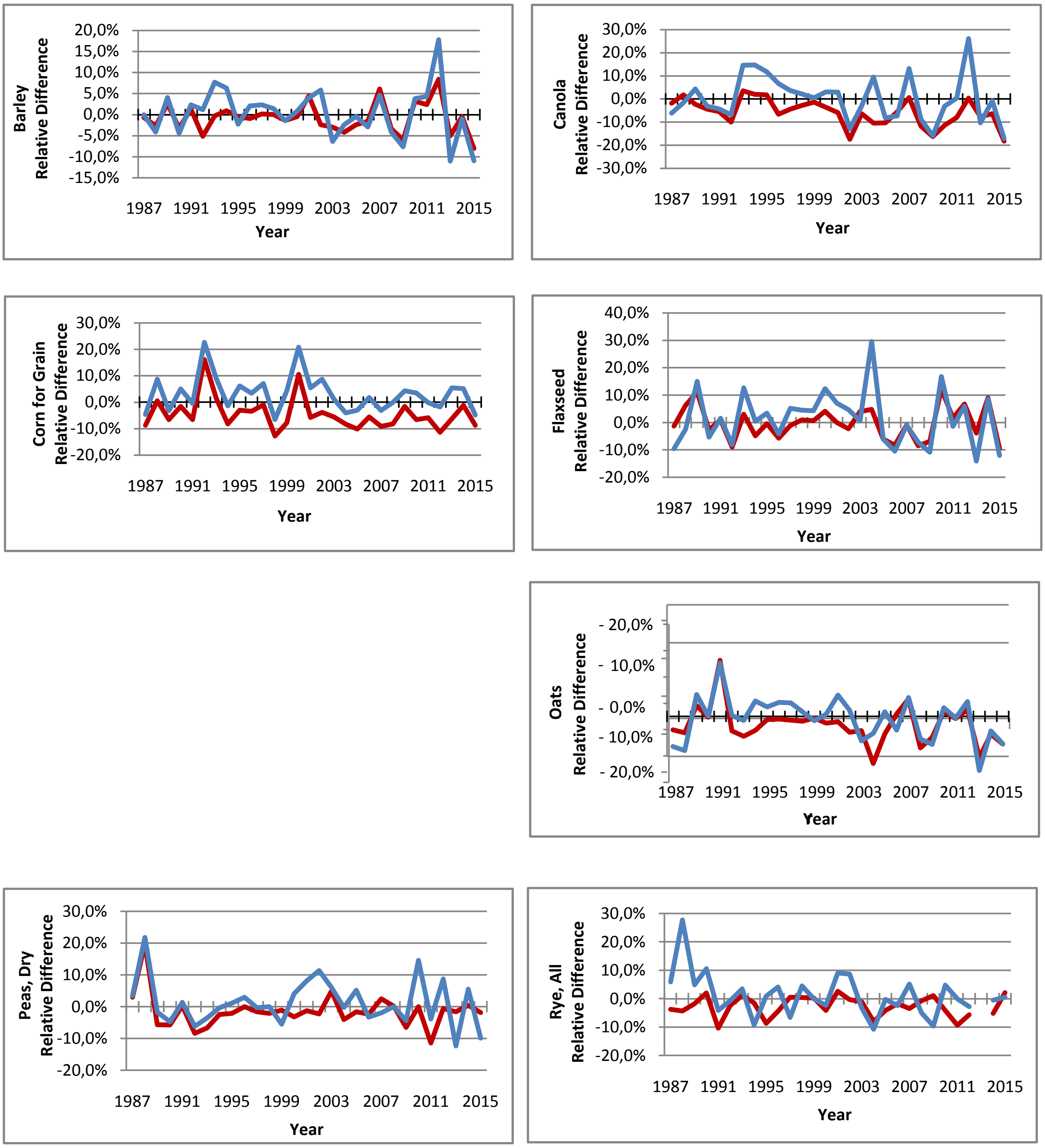
In cases where the estimates for some provinces were suppressed due to quality, but an estimate for the national level was still produced, only provincial estimates that were of an acceptable level of quality were used.

5. Results

5.1 Comparisons of the modelled and survey yields

Nineteen crops were introduced to the modelling process at Statistics Canada but published results in 2015 were restricted to 15 when rules on data availability and quality were implemented. The four crops suppressed were chick peas, coloured beans, sunflower seed, and white beans.

To verify the accuracy of the yield model,the relative difference of its yield estimates relative to those from the November Farm Survey were computed from 1987-2015. The September Farm Survey yield estimates were also compared to November Farm Survey yield results to provide a comparison of the accuracy of both methods.Figure 1 presents the comparison graphs for the 1987-2015 time series for the 15 crops for which modelled yield results were released in 2015.



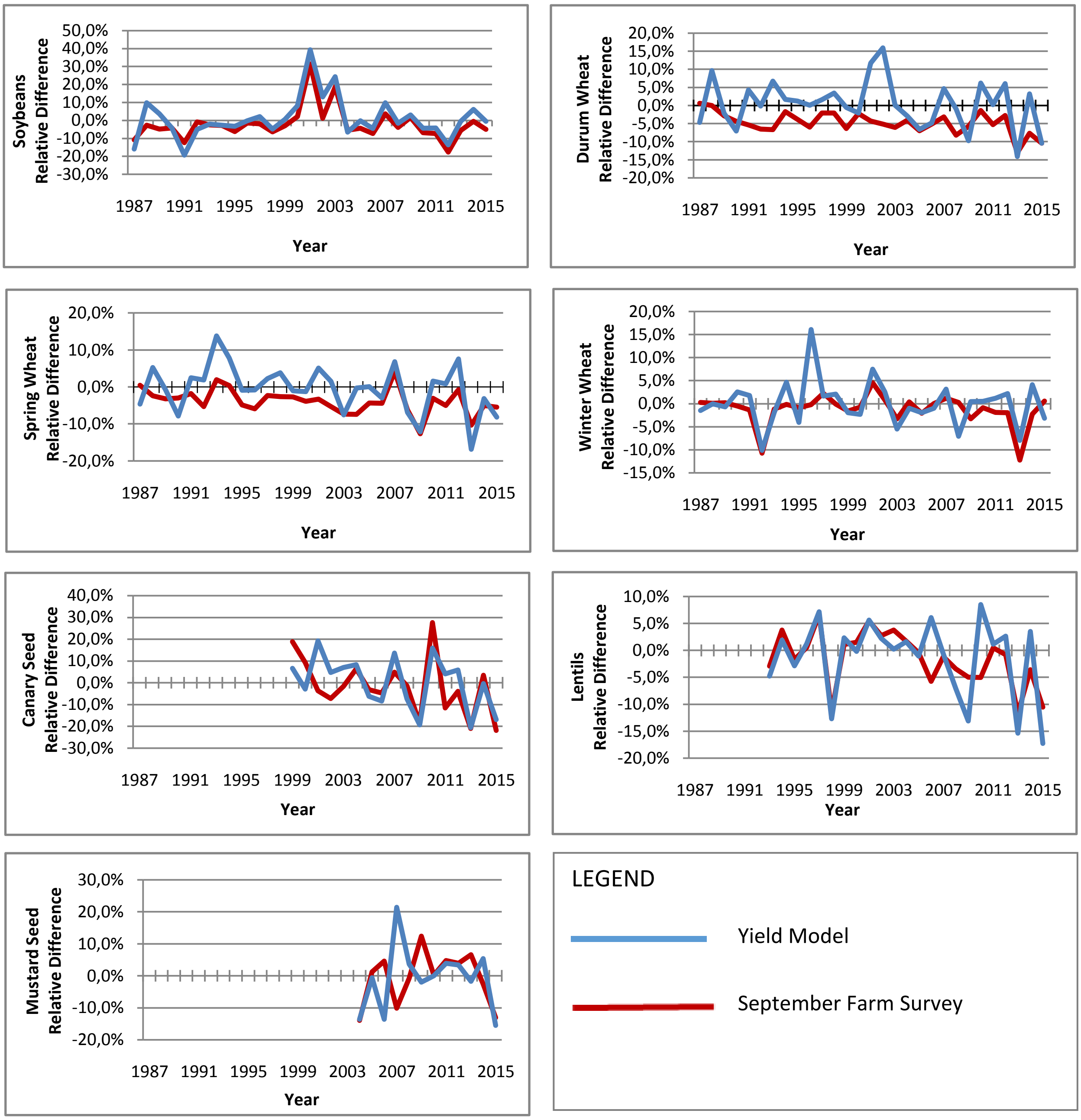


Figure 1. Relative difference of the yield model and the September Farm Survey from the November Farm Survey yields at the national level, 1987 to 2015.

The analysis shows that there is no consistent pattern when the yield model estimates and the September Farm Survey yield estimates are compared to the November Farm Survey for the 1987-2015 time series (Figure 1). Neither method is consistently closer to the November Farm Survey estimates for any crop. For soybeans and corn for grain, the two methods follow a similar pattern of estimates for the 29 years with regard to how the estimates change from year to year. However, this pattern is not present for the other crops. Additionally, for any given year, one method does not consistently perform better for all crops. In general, the yield model and the September Farm Survey yield estimates have comparable relative differences from the November Farm Survey estimates. However, the modelled estimates tend to have larger relative differences in cases where an extreme relative difference is observed (e.g., the maximum and minimum relative differences are larger).

One pattern that can be seen is that the September Farm Survey results tend to be low when compared with the November Farm Survey results (below the x-axis) more often than the model results. This is particularly evident with canola, corn for grain, durum wheat, spring wheat, and rye. For more details on the comparative analysis refer to Statistics Canada, 2015.

On September 17, 2015, Statistics Canada disseminated the Model-based Principal Field Crop Estimates for the first time as a supplement publication 3 weeks in advance of the September Farm Survey estimates and 11 weeks in advance of the November Farm Survey estimates (Statistics Canada, Table 001-0075). Feedback to the modelled estimates through government and industry consultation has been very positive because of reduced response burden and reduced survey cost all while maintaining relevance, accuracy, timeliness, accessibility, interpretability and coherence.

Table 1 contains the 2015 summary comparison for yield and relative difference between the yield model and the November Farm Survey and between the September Farm Survey and the November Farm Survey.

Table 1. Summary comparison at the national level of Statistics Canada's yield model, the September and November Farm Survey, 2015.

Crop	Yield Model August 31, 2015	September Farm Survey	November Farm Survey	Yield Model compared to November Farm Survey	September Farm Survey compared to November Farm Survey
	Yield (bushels per acre)			Difference (%)	
Barley	**57.8**	**59.8**	**65.0**	**-11.0**	**-8.0**
Canola	**32.6**	**32.2**	**39.4**	**-17.3**	**-18.3**
Corn for grain	**158.9**	**150.8**	**165.5**	**-4.0**	**-8.9**
Flaxseed	**20.5**	**21.1**	**23.3**	**-11.9**	**-9.3**
Mixed Grain	**65.6**	**67.5**	**65.4**	**0.3**	**3.2**
Oats	**79.6**	**79.4**	**85.7**	**-7.1**	**-7.4**
Peas, dry	**29.1**	**31.7**	**32.3**	**-10.0**	**-2.1**
Rye, all	**38.2**	**38.8**	**38.0**	**0.5**	**2.2**
Soybeans	**43.3**	**41.3**	**43.5**	**-0.5**	**-5.1**

Wheat, durum	**30.9**	**30.9**	**34.5**	**-10.3**	**-10.3**
Wheat, spring	**40.5**	**41.6**	**44.0**	**-8.0**	**-5.5**
Wheat, winter	**62.8**	**65.2**	**64.8**	**-3.1**	**0.6**
	Yield (pounds per acre)			**Difference (%)**	
Canary seed	**865**	**813**	**1,040**	**-16.8**	**-21.8**
Lentils	**1,151**	**1,246**	**1,392**	**-17.3**	**-10.5**
Mustard seed	**711**	**731**	**841**	**-15.4**	**-13.1**

The September and November yield estimates listed in Table 1 have been adjusted to take into account any suppression that was applied during the yield modelling process as described earlier thereby providing a normalized comparison of the results between the three occasions.

The yield model had less deviation for canola, corn for grain, mixed grain, oats, rye, soybeans, and canary seed. Conversely, the September Farm Survey had less deviation than the model from the November Farm Survey for yield for barley, flaxseed, dry peas, spring wheat, winter wheat, lentils, and mustard seed. The two methods had equal deviation for durum wheat yield.

In general, the results from 2015 yield model and the September Farm Survey estimates had deviations from the November Farm Survey estimates of varying degrees. For certain crops the yield model estimates had less deviation while for others the September Farm Survey estimates had less deviation. Both methods produce estimates that can be both very similar to the November estimates for some crops while having more significant deviation for other crops.

8. Summary

The estimates produced by the yield model were comparable to those produced by the September Farm Survey in terms of relative difference from the November Farm Survey estimates for the 15 crops modelled.

In 2015, modelled yield estimates for field crops deemed to have a sufficient level of quality were published as a preliminary estimate 3 weeks in advance of the September Farm Survey estimates and 11 weeks in advance of the November Farm Survey results. Statistics Canada consulted with provincial and federal government counterparts, members of the grain industry, and academia regarding the yield model. Based on a proven, non-intrusive, scientific method and the strong outreach support coupled with the federal government's desire to reduce respondent burden and survey cost, it was decided that, commencing in 2016, Statistics Canada would replace the September Farm Survey with the Model-based Principal Field Crop Estimates. The replacement of a statistical field crop survey with a remote sensing model-based administrative data approach is a first for any statistical agency worldwide. Moving forward, Statistics Canada and Agriculture and Agri-Food Canada are evaluating methods of using other administrative data sources (such as crop insurance and additional satellite crop classification data) to derive crop area estimates which can be used in conjunction with the modelled yield estimates to create reliable estimates of crop production.

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Modelling macronutrients trajectories: Dynamics patterns and much more

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ABSTRACT

To our knowledge, attempts to directly model longitudinal change in macronutrients and energy intake of a population, with taking into account that individual change may not occur in the same fashion (i.e., develops at same growth rate), have never been practiced. In this respect, ambition of this paper is to propose the latent approach, by means of Latent Growth Curve Modeling (LGCM; Bollen & Curran, 2006) to the analysis of change in the nutritional status, namely fats, proteins and carbohydrates, and energy intake) of a target population in order to understand the time trend of the nutritional patterns at individual level. To this end, LGCM is able to outline the functional form of the individual growth trajectories and estimates the degree of individual variation and covariation around these just specified functions along with individualizing points of convergence and curvature. The subsequent application of multivariate LGCM allowed to check for gender invariance within people belonging to the same family and for multiple developmental trajectories while passing from urban to rural zone. The longitudinal data used as real example were taken from China Health and Nutrition Survey (CHNS) Household Food Inventory. From this survey a sample of 1229 households from urban and rural area, comprising of two adult family members of different gender, with having complete records of 3-day macronutrients and energy intake in 2000, 2004, 2006, 2009, 2011 was randomly selected. Interestingly, linear trajectories were found for fats and proteins at family level with convergence in 2009, and in 2006 and in 2012 respectively at rural and urban family level, whereas non-linearity was found for carbohydrates and energy intake. These nonlinearities were accommodated with polynomial functions and piecewise linear components with curvatures and knots for energy intake focalized respectively in 2006 and 2007. On the whole, the trajectories highlighted an equilibrium in the growth process with decreasing in the rate of change while passing from an initial heterogeneous amount of macronutrients and energy intake in 2000 to a more homogeneous status over the subsequent time period up to 2011. These results seemed in line with Chinese agricultural

reforms started in 2004-05, and 2008-09, from which Chinese families took benefit from by following a more balanced diet as well.

Keywords: Macronutrients, Latent Growth Curve Models, Structural Equation Models.

1. The nature of dynamics patterns

We define dynamics patterns as connected routes of repeated measures of variables at individual level. Repeated measures can be associated to time, as they usually do with typical longitudinal studies, or to different situations of repeated measurement such as the strength of an external stimulus (e.g., drug dosage). The main rationale of dynamics patterns is to have repeated measures "assessed or administered in a within-subject fashion and ordered in some logical way" (Preacher, 2010; p. 187). By simultaneously observing how these repeated measures vary across waves of measurement means studying how each individual behavior changes in terms of those measures. Hence, the study of dynamics patterns concerns the study of change in individual behaviors and how they deviate from a group-level change in common behaviors. This study is known as growth curve modeling (Muthén, 2001; p. 291). Despite of the fact that individuals may differ or not, in such repeated behaviors their connected routes outline trajectories. All these trajectories can follow a common average path or depart from it (Bollen & Curran, 2006). Further, they may have a theory of change behind, or take form of unspecified curves, but what is pretty sure is that they are ruled by a lawful, often unknown, developmental path that encompasses continuous and/or discontinuous phases. This effort to find out types of laws that rule over individuals, and group of individuals, change has already been faced over a century of research (see Bollen & Curran, 2006; p. 9-14), but it is still an ongoing challenge across scientific disciplines. Notwithstanding, what is of actual experiment is to understand this individual growth changing behavior as much as it does in the real world where individuals do not develop at the same rate and everything covaries. In this manner, a concrete starting point has been placed by the latent approach to the analysis of change. In this respect, the spirit of this paper is pioneering as it wants to propose such approach to an unusual area of research like nutrition and therefore making known potentialities and cutting edges.

2. Latent growth curve modeling rationale and outcomes

Unfortunately, when a researcher is dealing with a large number of repeated observations and wants to understand their patterns it is impossible to capture an immediate functional form, or known rule, that summarizes all these individual dynamics at first glance. A researcher can hypothesize that the patterns may follow some growth theory in advance and therefore confirming, or disconfirming, this theory with imposing, more or less realistic, constraints on these paths. But, what happens when no theory is available at the outset? An opening simple answer rises up: *to leave the repeated measures free to covary and thus observing how they interplay each other over the waves of measurement*. By doing so, a researcher is indirectly postulating that a possible unobserved common pattern may rule over this longitudinal covariation among the repeated measures. This latter is the main rationale of the latent approach to the analysis of individual growth change: the unobserved common pattern is a latent trajectory outlined by latent common factors that gives rise to the way how the repeated measures covary across the waves of measurement. By *gambling* on this hypothesis, a researcher combines the study of growth curve modeling with structural equation modeling (SEM) that typically estimates relations between latent factors and observed variables. This fusion takes the name of latent growth curve modeling (LGCM; Bollen & Curran, 2006) whereas the aforementioned latent common factors take the name of latent growth factors.

The so-called unconditional LGCM is condensed in the following simple equation:

$$y_{it} = \alpha_i + \lambda_t \beta_i + \varepsilon_{it} \tag{2.1}$$

where y_{it} are the repeated measures of a variable y for each individual i across points in time t (t=0, n), α_i represents the i individual value of y at the initial time point (i.e., t=0) from which the change in y starts and needs to be compared with the following values $y_{it+1.}$ Hence, α_i is the well-known regression intercept for each individual value of y_i and thus it has a mean and a deviation from mean (i.e., variance): μ_α and $\sigma^2{}_\alpha$. Now, in the most common case that a change is occurring from the initial value α_i , and therefore $y_{it} \neq y_{it+n}$, a dynamic trajectory starts to take form with a slope β_i that defines the inclination (i.e., difference from the initial values) of the trajectory for each individual i and thus it also has a mean and a variance: μ_β and $\sigma^2{}_\beta$.

Granted that, α_i, and β_i are now a sort of covariates that want to commonly explain the dynamics patterns in the repeated measures y_{it} with controlling for the errors ε_{it} (with the usual assumptions of mean equal to zero for all i and t, uncorrelated with the covariates, non-autocorrelated and homoscedastic) from which these covariates depart to outline the dynamic change. This is the point at which SEM structure with latent factors takes action and the equation (2.1) gains, in turn, all the benefits of the SEM analytic technique. The covariates α_i, and β_i become common latent growth factors that vary and covary by means of the estimated growth parameters μ_α, $\sigma^2{}_\alpha$, μ_β, $\sigma^2{}_\beta$ and $\sigma_{\alpha\beta}$, respectively; λ_t are the factor loadings that represent the degree to which the latent growth factors are able to explain the dynamic change in the repeated measures or, in other words, the way how the progress of time (situation) influenced the change in the repeated measures. As a consequence, the simultaneity estimation of these SEM-based latent growth parameters permits to release the assessment of the compound symmetry and thus taking into account that individuals develop at different growth rate alike in the real world. Hence, LGCMs are more flexible than traditional ANOVA-like methods for longitudinal studies.

It is intuitive from the equation (2.1) that a researcher can outline many different functional forms starting from the basic linear function to high-order of polynomials until more complex known functions and their re-parametrizations (please refer to Preacher and Hancock, 2015) as well as hypothesizing high-order growth factors for modelling multiple measures and groups of respondents (e.g., multivariate and multilevel designs; Duncan, Duncan & Stryker, 2006). For example, should the function (2.1) not be linear, but depicting a known curvature it is still possible to select a new metric λ_t into the equation (2.1) that, in turn, advances via depending on the selected non-linear function. For example, for quadratic (2.2) and cubic (2.3) polynomials the function (2.1) respectively becomes:

$$y_{it} = \alpha_i + \lambda_t \beta_{1i} + \lambda^2{}_t \beta_{2i} + \varepsilon_{it} \tag{2.2}$$

$$y_{it} = \alpha_i + \lambda_t \beta_{1i} + \lambda^2{}_t \beta_{2i} + \lambda^3{}_t \beta_{3i} + \varepsilon_{it} \tag{2.3}$$

Where β_{2i} and β_{3i} are further new growth parameters that take into account the new curvatures. Running these models by means of SEM and checking for the well-known diagnostics it is possible to confirm or disconfirm the hypothesized functions until reaching the one that fits better. In addition, SEM framework allows to explore for non-linearity of the repeated measures by leaving λ_t to be freely estimated for t = 2, .., n, with just setting $\lambda_o = 0$ and $\lambda_1 = 1$ or $\lambda_o = 0$ and the last $\lambda_n = 1$ for the latent factor metric. So that, the other un-standardized factor loadings are able to empirically estimate the type of non-linearity over the underling repeated measures. Furthermore, another very useful strategy for accommodating non-linearity in the trajectories is the so-called piecewise linear LGCM (Bollen & Curran, 2006). It simply consists in breaking the non-linear trajectories in the so-called breaking points, or transition (Bollen & Curran, 2006) or even discontinuity points (Hancock, Harring & Lawrence, 2013) and therefore connecting these points with linear functions till reaching a spline trajectory and thus looking into how it fits. Essentially, once λ_t are formalized, the functional form of the repeated measures is nearly outlined and the latent growth parameters μ_α, σ^2_α, $\mu_{\beta j}$, $\sigma^2_{\beta j}$ and $\sigma_{\alpha\beta j}$ (with j=1, n) can be estimated. The metric for α_i is always 1 because the intercept is the factor that simply blocks the initial amount of the repeated variable when there is no growth over time, $\beta_{it} = 0$.

The literature stipulates further useful statistics that can be inferred from the latent growth parameters. The first one is the so-called relative gradient for each slope $(RG_\beta)=\mu_\beta/\sigma_\beta$ (Hancock & Choi, 2006). The information it provides is about how many trajectories have a positive or negative inclinations. Furthermore, if a researcher assumes that the growth rates are distributed as $N(\mu_\beta, \sigma^2_\beta)$ the subsequent non-central standard normal distribution for RG can be re-written as N(RG,1) and it is possible to compute the proportion of positive and negative slopes with using the well-known non-central normal density curve table. A second statistical index is the so-called *aperture* (Hancock & Choi, 2006). Basically, the aperture is the point in time where the individual trajectories converge. It is noteworthy noticing that with a linear trajectory only just one aperture point is possible, with a piecewise linear-linear trajectory as many aperture points as the spline lines, but with nonlinear functions there might be multiple apertures. To our knowledge the math to locate multiple apertures in nonlinear scenarios and the related software commands have to be still worked out by academics. So then, we just report the three simple equations to determine the *aperture shift coefficient* a^{ap}, and its related moments, for a general linear time/situation interval metric of {a, b} (Hancock & Choi, 2006):

$$a^{ap}=a + (\sigma_{\alpha\beta}/ \sigma^2_\beta) \tag{2.4}$$

$$\mu_a^{ap} = \mu_\alpha + (a - a^{ap})\, \mu_\beta \tag{2.5}$$

$$\sigma^2_a{}^{ap} = \sigma^2_\alpha - [(\sigma_{\alpha\beta})^2 / \sigma^2_\beta] \tag{2.6}$$

The aperture point and the moments permit, in turn, the estimation of the relative aperture location (RAL) and relative aperture variance (RAV) (Hancock & Choi, 2006):

$$RAL = - a^{ap} / (\lambda_p - \lambda_1) \tag{2.7}$$

$$RAV = \sigma^2_a{}^{ap} / (\sigma^2_\alpha + b^2\sigma^2_\beta) \tag{2.8}$$

RAL with values between 0 and 1 supplies information on the proportion of time span in which the aperture occurs (e.g., with RAL=0.30 the aperture occurs after 30% of the total time interval has passed) whereas with values of 0, below 0, 1 and over 1 it reveals that the aperture respectively occurs at the initial time point, below the investigated time span, on the final time point, over the investigated time span. RAV with values close to 0 indicates that the trajectories have a strong degree of convergence around the point a^{ap}, with exactly 0 there is perfect convergence. On the other hand, with RAV values close to 1 the aperture is wide and the convergence is weak since the trajectories tend to be parallel and distant each other; with exactly 1there is no convergence at all.

3. Real data example

In order to illustrate the strength of LGCM we used longitudinal real data from China Health and Nutrition Survey (CHNS) Household Food Inventory. From this survey a sample of 1229 households from urban and rural area, comprising of two adult family members of different gender, with having complete records of 3-day average macronutrients (fats, proteins and carbohydrates in grams) and 3-day average energy intake (in kcal) in 2000, 2004, 2006, 2009, 2011 was randomly selected. To simulate the growth change of the macronutrients and energy intake trajectories and to reflect the effective passage in time from 2000 (the reference point in time from which the change starts) to 2011the change in score per unit of time metric λ_t was fixed to the following unequal spaced units λ_{00}=0, λ_{04}=4, λ_{06}=6, λ_{09}=9, λ_{11}=11 so as to respect the yearly intervals {0,1}. The increasing sequence of numbers for λ_t hypothesizes how much an initial linear growth increases. For instance, the number 4 indicates that, on average, the change from 2000 to 2004 is 4 times as great as the change from 2000 to 2001 and so forth.

The analyses were initially conducted at member level in order to explore if there were similar functional forms for gender, separately. Successively, the final LGCMs were developed at family level both for the whole sample and territorial sites (i.e., urban vs rural) by applying multivariate representations of the growth process. These high-order levels of latent growth factors models accommodates for intra-class correlation occurring at members belonging to the same family (i.e., unique errors covariances free to covary) and for invariance of members trajectories (i.e., factor loadings between the first and the second order fixed to be equal over time of each family member; see Duncan, Duncan & Stryker, 2006; p. 69-74). In order to preserve space, we report results at family levels only since they are also the most relevant. Robust maximum likelihood (RML) estimation within LISREL 8.8 (Jöreskog & Sörbom, 2007) for fats and proteins individual trajectories provided good data-model fit (according to the main and well-known SEM fit indices and cut-off criteria: Chi-square not significant, Root Mean Squared Error of Approximation (RMSEA) under 0.05, Comparative Fit Index (CFI) over 0.95, Standardized Root Mean Squared Residual (SRMR) under 0.09) for common routes of linear growths in both gender and thus at family level (whole sample): Chi-square (df)=661.69(178), p<0.001, RMSEA=0.047 with 90 % Confidence Interval (CI) for RMSEA = (0.043 ; 0.051), CFI=0.94, SRMR=0.056. Latent growth factors parameter estimates and statistics are reported in table 1. Intercept and slope variances were statistically significantly different from zero with yielding to a significant individual difference of fats and proteins trajectories both at initial level and in the rate of change, although slope variances were smaller than intercept variances. These results would mean that fats and proteins patterns became even more similar in their rate of change. Interestingly, the covariance between the growth factors is significant and negative, and then the correlation is of -0.55. It means that the families with low fats and proteins score started to grow more, while the ones with high score to grow less. These latter were the most part since the RG provided 58% of family trajectories with negative slopes. Besides, the mean value over the time span was significant and negative as well. The statistics RAL and RAV showed a weak tight of convergence after 85.8% of the total time has passed, so then roughly 9.4 years after the initial 2000, in the first months of 2009.

A very interesting result was found when the sample was split in urban (i.e., n=362) and rural site (n=867). Although the dynamics patterns for fats and proteins were linear for both urban and rural families (i.e., for urban: Chi-square (df)=309.64(178), p>0.001(p=0.162), RMSEA=0.045, with 90 % CI for RMSEA = (0.037 ; 0.054), CFI=0.96, SRMR=0.066; for rural: Chi-square (df)=615.42(178), p<0.001, RMSEA=0.053, with 90 % CI for RMSEA = (0.049 ; 0.058), CFI=0.93, SRMR=0.064). For the former the trajectories were most negatively inclined (see table 1) with showing a decreasing across years with a convergence, although not very strong, above the time period and exactly slightly more than one year beyond 2011, in 2012. On the contrary, fats and proteins trajectories for rural families were pretty flat with a convergence, although pretty weak as well, after 55.6% of the time span has passed and therefore after 6.11 years, in 2006.

Completely different situation was found for carbohydrates and energy intake dynamics patterns. In order to preserving space and due to similar results we present here just the results from energy intake (in kcalories). Since the observed variances for kcalories were extreme, the measures have been rescaled (i.e., multiplied by 0.1) in order to facilitate the model convergence (Hancock & Mueller, 2010) without affecting differences among the scores (Kline, 2011). The fit indices for linear trajectories of energy intake by gender suggested to explore potential forms of new curvatures that depart from linearity (i.e., for males: Chi-square (df)=94.86(10), p<0.001, RMSEA=0.083, with 90% CI for RMSEA=(0.068; 0.099), CFI=0.86, SRMR=0.051; for females: Chi-square (df)=68.12(10), p<0.001, RMSEA=0.069, with 90% CI for RMSEA=(0.068; 0.099), CFI=0.91, SRMR=0.038). By doing so, LGCMs for energy intake individual trajectories at family level were run with fixing the first λ_{00} and the last λ_{11} loadings respectively to 0 and 1 while leaving the others to be freely estimated (Bollen & Curran, 2006). This strategy permits to discover the proportion of cumulative change occurred from the initial time point to the specific time period in reference to the total change of the entire period. The trend was quite similar for both family members. By explaining it for males (M) the values of λ_{04}=0.19, λ_{06}=0.09, and λ_{09}=0.28 respectively reflected that 19%, 9%, 28% of the total change in energy intake occurred between 2000 and 2004, 2000 and 2006, 2000 and 2009. By computing the following differences (0.19-0.09=0.10) and (0.28-0.09=0.14) it yielded to 10% of the total change between 2004 and 2006 whereas 14% between 2006 and 2009. Similar results were found for females (i.e., λ_{04}=0.19, λ_{06}=0.09, and λ_{09}=0.26). As a consequence, it is straightforward noticing that most of change in the energy intake occurred after 2006 and these two trends seem to reflect an up and down growth process that departs from linearity to outline a cubic polynomial function with a potential curvature after 2006.

Table 1: *Estimates and statistics for fats and proteins common trajectories at family levels*

Whole sample

Parameter	σ^2_α	σ^2_β	$\sigma_{\alpha\beta}$	$\rho_{\alpha\beta}$	μ_α	μ_β
Estimate	149.55	1.27	-7.63	-0.55	77.99	-0.22
t-values	8.71	4.87	-4.32	-4.32	102.24	-3.44
Statistic	RG	N(RG;1) +	N(RG;1) -	ap	RAL	RAV
	-0.195	42%	58%	-6.01	0.858	0.988

Urban site

Parameter	σ^2_α	σ^2_β	$\sigma_{\alpha\beta}$	$\rho_{\alpha\beta}$	μ_α	μ_β
Estimate	327.63	3.36	-25.68	-0.77	88.37	-0.75
t-values	6.72	4.77	-5.08	-5.08	54.94	-5.02
Statistic	RG	N(RG;1) +	N(RG;1) -	ap	RAL	RAV
	-0.409	34%	66%	-7.64	1.09	0.975

Rural site

Parameter	σ^2_α	σ^2_β	$\sigma_{\alpha\beta}$	$\rho_{\alpha\beta}$	μ_α	μ_β
Estimate	106.95	0.91	-3.54	-0.36	73.88	-0.01
t-values	6.68	3.58	-2.15	-2.15	88.34	-0.13
Statistic	RG	N(RG;1) +	N(RG;1) -	ap	RAL	RAV
	-0.010	50%	50%	-3.89	0.556	0.990

Note: t-values <|2| are not significant.

As a matter of fact, by applying equation (2.3) to the energy intake repeated measures we obtained excellent fit indices: Chi-square (df)=37.38(29), p>0.001(p=0.137), RMSEA=0.015, with 90% CI for RMSEA=(0.00; 0.028), CFI=1.00, SRMR=0.018. So then, the energy intake dynamics are definitely cubic. Nevertheless, in order to better detangle these nonlinear patterns, a piecewise LGCM strategy was applied here with splitting the curve into two linear trajectories and fixing the breaking point at year 2006 from which a second line departs. By doing so, the loadings λ_{06}, λ_{09}, and λ_{11} of the second linear slope β_{2i} were respectively fixed to 0, 3 and 5 according to the initial metric and thus simulating a new linear form departing from 2006. The piecewise linear model fitted well: Chi-square (df)=100.76(35), p<0.001, RMSEA=0.039, with 90% CI for RMSEA=(0.030; 0.048), CFI=0.97, SRMR=0.029. In the tables 2 and 3 are depicted the cubic and the piecewise linear LGCMs growth parameters for energy intake directly at family level (results about urban and rural area were not shown for preserving space. They can be requested, but they showed similar negative trends although more marked in the urban site families). Three slope factors (table 2) described the curvilinear function with showing significant variances in decreasing sequence indicating that the growth change in energy intake became more and more similar across individuals while passing time. This was a decreasing change since two factor means out of three were negative along with higher percentages of negative slopes as well. The covariances (correlations) indicated this decreasing growth process that already started from the linear part of the polynomial function (i.e., parameters of slope β), with a little increasing when passing to the quadratic part until decreasing again with a steeper acceleration down in the cubic part. These results were confirmed more clearly by piecewise linear model (table 3) with a decreasing of energy intake especially after 2006. Furthermore, a strong convergence point (i.e., $RAV_{\beta\beta2}$=0.04) occurred when roughly 21.5% of time passed after 2006. It means after 1.07 years after 2006, in 2007.

Table 2: *Estimates and statistics for energy intake trajectories at family level*

Family whole sample cubic trajectories

Parameter	σ^2_α	σ^2_β	$\sigma^2_{\beta2}$	$\sigma^2_{\beta3}$	μ_α	μ_β	$\mu_{\beta2}$	$\mu_{\beta3}$	RG_β	$RG_{\beta2}$	$RG_{\beta3}$
Estimate	4214.72	1195.70	45.49	0.16	246.49	-6.15	1.61	-0.12	$^+$43%	$^+$59%	$^+$39%
t-values	22.50	8.33	5.21	4.97	143.31	-4.24	4.58	-5.47	$^-$57%	$^-$41%	$^-$61%

Parameter	$\sigma_{\alpha\beta}$ ($\rho_{\alpha\beta}$)	$\sigma_{\alpha\beta2}$ ($\rho_{\alpha\beta2}$)	$\sigma_{\alpha\beta3}$ ($\rho_{\alpha\beta3}$)	$\sigma_{\beta\beta2}$ ($\rho_{\beta\beta2}$)	$\sigma_{\beta\beta3}$ ($\rho_{\beta\beta3}$)	$\sigma_{\beta2\beta3}$ ($\rho_{\beta2\beta3}$)
Estimate	-1670.68(-0.74)	232.95(0.53)	-10.24(-0.39)	-218.01(-0.93)	11.66(0.84)	-2.64(-0.98)
t-values	-15.84	10.48	-7.80	-6.30	5.73	-5.02

Table 3: *Estimates and statistics for energy intake trajectories at family level*

Family whole sample piecewise linear-linear trajectories

Parameter	σ^2_α	σ^2_β	$\sigma^2_{\beta2}$	$\sigma_{\alpha\beta}$ ($\rho_{\alpha\beta}$)	$\sigma_{\alpha\beta2}$ ($\rho_{\alpha\beta2}$)	$\sigma_{\beta\beta2}$ ($\rho_{\beta\beta2}$)	μ_α	μ_β	$\mu_{\beta2}$
Estimate	635.75	24.37	103.53	-29.37 (-0.24)	35.30 (0.14)	-45.12 (-0.90)	246.04	-0.64	-3.35
t-values	2.45	2.16	3.57	-0.57	0.49	-2.74	145.78	-1.88	-5.30

Statistic	RG_β	$RG_{\beta2}$	$ap^{\alpha\beta}$	$ap^{\beta\beta2}$	$RAL^{\alpha\beta}$	$RAV^{\alpha\beta}$	$RAL^{\beta\beta2}$	$RAV^{\beta\beta2}$
	-0.130 ($^+$45%; $^-$55%)	-0.329 ($^+$47%; $^-$63%)	-1.20	-0.43	0.171	0.96	0.215	0.04

4. Wrap-up and conclusion

At present, we do believe that by attempting to detangle the complexity of nutritional growth processes in the human over a time span, or different situations of intervention, requires of inspecting variations at individual level. In this respect, what is needed is of a statistical technique that is able to estimate variations and shared-variations among individual trajectories, simultaneously. Advances in this direction have been made by latent growth curve models. Latent growth parameters of such curves permit to catch a lot of detailed information that deserve to be further investigated. The real data example concerning fats, proteins, carbohydrates and energy intake individual trajectories of Chinese people collected in unequal blocks of years from 2000 to 2011 showed different growth functions. Nevertheless, all the individual trajectories tended to be negatively inclined with also reducing the high discrepancies occurred before Chinese agricultural reforms took place in 2004-05 and 2008-09. The former introduced direct subsidies to farmers, agricultural tax reduction, support to seed and machinery purchases whereas the latter introduced investments to housing, to rural constructions and infrastructure so as to enhance domestic demand and people's livelihood . These reforms presumably encouraged people to follow a more balanced diet since the general reducing of macronutrients and energy intake discrepancies yielded to many convergence points (in 2006, 2007, 2009, 2012) and interesting curvatures in 2006 occurred both after and throughout the corresponding aforementioned time intervals of such reforms.

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THEMATIC SET

G44

SAMPLING AND MEASUREMENT PROBLEMS FOR AGRICULTURE CROP PRODUCTION ESTIMATION

Session Organizer
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Small area estimation for crop acreage in remote sensing assisted crop survey—a case of major crop acreage estimation in Liaozhong county
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DOI: 10.1481/icasVII.2016.g44d

Small Area Estimation for Crop Acreage in Remote Sensing Assisted Crop Survey

— A Case of Major Crop Acreage Estimation in Liaozhong County

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ABSTRACT

Applying remote sensing to estimate the planted acreage is typically by using regression estimator or calibration estimator which is taking advantages of combining the sample data from ground survey with satellite image classification. For most cases of regression estimator, the crop acreage estimation for a target population such as a province or county only satisfies the precision for itself but could not be disaggregated to small areas, such as county and town level statistics.

Taking the Liaozhong county affiliated to Shenyang city, Liaoning province as a study area, the satellite images from the moderate resolution Landsat 8 OLI is classified for rice and corn as auxiliary information for population, and high resolution Chinese GF-1 and ZY-3 are visually interpreted for rice and corn which is regarded as ground truth. The whole county is segmented into grids of 100m*100m as sampling units, a simple random sampling is adopted to select samples with replicates 1000 times to do simulation of building small area models. From our simulation study, it reveals that a basic level small area model in the form of one-response multiple regression with random effects and fixed effects are both feasible to produce the estimates at town and township level. Meanwhile, the aggregate of estimates of every town could (approximately) be the estimates for the county under the assumption of linear regression. It is concluded that the small area estimation method is applicable to solve crop acreage estimation from province to county level simultaneously when targeting an entire province.

Keywords: Crop Acreage, Small Area Estimation, Remote Sensing

1. Introduction

China is a major agricultural production country as well as a large consumption and trade country in terms of farm products. Depending on the various agricultural information especially on the planted acreage statistics of major grain crops, it has been an important gist for decision making with respect to grain and food policy as well as economic development plans at national level. To acquire the planted acreage of major grain crops and their spatial distribution in a timely, accurate, quantitative way is of significance for making decision on agricultural production at various levels of governments, in order to ensure food security, steer and adjust the crop planting structure through macro-economic control, as well as improve the operational management for relevant enterprises and farms (Blaes and Vanhalle et al.; Tao and Yokozawa et al.; Chauhan and Arora et al.). The traditional approach to obtain crop acreages are usually conducted by a sample survey usually by a national statistics agency. However, this process is time-consuming, labor-intensive and lacking in spatial information (Ma et al.). Remote sensing has been used for crop acreage estimation over the last few decades and is considered to be an effective tool for detecting the crop area extents and changes at regional or global scales (Hall and Badwar; Yang et al.; Xiao et al.). Some countries has already conducted a series of operational programs which aims at the estimation for land cover/land use and crops acreage, such as the USA (LACIE,1974-1977; AGRISTARS,1980-1986; CDL,1997-2010), European Union (MARS,1998; LUCAS, 2001-2009; Geoland2, 2008(2011)) and ROK (Implement RS Application System, IRSAS, 2008-2012).

Similarly to the American and European remote sensing programs for crop acreage estimation, since year 2010 the National Bureau of Statistics (NBS) of China has collaborated with external research institute to preliminary establish an operational business mode—Remote Sensing Assisted Crop Survey (RSACS) for major provinces in terms of grain outputs in China. The RSACS basically involves (1) selecting sample segments for each individual province based on area frame, (2) conducting field survey and collecting crop data, (3) crop spatial classification based on moderate satellite images, (4) crop acreage estimation.

Many studies have been carried out on crop acreage estimation for remote sensing assisted crop survey. To produce the estimates of crops acreage for a target population, there are usually three approaches could be adopted (F.J. Gallego). The first is direct expansion estimator which is a typical sampling approach to produce the estimates by only using survey samples. The second is called calibration estimator which is based on the crop classification result from remote sensing through adjusting the classification by confusion matrix. The third is regression estimator which refers to build a linear regression model by combining the ground survey data with the classification results from remote sensing. Theoretically, the regression estimator could gain precision of estimation due to combing the ground survey data with crop classification from remote sensing, which is taken as an auxiliary information for population. The regression estimator is essential derived from linear regression method which could be widely adapted to a particular problem solving, for example, Yaozhong Pan proposed an approach to estimate winter wheat area through building regression on Crop Proportion Phenology Index (CPPI) which disaggregated from the MODIS vegetation index (VI) (Pan et al.). The Chinese RSACS has also developed a feasible solution on acreage estimation for major crops such as wheat, corn, rice at provincial level by using linear regression method. However, the current methods of crop acreage estimation mostly concentrate on producing the estimates for the target population (province) but could not be disaggregated to sub-regional (county) levels.

In the Chinese context of remote sensing assisted crop survey, the sample segments and crop classification are directly linked to meet the requirements for the target province, while the estimates for crop acreages are expected to meet the precision for both province and county level. From literature study, small area estimation is the most dominant approach to solve the multi-level estimation such as estimates for both county and province level simultaneously. In 1988 a nested-error small area model is specified for the relationship between the reported hectares of corn and soybeans within sample segments from ground survey and the corresponding satellite determination for areas under corn and soybeans, and predictions of mean hectares of corn and soybeans per segment for the 12 Iowa counties are presented (Battese G.E. et al). In 2003 small area estimation is applied in a survey conducted in the Rathbun lake Watershed in Iowa, erosions are estimated for 61 small areas within the study region (Opsomer J.D. et al). In 2006 Small area model which included sampling and model weights was proposed and applied in agriculture for predicting minor crops (Militino A.F.).

In this study, we attempt to produce the crop acreage estimation at multi-levels by using method of small area estimation. The study area is chosen in Liaozhong county which is affiliated to Shenyang city, Liaoning province of China. Two kinds of spatial resolution satellite images has been acquired and processed for year 2014. The visual interpretation results from high resolution GF-1 and ZY3 for rice and corn was regarded as ground truth, while extracted crop classification for rice and corn from the moderate resolution Landsat 8 OLI was taken as the auxiliary information for population. We explored the small area model of basic unit level with random effects and fixed effects respectively by combining the ground truth data with auxiliary information of population. Given different sampling fraction under simple random sampling by using Monte Carlo simulation, the result of coefficient of variation (C.V) derived both from the model based mean square error (MSE) and simulation based MSE are computed and make comparison.

2. Experimental Area and Procedures

2.1 Experimental area

We choose the Liaozhong county, which is affiliated to Shenyang city of Liaoning province, as experimental area or target population in sampling terminology. There are altogether 20 towns and townships within the Liaozhong county, regarded as small areas or domains in our study. Liaozhong located in 122°28~123°6′ longitude east and 41°12′~41°47′ latitude north, having the total territory area around 1460 square kilometers. Liaozhong is situated in lower tier of Liaohe river watershed, belong to a washed plain impacted by Laiohe river and Hunhe river. On annual average, the cumulative sunshine hours are 2575 hours and cumulative precipitation is 640 millimetre, it is suitable for agricultural production. The major species for grain crops are rice, corn and soybean.

2.2 Moderate spatial resolution images

For large scale crop monitor program by using remote sensing, usually the moderate resolution satellite images are adopted to extract optical spectrum to distinguish the crops. In this study, Landsat 8 OLI satellite imagery on June 4, August 7 and September 8 are acquired respectively, and geometry correction as well as radiation correction are processed. Based on post-processed standard orthophoto images, a maximum likelihood classifier (MLC) is adopted to extract the rice and corn on pixel-base.

The three temporal images are classified for rice and corn individually by using MLC, and then the final distinguished crops of rice and corn are obtained by detecting the dynamic change of three temporal results. In the process of MLC applied to distinguish different crops, the real crop survey data in 2014 from Liaoning Survey Organization of National Bureau of Statistics(NBS) had been used as training set of samples when applying MLC. From the ongoing crop sample surveys conducted in Liaozhong county by the survey organization of NBS, we had 15 sample villages and each village allocated 5 sample segments in the size of 2 hectares. Altogether there are 75 sample segments of survey data could be used as ground truth in the process of satellite image classification. Finally the classified results and spatial distribution for rice and corn are obtained in format of vector data, which covers the whole county and serves as auxiliary information of population.

2.3 High spatial resolution images

We acquired the Chinese GF-1 and ZY-3 satellite images (high spatial resolution imagery) to be visually interpreted to distinguish corn and rice corresponding to each arable field or plot respectively. Subject to the limitation of acquisition of qualified satellite images, we have acquired one temporal GF-1 images dated on October 7, 2014 and one temporal ZY-3 images dated on June 4 and June 14, 2014 before the autumn harvest. The acquired high resolution images are pre-processed by geometry and radiometric correction as well as a fusion of 2m panchromatic and 8m multi-spectral images. Taking the advantages of the coverage of delineated cropland for this county being obtained from a previous land survey, it facilitated the visual interpretation to distinguish of rice and corn within the cropland effectively. The result of visual interpretation is used as an approximate ground truth for corn and rice, and is also applied to assess the accuracy of crop classification from moderate resolution images.

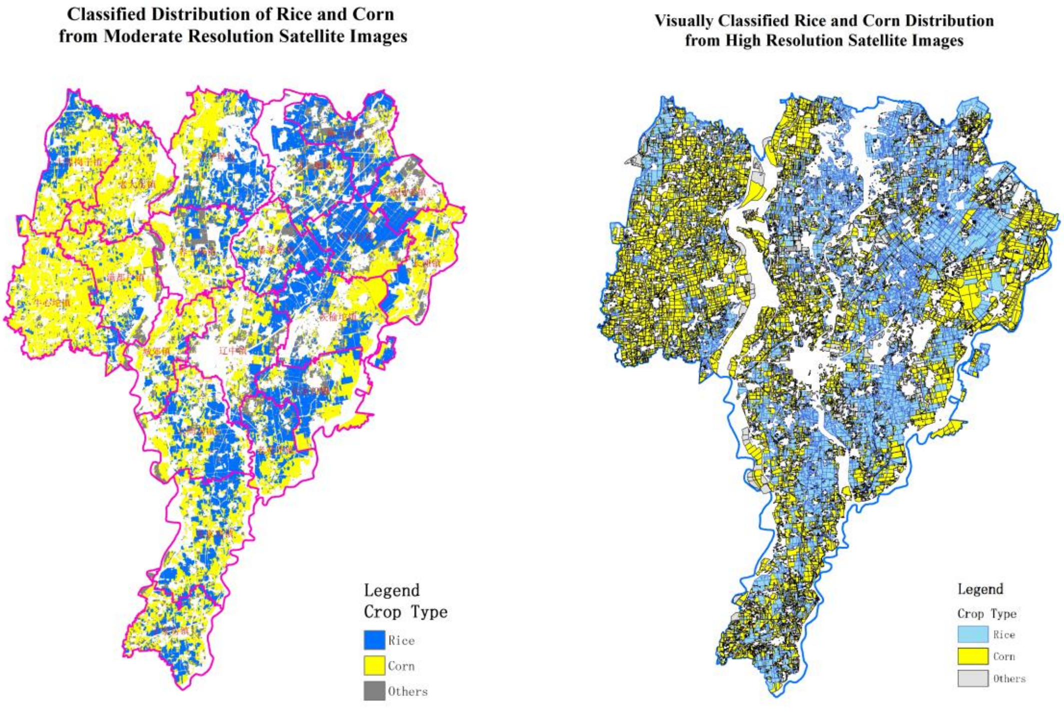

Figure 1: *Planted distribution of rice and corn from moderate and high resolution satellite images respectively.*

2.4 Sampling design

With the facility of GIS system, we delineated the whole territory of Liaozhong county into squared grids in size of 100 meters×100 meters. There are altogether 138279 grids, which are regarded as sampling units. A simple random sampling is adopted to select samples, and sampling fraction are chosen as 0.07%, 0.14%, 0.25%, 0.5%, 1%, 2%, 5% respectively to make comparison. In our study, the crop classification from the satellite images of Landsat 8 is taken as the auxiliary information for population, while the crop interpretation from the GF-1 and ZY-3 is regarded as data of ground truth.

2.5 Analysis for multi-level estimation

We probe the multi-level estimation for major crop acreage in the context of remote sensing assisted survey in Liaozhong county, which aims to produce the crop acreage estimates at town level and simultaneously generate the estimates for the county. The method of small area estimation is adopted, and a basic unit level model for small area is specified. The small area model is set in two scenarios for the effects of small area, one is the random effects and the other is fixed effects. Given the sampling scheme of simple random, a replicate of 1000 samples are selected for crop acreage estimation and consequent precision assessment. For each town and township, the estimate precision derived from the small area model is compared with the precision from direct domain estimation. In our study, we present simulation results as the following: (1) Computing the MSE of the model according to parameter estimation such as Empirical Best Linear Unbiased Prediction (EBLUP) and its CVs, (2) Based on the estimates from each individual model from replicates, computing the MSE and its CVs by simulation, (3) Based on the direct domain expansion, computing the mean squared error (MSE) and its coefficient of variation (CVs).

3. Multi-level Estimation by Small Area Model

3.1 Small area model with random effects

3.1.1 Model setting

For the crop of interest y_{ij}, assuming the random effects for small area, the adopted unit level small area model is as follows:

$$y_{ij} = \mu + X_{ij}^{T}\beta + v_i + e_{ij}, \quad j = 1,2,...,n_i \;, \quad i = 1,2,...,m \tag{1}$$

Where, y_{ij} is a specified crop (rice or corn) acreage for the jth sample grid in the ith town and township, m is the total number of towns and townships, in our case m=20, while n_i is the sample size in the ith town and township, μ is the intercept in the model, $X_{ij} = (x_{ij1},...,x_{ijp})'$ refers to the crop classification results from the moderate satellite which is composed of the variables $x_{ij1},...,x_{ijp}$. Random effects v_i and error term e_i are independent and identically distribution, subject to normal distribution with mean 0 and identical variance σ_v^2 and σ_e^2 respectively.

From the generalized ordinary least square method, we have

$$\hat{\beta} = \left(\sum_{i=1}^{m} X_i' V_i^{-1} X_i\right)\left(\sum_{i=1}^{m} X_i' V_i^{-1} Y_i\right) \tag{2}$$

$$\hat{v}_i = \frac{\sigma_v^2}{\sigma_v^2 + \sigma_e^2 / n_i}(\bar{y}_i - \bar{x}_i\hat{\beta}) \tag{3}$$

Where, $V_i = \sigma_v^2 1_{n_i}^{'} 1_{n_i} + \sigma_e^2 I_{n_i}$, $X_i = (X_{i1},...,X_{in_i})'$, $Y_i = (y_{i1},...,y_{in_i})'$, $\bar{x}_i$ is the sample mean for the auxiliary information of the ith town and township.

Hence, the estimate for the sub-population total of the ith town and township is as follows:

$$\hat{Y}_i = N_i[\bar{X}_{ui}\hat{\beta} + \frac{\sigma_v^2}{\sigma_v^2 + \sigma_e^2 / n_i}(\bar{y}_i - \bar{x}_i\hat{\beta})] \qquad (4)$$

Where, $\bar{X}_{ui}$ is the sub-population mean of classified result of rice or corn from moderate satellite images of the ith town, N_i is the total number of grids in the ith town and township.

For the variance estimation of random effects v_i and error item e_i, we adopt the moment method introduced by Fuller and Battese（1973）:

$$\hat{\sigma}_e^2 = SSE(1)/(n - m - p_1), \quad \hat{\sigma}_v^2 = \max\{[SSE(2) - (n-p)\hat{\sigma}_e^2]/\eta, 0\}$$

Where, $SSE(1)$ is the sum of squared residuals from the regression $y_{ij} - \bar{y}_i$ on $X_{ij} - \bar{x}_i$, $SSE(2)$ is the sum of squared residuals from the regression y_{ij} on X_{ij}, p_1 is the number of non-zero in $X_{ij} - \bar{x}_i$, $\eta = \sum_{i=1}^{m} n_i - n_i^2 \bar{x}_i (\sum_{i=1}^{m} X_i^{'} X_i)^{-1} \bar{x}_i^{'}$. If the estimates of variance plugging into formula (3) and (4), then we have the total estimate $\hat{Y}_i^E$ for the ith town and township by EBLUP estimation:

$$\hat{Y}_i^E = N_i[\bar{X}_{ui}\hat{\beta}^E + \frac{\hat{\sigma}_v^2}{\hat{\sigma}_v^2 + \hat{\sigma}_e^2 / n_i}(\bar{y}_i - \bar{x}_i\hat{\beta}^E)] \qquad (5)$$

Where, $\hat{\beta}^E$ is the estimate of β when plugging into the estimates of variance in formula (2). Alternatively the parameter estimates could be estimated by the ML or REML method, there are no significant difference among the estimates.

3.1.2 MSE of EBLUP at town level

For each small area (town) of the model, the MSE of Empirical Best Linear Unbiased Prediction depends on the model, Rao(2003) gave the formula as follows.

$$MSE(\hat{Y}_i) = g_{1i}(\hat{\sigma}_v^2, \hat{\sigma}_e^2) + g_{2i}(\hat{\sigma}_v^2, \hat{\sigma}_e^2) + 2g_{3i}(\hat{\sigma}_v^2, \hat{\sigma}_e^2) \qquad (6)$$

Where the definition of $g_{1i}(.)$, $g_{2i}(.)$ and $g_{3i}(.)$ are referred to Rao's literature Small Area Estimation.

3.1.3 Population total at county level

In the random effects model, the sum of acreage estimate Y_i for the total number of small area $i = 1$ to m is approximately equal to the total acreage at county level in the assumption of general linear regression. In fact, sum of the expectation of each Y_i is equal to expectation of total $\hat{Y}$. Due to the $E(v_i)=0$, we have the follows.

$$E(\hat{Y})=E(\hat{Y}_1)+E(\hat{Y}_2)+...+E(\hat{Y}_m) \quad (7)$$

3.2 Small Area model with fixed effects

3.2.1 Model setting

The formation of prediction model with fixed effects of small area is the same as the model in equation (1). The only difference is that v_i is assuming as fixed effects instead of random effects, that is to say for each small area (town) there is a fixed value of v_i in the model.

By differential method for the parameter estimation, we have:

$$\hat{\beta}=\left(\sum_{i=1}^{m}X_i^TQ_iX_i\right)\left(\sum_{i=1}^{m}X_i^TQ_iY_i\right) \quad (8)$$

$$\hat{v}_i=\bar{y}_i-\bar{x}_\mathbf{i}^\mathbf{T}\hat{\beta}-\bar{y} \quad (9)$$

Where $Q_i=I_{\mathbf{n}_i}-\frac{1}{n_i}1_{\mathbf{n}_i}1_{\mathbf{n}_i}^T$, $X_i=(x_{i1}^T,...,x_{in_i}^T)^T$, $Y_i=(y_{i1},...,y_{in_i})^T$, $\bar{x}_i$ is the sample mean of auxiliary information from the ith town and township.

The estimate for the population mean of small area is as follows:

$$\hat{\bar{Y}}_i=\bar{X}_{ui}^T\hat{\beta}+(\bar{y}_i-\bar{x}_i^T\hat{\beta}) \quad (10)$$

Where $\bar{X}_{ui}$ is the sub-population mean of classified rice or corn from moderate satellite images of the ith town. $\bar{y}_i$ is the sample mean of the ground truth for rice or corn of the ith town. $\bar{x}_i$ is the sample mean of the classified rice or corn of the ith town.

Then the estimate for the population total of small area is $N_i\hat{\bar{Y}}_i$.

The estimate for the error term e_i is as follows:

$$\hat{\sigma}_e^2=SSE(1)/(n-m) \quad (11)$$

Where, $SSE(1)$ is the sum of squared residuals from the regression $y_{ij}-\bar{y}_i$ on $X_{ij}-\bar{x}_i$.

3.2.2 MSE of model prediction at town level

For each small area (town), the MSE which depends on the model is as follows:

$$MSE(\hat{Y}_i)=E(\hat{Y}_i-Y_i)^2=n_i^2(\bar{X}_i-\bar{x}_i)^T(\sum_{i=1}^{m}X_i{}^TQ_iX_i)^{-1}(\bar{X}_i-\bar{x}_i)+n_i\hat{\sigma}_e^2 \quad (12)$$

Where, $\hat{Y}_i$ is the estimate of crop acreage from the ith town, Y_i is the approximately real planted acreage which is visually interpreted from the high resolution satellite imagery. $\bar{X}_i$ and $\bar{x}_i$ are sub-population mean and sample mean of the crop acreage which are classified from moderate satellite imagery. The definition of X_i is the same as in formula (8) , and the definition of $\hat{\sigma}_e^2$ is the same as in formula (11).

3.2.3 Population total at county level

In the fixed effects model, for total estimates of each town and township level, we have:

$$\hat{Y}_i = N_i \bar{X}_{\mathbf{ui}}^{\mathbf{T}} \hat{\beta} + N_i(\bar{y}_i - \bar{x}_{\mathbf{i}}^{\mathbf{T}} \hat{\beta}) \quad (13)$$

To sum up Y_i over the number of m towns and townships, we have the total estimates for entire county as follows:

$$\begin{aligned} \hat{Y} &= \sum_{i=1}^{m} [N_i \bar{X}_{\mathbf{ui}}^{\mathbf{T}} \hat{\beta} + N_i(\bar{y}_i - \bar{x}_{\mathbf{i}}^{\mathbf{T}} \hat{\beta})] \\ &= \sum_{i=1}^{m} N_i \bar{y}_i + \sum_{i=1}^{m} N_i (\bar{X}_{\mathbf{ui}}^{\mathbf{T}} - \bar{x}_{\mathbf{i}}^{\mathbf{T}}) \hat{\beta} \end{aligned} \quad (14)$$

Therefore, the sum of acreage estimates Y_i for the total number of small area $i = 1$ to m is exactly equal to the total acreage at county level in the assumption of general linear regression. Similarly, under the context of sampling weight to be applied, the sum of acreage estimates over all of small areas is also exactly equal to the total acreage at county level in the assumption of general linear regression.

4. Simulation Results

4.1 Experimental Data

For the experimental area Liaozhong county, we have delineated the whole territory into grids in size of 100 meters ×100 meters. There are altogether 138279 grids which is used as the sampling units (PSU). The information used in small area model building are as follows (Table 1), among them column (5) and (6) are used as dependent variables, column (7) and (8) are used as independent variables. In our study, the Liaozhong county is the target population, and its affiliated 20 towns and townships are regarded as small areas (domains). Two major crops of rice and corn are our variables of interest.

Table 1: *Crop area from visual interpretation and classification by town and township*

Unit:Hectare

Town ID (1)	Town Code (2)	Town Name (3)	Number of PSU (4)	Rice Area: Truth (5)	Corn area: Truth (6)	Rice Area from OLI8 (7)	Corn Area from OLI8 (8)
1	210122100	Liaozhong	6647	1750.008	2129.939	1352.919	1990.517
2	210122101	Ciyutuo	8434	3020.741	2931.661	2646.791	2244.159
3	210122102	Yujiafang	6307	1466.566	2458.064	1277.625	1535.788
4	210122103	Lengzipu	9796	3714.180	3016.737	3256.117	2997.363
5	210122104	Manduhu	7761	1072.259	4020.944	793.871	3767.203
6	210122105	Zhujiafang	8781	2642.468	3605.698	2330.282	2354.021

7	210122106	Liuerpu	5990	2856.171	1038.542	2519.282	785.550
8	210122107	Xinmintun	3792	1623.280	647.918	1337.879	698.411
9	210122108	Yangshigang	6335	3020.798	813.376	2870.082	712.628
10	210122109	Xiaojiamen	6492	2608.219	2228.829	2337.943	2175.943
11	210122110	Changtanzheng	5627	930.406	3164.420	839.103	2677.139
12	210122111	Sifangtai	6229	3216.909	1263.475	2985.907	981.072
13	210122200	Chengjiaozhen	4780	757.650	2209.059	542.686	2130.448
14	210122201	Liujianfang	8470	3246.437	2481.732	2885.688	2193.679
15	210122202	Yangshipu	6342	1692.727	1906.360	1380.257	1951.681
16	210122203	Panjiapu	5381	2236.938	1198.193	1901.378	1083.401
17	210122204	Laoguantuo	5235	2218.991	1433.240	1970.074	1585.276
18	210122205	Laodafang	7179	965.132	3844.526	478.141	3835.990
19	210122206	Dahei Gangzi	7917	2257.346	3573.115	1469.630	3720.634
20	210122207	Niuxintuo	10784	1201.306	6568.248	789.193	6389.981
Total			138279	42498.532	50534.077	35964.847	45810.884

We adopted simple random sampling to select samples, and designated seven different sampling fraction respectively as follows: (1) 0.07%, (2)0.14%, (3)0.25%, (4)0.5%, (5)1%, (6) 2%, (7) 5%.

With respect to each sampling fraction, we do the simulation by selecting the samples k=1000 times. In our case, we adopted small area model to estimate the rice and corn acreage for each town and township. We attempted two scenarios for the small area with random effects and fixed effects respectively. Meanwhile, In order to assess the estimate precision from the method of small area model, we compared the results with that from the direct expansion estimation for small area.

For the 1000 replicate samples, in order to compare the estimate precision of crop acreage, we computed the MSE and C.Vs with respect to rice and corn acreage for each town and township by the following three approaches: (a) direct expansion for domain estimates; (b) model prediction (EBLUP) from the small area model; (c) the estimates (prediction) for each town and township based on each individual small area model from replicates.

For the above approaches (a) and (c), the mean square error (MSE) for each small area i could be computed by replicates.

$$MSE_s(\hat{Y}_i) = E(\hat{Y}_{ir} - Y_{ir})^2 = \sum(\hat{Y}_{ir} - Y_{ir})^2 \Big/ k \qquad (15)$$

Where, $\hat{Y}_{ir}$ is the rice or corn planted acreage estimated from the rth replicate of the ith town and township. While Y_{ir} is the rice or corn truly planted acreage from the rth replicate of the ith town and township. Converting to coefficient of variation (CV), we have:

$$C.V(\hat{Y}_i) = \frac{\sqrt{MSE_s(\hat{Y}_i)}}{Y_i} * 100\% \qquad (16)$$

For the above approach (b), for each replicate we got $MSE_r(\hat{Y}_i)$ and $C.V_r(\hat{Y}_i)$ from model itself, then taking the average of all these $C.V_r(\hat{Y}_i)$ as a result of $C.V(\hat{Y}_i)$.

4.2 Simulation results for rice and corn

Referring to the formation of equation (1), y_{ij} refers to rice or corn real planted acreage from approximate ground truth, X_{ij} refers to rice and corn acreage which is classified from image. There are m=20 towns and townships in Liaozhong county. We illustrate the simulation results from the small area model with random effects and fixed effects.

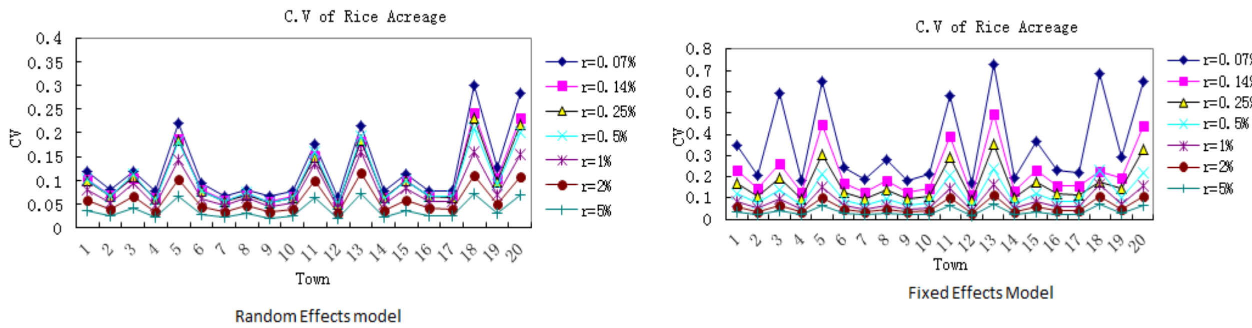

Figure 2: *C.Vs of rice acreage from MSE of Prediction for small area model*

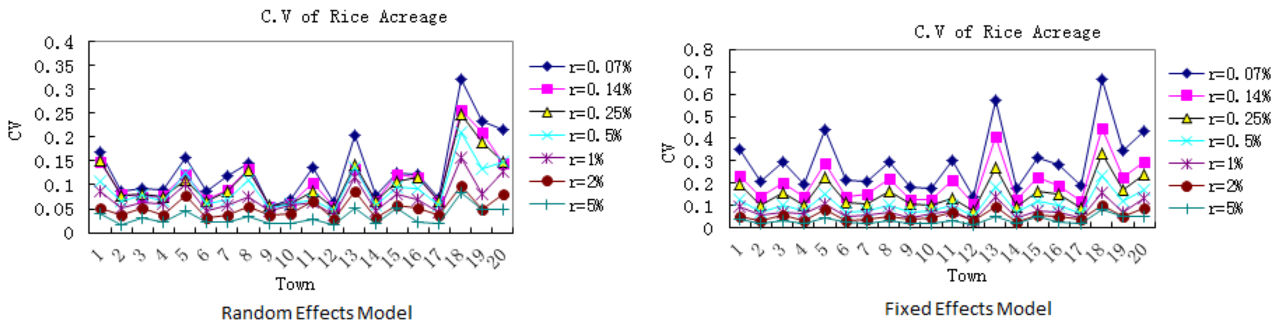

Figure 3: *C.Vs of rice acreage from MSE based on individual estimates derived from models*

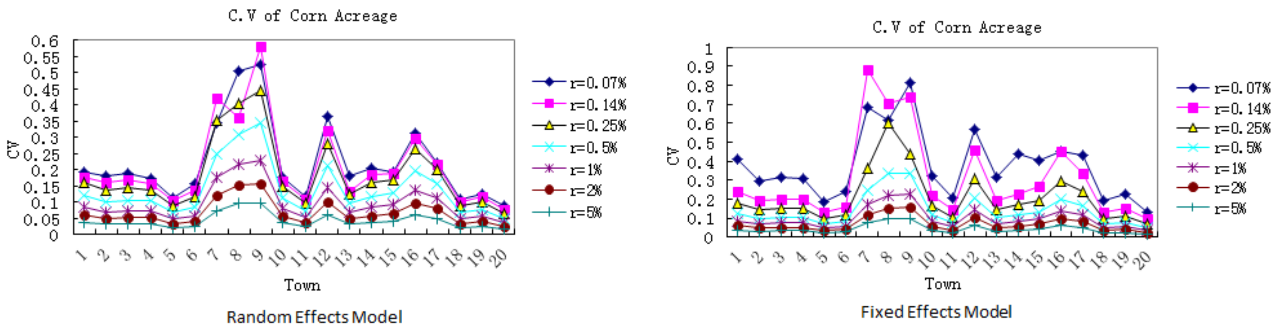

Figure 4: *C.Vs of corn acreage from MSE of Prediction for small area model*

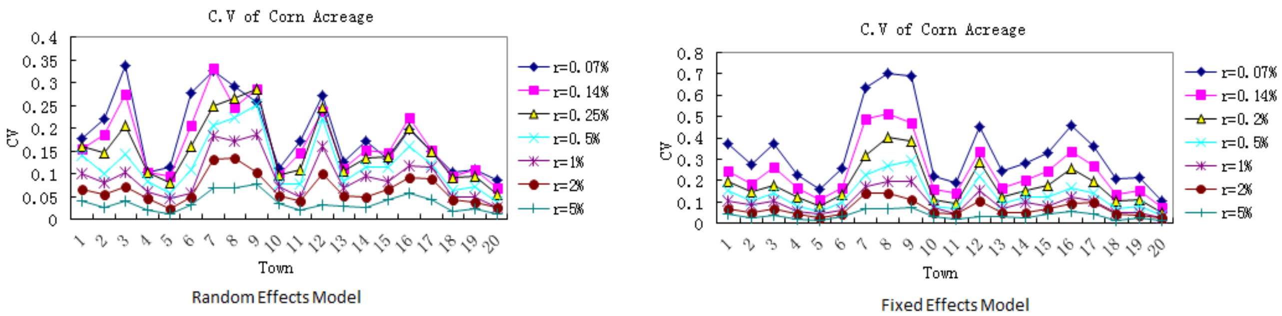

Figure 5: *C.Vs of corn acreage from MSE based on individual estimates derived from models*

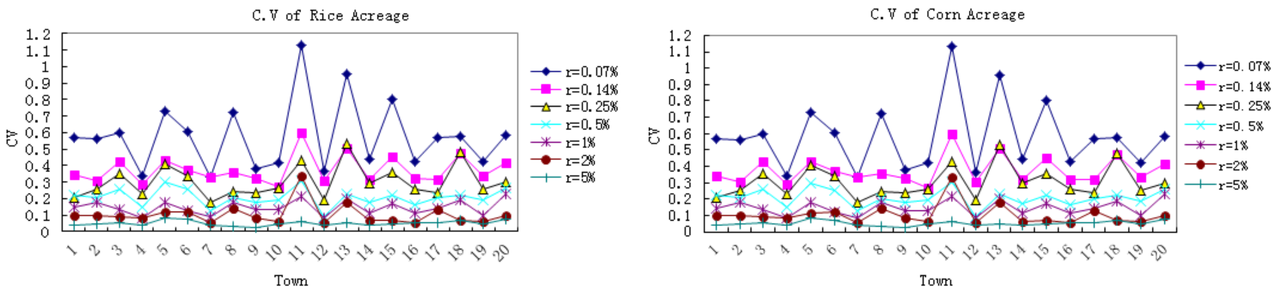

Figure 6: *C.Vs from the direct expansion for domain estimates*

The above Figure 2 and Figure 3 are C.Vs of rice acreage computed from model based MSE (approach b) and simulation based MSE (approach c) respectively. Similarly, Figure 4 and Figure 5 are C.Vs of corn acreage computed from model based MSE (approach b) and simulation based MSE (approach c) respectively. For small area model, if model fitness is good enough, then the MSE derived from the model should be very close to the MSE calculated from the simulation. To simplify the assessment of estimate precision for small areas, we could focus on the C.Vs results of Figure 3, Figure 5 and Figure 6 to make comparison.

Obviously, the precision of estimates gain significant improvement for small areas either in random effects model or fixed effects model especially for a smaller sampling fraction, compared with the direct domain estimation approach. For small area model with fixed effects, it holds on an additive property under the assumption of linear model that the aggregate of all estimates of each town and township is strictly equal to the population total for the whole county. While for the small area model with random effects, the above equilibrium is approximately hold on.

In our simulation, we also examined the C.Vs of aggregate at county level from summation of individual estimates of towns and townships in either random effects or fixed effects model. The C.Vs are even outperformed than that of a direct expansion at county level (Table 2).

Table 2: *C.V of rice and corn acreage at county level*

Sampling Fraction	Direct Expansion: Ground truth		Model Simulation Random Effects		Model Simulation Fixed Effects	
	C.V of Rive	C.V of Corn	C.V of Rice	C.V of Corn	C.V of Rice	C.V of Corn
r=0.07%	14.60%	12.28%	8.22%	10.74%	6.06%	5.77%
r=0.14%	8.62%	6.65%	7.21%	8.69%	4.20%	4.12%
r=0.25%	7.20%	5.26%	6.76%	6.75%	3.04%	3.32%
r=0.5%	4.82%	3.62%	4.78%	3.83%	2.14%	2.53%
r=1%	4.21%	3.12%	2.55%	2.20%	1.35%	1.78%
r=2%	2.25%	1.81%	1.53%	1.25%	1.15%	1.02%
r=5%	1.18%	1.08%	0.79%	0.71%	0.71%	0.63%

5. Discussion and Conclusion

5.1 Precision Efficiency

Especially in the scenario of small sampling fraction, our study illustrates that model fitness of small area model with random effects is better than that of model with fixed effects, which is reflected in the results of statistical test for parameters as well as the efficiency gain of precision. To examine the precision of estimates for each individual town and township, it is obviously that the C.Vs (defines as in section 4.1) is relatively lower when applying random effects model compared to fixed effects model especially for a smaller sampling fraction. When sampling fraction is 0.07%, taking the average C.Vs of rice acreage and corn acreage for all the 20 towns as indicators, the ratio of the C.Vs from random effects over the C.Vs from fixed effects is around 44% and 60% respectively, this implies that model fitness of random effects in this scenario is better. When sampling fraction is increased to 5%, the ratio of the C.Vs from random effects over the C.Vs from fixed effects is around 98% and 99%, this implies there is no significant difference between random or fixed effects model. On average, the ratios corresponding to all the other scenarios of sampling fraction lies in between of lower level 44% and upper level 99%.

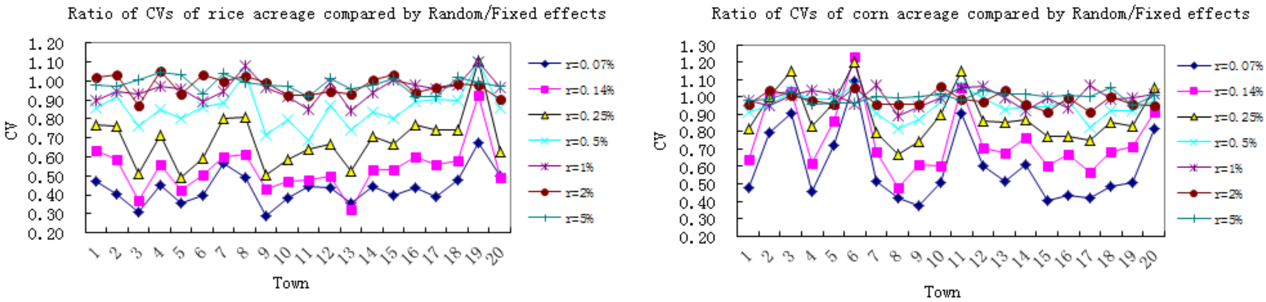

Figure 7: *The ratio of CVs from MSE under model with random effects versus fixed effects*

5.2 Model Fitness

In real situation, the setting of small area model either with random effects or fixed effects mostly depends on the user's assumption and understanding to the problem solving. In econometrics, usually the Hausman test is used to check whether there is a fixed or random effects preferred to the underlined component. But the validity of the Hausman test not always guaranteed, that means sometimes it is difficult to determine whether to choose fixed effects or random effects. In this study, even if the small area model with fixed effects does not have a sufficient model fitness compared with that of model with random effects especially when a smaller sampling fraction, it is also robust to predict a reasonable results for each town and township when we scrutinize the estimates and its C.Vs. Therefore, it implies that small area model with either random effects or fixed effects are mostly feasible to produce estimates for domains like town and township in this case.

With regard to the multi-level estimation both for the town and county level simultaneously, for the model with fixed effects the summation of each estimate of towns exactly equals the estimate for the whole county under the assumption of general linear regression. While for the model with random effects the summation of each estimate of towns approximately equals the estimate for the whole county under the assumption of general linear regression.

5.3 Model Sensitivity of Classification Accuracy

As we have seen, small area model of basic unit level with random effects or fixed effects is constructed by combining the ground truth data with classified image data regarded as auxiliary information of population. Since the satellite image classification affected by many factors such as the image quality and classification methods, the accuracy of classification may varied from good to medium. Given the certain sampling fraction, the model precision for estimates at town level could be impacted by the classification accuracy.

Based on the originally classified vector data from Landsat 8 OLI, which overall accuracy for rice and corn are around 85% and 90% respectively. In order to simulate different accuracies for classification, we added a disturbing term which is a certain constant multiply a random number subject to the standardized normal distribution for each grids. Then we calculated the accuracy of classification again by comparing the pseudo classified data with ground truth from visually image interpretation.

For the random effects model, the average C.Vs of rice acreage and corn acreage at town level corresponding to various accuracies are shown in Figure 8. Taken rice as an example, when sampling fraction is 0.07% and classification accuracy is 80%, the average C.Vs at town level is around 10.7%. Given the classification accuracy at 65%, in order to obtain the same average C.Vs at around 10.7%, we need to have the sampling fraction at 0.14% which means a doubled sample size. It reveals that both classification accuracy and sample size determines an expected CVs at town and township level. In practice, we need to consider the trade-off of more accurate classification or field work of samples.

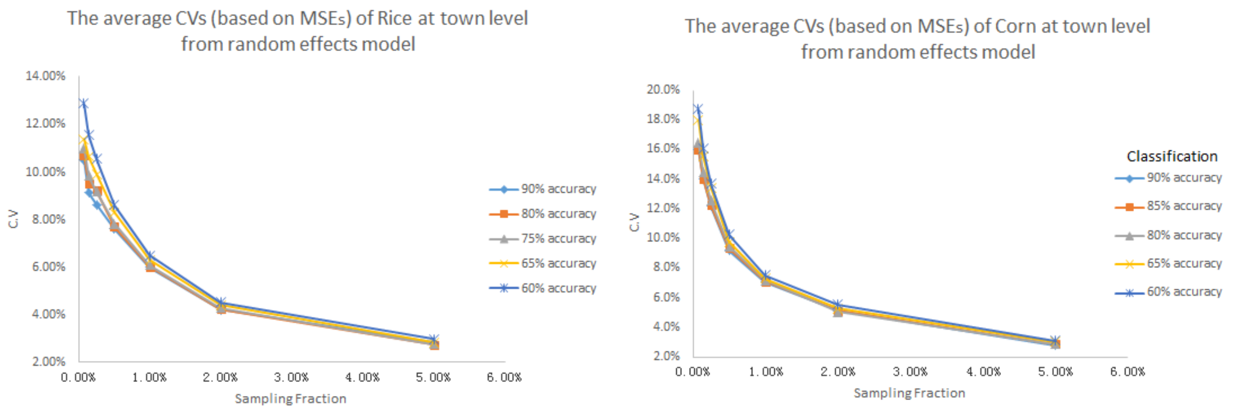

Figure 8: *The average CVs at town level under random effects model with various accuracy*

5.4 Conclusion

In this study, it is illustrated that a basic level small area model in the form of one-response multiple regression with random effects and fixed effects are both feasible to produce the estimates at town and township level. Compared with the fixed effects model, the random effects model gains more efficiency in terms of its C.Vs for town and townships level. Taking the advantages of small area model which combines the sample data with auxiliary information of population, this method could produce the estimates for each small area even if there is rare or none sample within the domain. Given a certain sampling fraction, a more accurate classification for crops which is taking as auxiliary information for population will benefit the estimate precision for each town and township from small area model.

Small area model provide a solution to produce estimates not only for the towns and townships but also for the entire county simultaneously. For fixed effects model, the aggregate of estimates of every town and township is exactly equal to the estimates for the county under the assumption of linear regression. While for random effects model, this additive property is approximately hold on. Therefore, it is provide a solution for multi-level estimation by applying small area model.

In practice, for the crop surveys which samples are selected from province as target population like the business mode of China's agricultural statistics, there would be a significant precision gains of applying small area model which could produce the estimates for every county as well as province itself in a coherent way.

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Role of Earth Observations for Crop Area Estimates in Africa. Experiences from the AGRICAB Project

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ABSTRACT

Despite major technological advancements, Earth Observations (EO) are nowadays seldom used in national agricultural statistical systems at an operational level. This is with the exception of a few countries and is especially true in Africa (but for Morocco, South Africa and a few other cases). Moving from small tests confined to research to operational contexts, poses a number of challenges. There are many aspects that still restrict the use of this technology: the high cost of some of the images, the level of expertise, overall organisation and institutional arrangements needed to operationally run the different components of the system.The FP7 AGRICAB project provided an important opportunity to evaluate the role of EO specifically for crop area estimates using spatial frames in Africa. This is with reference to: 1) the construction and stratification of a (point) sampling frame, 2) the support to the ground surveys, and 3) the use of the image classifications to further improve the accuracyof the estimates from the surveys alone. The approach was tested in selected areas in Mozambique, Senegal and Kenya. The contribution of EO for the last aspect cited was evaluated only for the latter two areas, where high geometric resolution images (RapidEye) were used. Sampling frames were built based on high geometric resolution images accessible through Google Earth. This contributed significatively to the frame construction and to increased sampling efficiency through land cover stratification. As to the use of EO for survey preparation/execution, the images also provided invaluable support to the geolocation of sampling units especially if combined with GPS. Finally, EO data were used for reducing the variance of ground estimates. If a high correlation between the classification of the image and the ground truth exists, it is possible to produce estimates with a lower sampling error. From a theoretical point of view a perfect correlation between spectral signatures of a generic crop and the corresponding parcel, would promote pure remote sensing approaches such as pixel counting and sampling frames combined withground surveys unnecessary. Unfortunately this high correlation rarely exists and in most cases satellite images cannot be used directly. Confusion matrixes generated from the supervised classifications of the test areas showed a very low overall accuracy and hence, a very low contribution to the reduction of the variance of the estimates which was evaluated further in terms of net efficiency and cost efficiency. This was to be expected, considering the characteristics of most Sub-Saharan agricultural landscapes, i.e.: small fields vs. pixel size, continuous and mixed cropping, low planting densities. The use of multi-temporal images and the combination of optical and radar EO data can probably increase such correlation although a rigorous cost/benefits analysis would be needed to evaluate its added value also in view of new satellite products (e.g. those provided by the Sentinel missions).

Keywords: spatial frames, satellites, relative efficiency

1. Introduction

There are two main methods to derive crop area statistics from Earth Observations (EO) data: pure remote sensing approaches such as pixel counting, and methods combining field survey data and image classification results (FAO 2015). Pixel counting is the more direct way, although it is often criticized for the bias which can be introduced (Gallego at al., 2008 and Gallego et al., 2010). This seems to be especially true with reference to smallholders farming systems in Sub-Saharan Africa.

Despite major technological advancements, EO are nowadays seldom used in national agricultural statistical systems in an operational way. There are a limited number of countries where this occurs worldwide and, apart from Morocco, South Africa and a few other cases, this is especially true for Africa.

Moving from small tests confined to research to operational contexts, poses a number of challenges. There are many aspects that still restrict the use of this technology: depending on their use, the high cost of some of the images, the level of expertise required, overall organisation and institutional arrangements needed to run operationally the different components of the system.

The FP7 AGRICAB project provided an important opportunity to evaluatethe contribution of EO specifically for crop acreage estimates using spatial frames in Africa. This is with reference to three levels in the methodology: 1) construction and stratification of a point sampling frame, 2) support to the ground survey, and 3) its use to further improve the accuracy of the estimates from the survey alone.

The project initially targeted selected areas in Senegal, Kenya and Mozambique and together with national partners mandated with agricultural statistics in the countries. EO products were effectively used in all areas. However only in the case of Senegal and Kenya, where images with high geometric resolution were available, it was possible to cover all cited levels of application.Due to the cloud cover, for MozambiqueEO products were used only atthe first two levels.

2. Materials and Methods

2.1 Materials

The areas selected were the District (Département) of Nioro Du Rip in Senegal, and the County of Kakamega-Butere in Kenya. As mentioned, only for these areas it was possible to acquire images with high geometric resolution.In Mozambique the area selected was the District (Distrito) of Inharrime. The three areas are indicated in Figure 1.

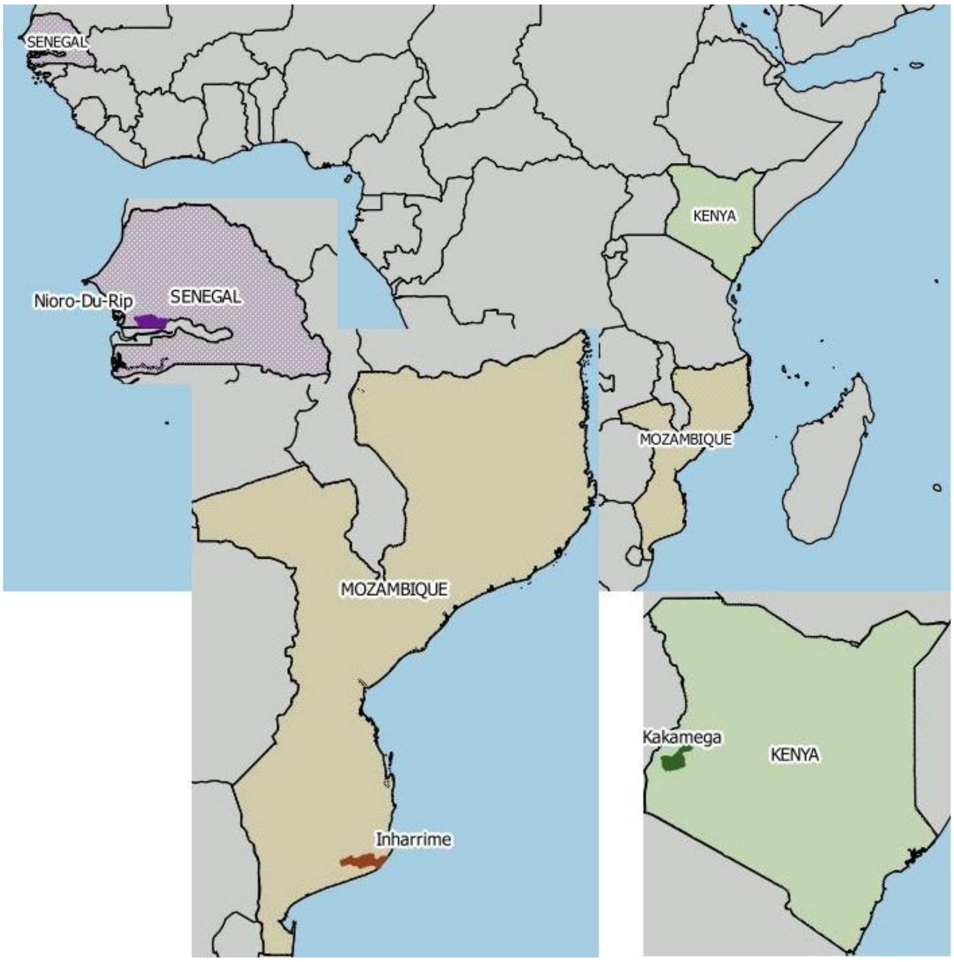

Figure 1: *The three areas of interest*

The EO images used belong to the RapidEye satellite constellation. For the cited study areas the provider programmed the image acquisition at a convenient time with reference to the presence of the targeted crops. Harvesting periods relating to the two area tests were indicated by experts from the respective Ministries of Agriculture who have knowledge of the climate and the characteristics of the selected test areas. In Kakamega-Butere the period was 15 May - 30 June while in Nioro Du Rip, 15 August - 30 September.

Table 1: *Main features of RapidEye images.*

MISSION CHARACTERISTIC	INFORMATION	
Number of Satellites	5	
Spacecraft Lifetime Over	7 years	
Orbit Altitude	630 km in Sun-synchronous orbit	
Equator Crossing Time	11:00 am local time (approximately)	
Sensor Type	Multi-spectral push broom imager	
Spectral Bands	Capable of capturing all of the following spectral bands:	
	Band Name	**Spectral Range (nm)**
	Blue	440 510
	Green	520 590
	Red	630 685
	Red Edge	690 730
	NIR	760 850
Ground sampling distance (nadir)	6.5 m	
Pixel size (orthorectified)	5 m	
Swath Width	77 km	
On board data storage	Up to 1500 km of image data per orbit	
Revisit time	Daily (off-nadir) / 5.5 days (at nadir)	
Image capture capacity	4 million sq km/day	
Camera Dynamic Range	12 bit	

As it discussed in the next sections, satellite images are complementing survey data. A description of the content of such information as well as the way in wich ground data are collected is also given in the next setions.

2.2 Sampling Frame Construction

The sampling frame is the most important element in methodology developed. Its functions are:

- to enumerate all the units of the population;
- to label and stratify the same units based on a limited number of land cover classes;
- to allow the extraction of sampling units for a specific statistical survey;
- to subsequently extrapolate to the universe the values derived from the sample.

The construction of the frame requires the following steps:

Defining the units of the population. These units are represented by geographic points located at the vertices of a grid of 500 x 500m. All points within an administrative boundary represent the population whose parameters (crop area in this case) we intend to estimate.

Building the frame. This implies assigning (labelling) the land cover type to each unit based on very few and simple classes. This is done through on screen visual interpretation of satellite imagery. The images do not necessarily need to be of the same year of the survey, nor need to be taken during the growing season; the higher the resolution, the better, since it allows a more accurate identification of the named classes. In this respect very high resolution (VHR), i.e. sub-metric satellite images freely available on Google Earth or similar sources were found to be the most suitable basis to derive the land cover types related to the points making the population.Only in a few cases high resolution images were not available.

Stratification. The land cover classes assigned to the points in the frame provide a basis for its further stratification.

Satellite images are importantfor the construction of the frame. Without their contribution the said frame would rely on ortho-photographs in digital format (which are simply not available in most African contexts) or be built using only topographic maps. These maps in most cases do not contain information useful for the stratification hence reducing the efficiency of the statistical system as a whole.

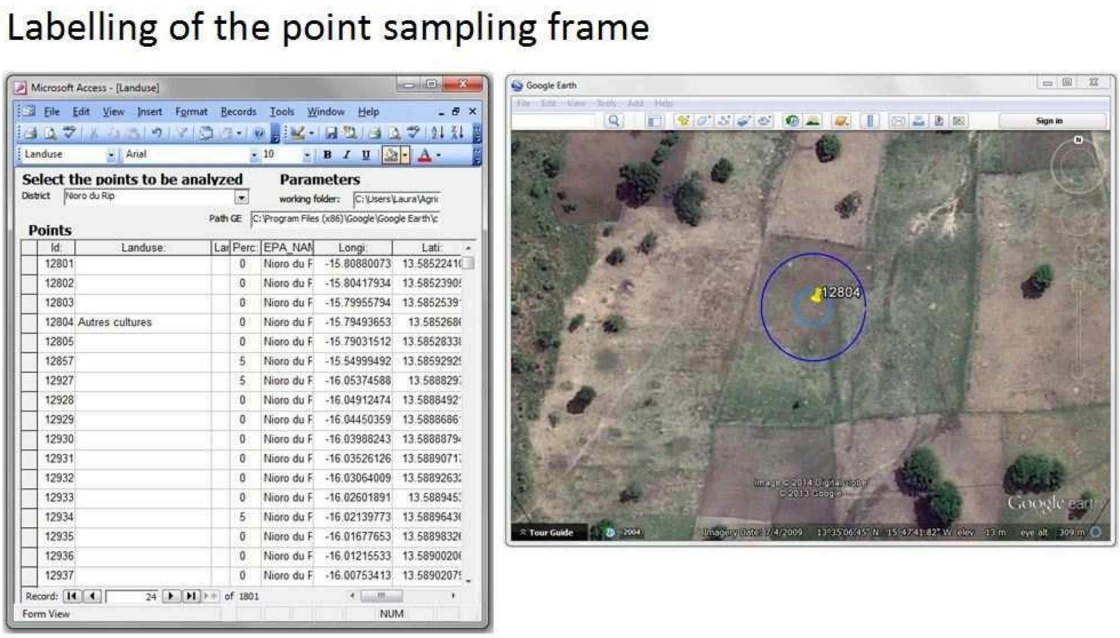

Figure 2: *Labelling of the point*

2.3 Support to ground-survey

The ground survey consists of the identification of crop types and other additional information in each sampling point. In this way objective, verifiable and repeatable data on crop occurrence can be collected based on rigorous sampling schemes. The ground observations are carried out by the surveyor whit reference to an area (usually a circle of fixed radius) around each point.

When carrying out the ground survey, the surveyor is faced with a number of challenges such as poor road network and lack of topographic information. Areas are also often largelyuninhabited,with long distances between points, and may present poor accessibility as well as specific dangers. Therefore the survey must be carefully planned beforehand and constantly revised on the ground.

Recent, very high resolution EO products are required for the purpose.There are usually three types of maps available to the surveyors, all having satellite information as a backdrop image. Examples are given in Figure 3. An “indexmap” is used as a topographic base map to locate the tiles. A “tile map” is a portion of the base map, generally at a 1:50.000 scale, and contains the points which should be visited by a surveyor. A “(sample frame) point map”,generally at a 1:2.000 scale, which is used together with a hand held GPS to identify and access the sampling point. Such map with the sampling units superimposed on satellite images can greatly facilitate the proper recognition of their position. For the geolocation of the points one should not rely exclusively on most GPS used in these types of surveys, which have known limitations in their geometric accuracy.

It is important to underline that the type of land cover and crop type information which needs to be associated to each point, cannot be derived directly from the satellite images used in the construction of the frame and in its stratification. This is due to the fact that such images are usually taken before the ground survey (i.e. when the cloud cover is minimal). Therefore they usually do not allow for a proper identification of the crop type or, if this is the case, may represent crops which have changed over the different cropping seasons.

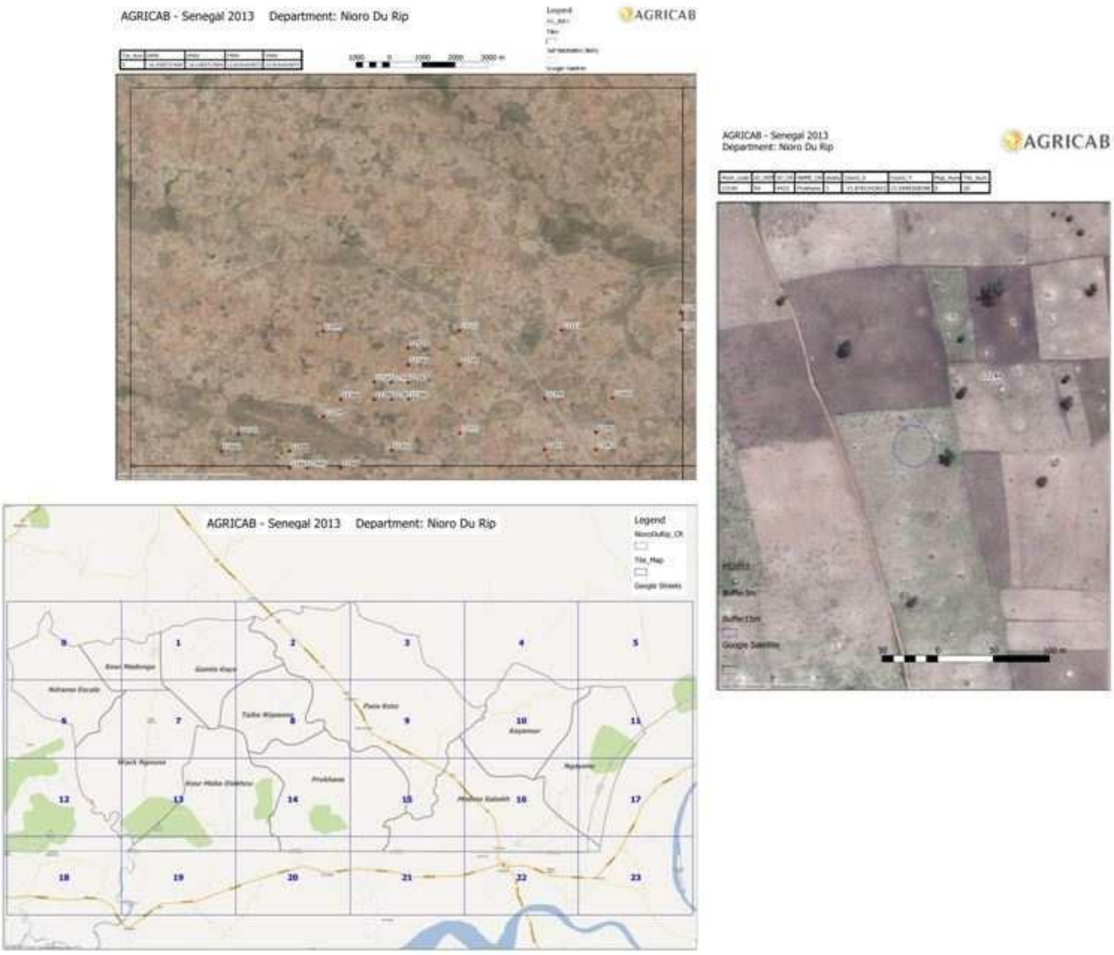

Figure 3: *Field Maps (from bottom left: Index, Tile and Point Map)*

Using the point maps, the surveyor can also plan the best itinerary to reach the different sampling units. Each surveyor has access to a series of field tools (the same field maps, field forms and a GPS). These would allow him a) to reach, as quickly as possible, each sampling unit and to identify with high accuracy (from a geographical point of view)the point of observation of the same unit, b) to identifythe type of crop according to a pre-defined legend and classification rules. An illustration of the field tools is given in figure 4.

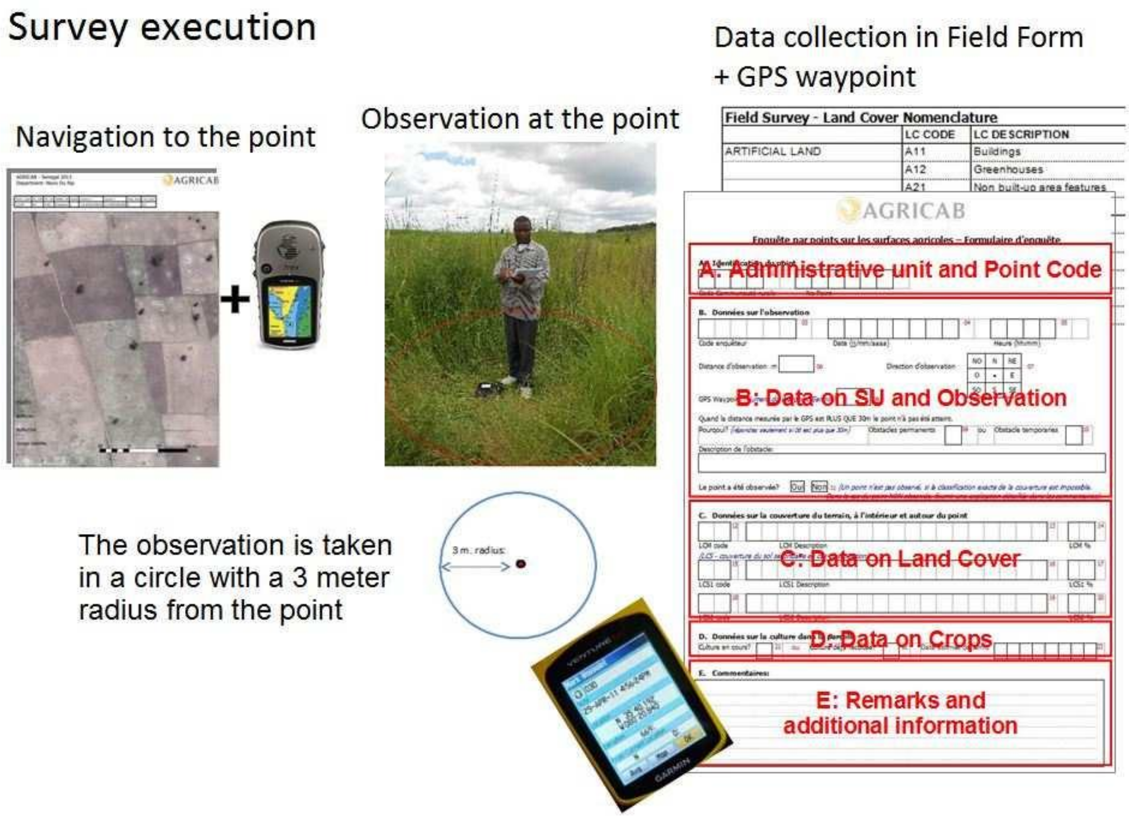

Figure 4: *Survey field tools*

Based on the experience in the different surveys conducted we can conclude that VHR images, combined with other baseline information and the location of the same sampling units provide an invaluable support for survey planning and execution. They make it possible to carry out the survey quickly and rigorously without the need of contacting the farmers.

2.4 Use of the image classifications to further improve the accuracy of the estimates from the ground surveys

This is, at least in principle, one of the most important aspects related to the application of EO data for crop area estimates. If a high correlation between the classified images and the ground truth exists, it is possible to generate crop area estimates characterized by a lower sampling error (expressed in terms of coefficient of variation, or CV). The RapidEye images acquired for the two study areas have been processed with the aim to verify the degree of the correlation between the spectral signatures of the main crop types and the corresponding ground truth observed during the survey. The following procedures have been utilized for processing the satellite images:

Image pre-processing.includes geo-referencing through registration of images, mosaicing of the RapidEye tiles with the same dates and same atmospheric conditions, production of masks to remove non-agricultural areas from the classification (otherwise introducing a bias).

Spectral signature extraction. The final outcomes of this step area number of Regions Of Interest (ROI) which are then used to guide the classification and to provide the ground truth locations needed for generating the confusion matrix.

The extraction was carried out using the observations collected during the surveys. Data varyaccording to the study areas and the respective methodologies. For Kenya the ground truth was based on the "Field Sample Points" grid(around 1.000 points) and on an additional sample of "Photo-clusters"(each cluster is a meshof 100 points with 50 meters spacing). This sample was classifiedby visual interpretation of aerial ortho-photos collected by the Department of Resource Surveys and Remote Sensing (DRSRS) during the survey period. In Senegal the available ground truth came from the "Field Sample Points" grid data (again around 1.000 points collected in the field) and the "Parcel Segments"data collected by the “Direction de l'Analyse, de la Prevision et des StatistiquesAgricoles” (DAPSA) of the Ministry of Agriculture, with the support of the “Centre de SuiviEcologique” (CSE). Crop sample areaswere collectedby GPS during the “Enquêteagricole 2013” in conjunction with the AGRICAB point frame survey. The procedure needs to be adjusted to each area due to differences in the type of the ground truth data i.e. to differences in the classification rules applied and tothe geometry of the data (points or areas). Such information is often collected in difficult environmental conditions and this goes sometimes to the detriment of its quality and accuracy. Moreover important factors related to the spectral signature (phenological state, health conditions, farmingpractices, water stress, etc.) could not always be captured during the surveys.

Supervised classification of the images. The final mask, the mosaics and the ROI dataset were imported in a GIS environment. In Kenya the classification was carried out based on the QGIS and GRASS open source solutions, while in Senegal the software ERDAS was used.The ROI dataset was used to generate the signature files, one for each mosaic. The classification was performed applying the maximum likelihood classifier (pixel based).

Considering the available information it was decided to classify the images focusing on the most representative crops: Sugarcane and Maize for Kenya and Millet, Maize, Sorghum and Groundnuts for Senegal. All the other land use classes were grouped as "other land cover/land use” (LC/LU).

The following tasks were performed for the classification:

- **use ofsub-classes** in order to cover as much as possible the various spectral signatures that characterize each LC/LU class;
- **adding the most important natural/non-agriculture sub-classes** to reduce the variance in the classification of the agricultural classes;
- **aggregating the sub-classes** corresponding to the various spectral classes obtained from the images in LC/LU classes and all the non-agricultural sub-classes as "Other LC/LU";
- **filtering the classified pixels** with a confidence level of at least 66% to70%;
- **calculating the confusion matrix** and the accuracies;

An example of the original image and of the classification is given in Figure 5.

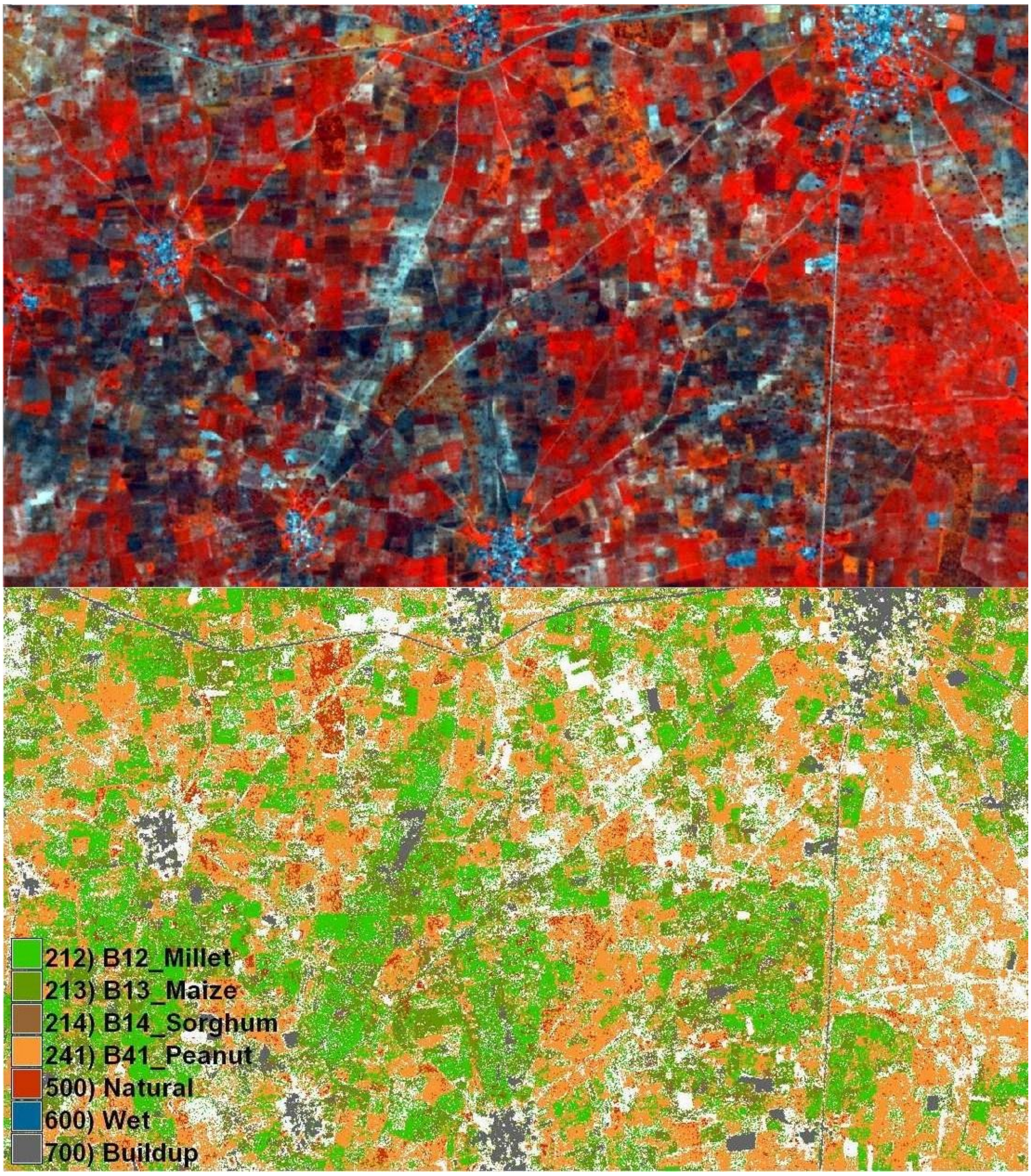

Figure 5: *Example of the original image and the classification in Senegal, Nioro Du Rip. From top: composite RGB 543 and classified raster image*

The accuracies derived from the confusion matrix should not be regarded as a post classification assessment, but rather as an indicator of the validity of the classificationin further reducing the estimates based on ground survey data alone.

Second stratification. The classification provides information on land cover and crop types that could be used to achieve better estimates of crop areas. The principle is that this information, known for the whole of the population and not only for the sampling units, can be used to build a stratification of the population in homogeneous strata where the variance of the estimates is expected to be significantly lower than in the population as a whole.

A new stratification is performed on top of the initial one (see 2.2), using a binary classification for each point in the sample frame.For instance in the case of maize four new strata are derived as a combination of the original strata, and the points classified as maize (or "not-maize") in the image.

3. Results

As shown in the tables 2 and 3 below, the confusion matrices generated in the two different study areas show a very low overall accuracy in the classification: around 45% for Senegal and around 40% for Kenya. For the main crops occurring in each area omission and commission errors are relatively better.

Table 2: *Confusion matrix Nioro Du Rip, Senegal*

		GROUND TRUTH							
	CLASS	B12	B13	B14	B41	NAT	Row Sum	COMMISSION ERROR	User's Accuracy inclusion
CLASSIFICATION	B12 millet	**56**	18	2	44	7	**127**	55.91%	
	B13 maize	40	**17**		28	7	**92**	81.52%	
	B14 sorghum	1	1		4		**6**	100.00%	
	B41 groundnut	19	13		**92**	8	**132**	30.30%	
	NAT	3	1		11	**3**	**18**	83.33%	
	Column Sum	**119**	**50**	**2**	**179**	**25**	**375**		
	OMISSION ERROR	52.94%	66.00%	100.00%	48.60%	88.00%	ACCURACY OVERALL	**44.80%**	
		Producer's Accuracy exclusion							

Table 3: *Confusion matrix Kagamega-Butere (Kenya)*

		GROUND TRUTH						
	CLASS	B13	B35	Z99	Row Sum			
CLASSIFICATION	B13 maize	**10**	11	22	**43**	76.74%	COMMISSION ERROR	User's Accuracy inclusion
	B35 sugar cane	10	**22**	14	**46**	52.17%		
	Z99 Other LC/LU	6	5	**14**	**25**	44.00%		
	Column Sum	**26**	**38**	**50**	**114**			
		61.54%	42.11%	72.00%	OVERALL ACCURACY	**40.35%**		
		OMISSION ERROR **Producer's Accuracy exclusion**						

Possible reasons behind these low accuracies can be ascribed to several factors. Some factors are of general applicability while others are especially important in the agricultural landscapes targeted in this study (i.e. characterized by small-holder farmers, with low levels of management and crop densities). Altogether they all contribute to the fact that the relationship between crops on the ground and their spectral signature is less evident:

Geometric resolution: related to the pixels size. In this case parts of the cropped areas can be characterised by fields which are too small to be shaped by the pixels. This aspect could, at least in principle, be reduced by the introduction of EO data with higher geometric resolution.

Atmospheric conditions: different atmospheric conditions can occur, even at local level, when the dates of the images are distant in time.

Crop phenology: each crop speciesand even variety develops according to different phenological phasesto which representative spectral signatures can be associated.It is thus very difficult that crops reach the most representative spectral signature at same time.

Seeding date: even within a species and variety having a specific phenology, the starting (i.e. seeding) date of the crop cycle can change according to several factors including climate and, locally, topography and soil conditions. Management choices of farmers are also very important.

Continuous cropping: the agro-ecologic conditions allow some overlap in the growing cycles of crops especially in sub-tropical environments.

Intercropping: in the same parcel different crops are sown at the same time or with a little time lag (relay cropping) resulting in a non-distinctive spectral signature, being a mix between two existing classes. A similar problem is given in case of weeds.

Crop density: it relates to farmers management practises, soil fertility, pathologies, water stress. Soil in the background alters the natural spectral signature.

Difficulty in determining the best date to collect the satellite images: it is due to the unpredictability of the weather conditions and the lack of synchronization of cultural practices/crops phenology.

The area estimations can be now calculated based on the binary stratification described in section 2. The crops where the classification performs better are selected for this purpose, i.e. Groundnuts in Senegaland Maize in Kenya (Butere-Mumias only). Results are given in Table 4 and 5:

Table 4: *Estimations with and without the image classification: Groundnuts, Senegal*

Approach	Crop area (ha)	StdDeviation	CV
only survey	72.229.70	2.713.10	3.76
survey + classification	72.597.02	2.688.12	3.7

Table 5: *Estimations with and without the image classification: Maize, Kenya*

Approach	Crop area (ha)	StdDeviation	CV
only survey	29.537.73	2.633.56	8.92
survey + classification	29.421.20	2.615.51	8.89

Comparing the results above the gain in precision (expressed in terms of reduction of the CV) achieved introducing the classification in the area estimates can be observed. Since there is only a minor decrease in the CV for both areas and crops, one can conclude that the contribution of the image classifications to further improve the accuracy of the estimates from the surveyis altogether very modest.

A more formal way to assess the contribution of EO data can be expressed in terms of Relative Efficiency (RE), which is the ratio between the variance of the ground survey area estimate and the variance after this estimate has been corrected withthe aid of classified satellite images. RE values close to 1 indicate that the EO contribution towards reducing the sampling variance estimations is very low:

$$RE = (Var.withouteo \,/\, Var.with\ eo)$$

Where:

Var.without eo = Variance estimation obtained without the contribution of EO data
Var.with eo= Variance estimation with the contribution of the EO data.

In both areas the RE is in the order of 1.01 (1.009 for Senegal and 1.007 for Kenya).If the cost components are known, also the cost efficiency can be computed. This is expressed in terms of Net Relative Efficiency (NRE) and calculated as follows:

$$NRE = RE \times (Costs\ without\ eo / Costs\ with\ eo)$$

Where:

Costs without eo = Costs without the contribution of EO data (i.e. ground survey costs).
Costs with eo = Costs considering the contribution of EO data (i.e. ground survey costs, cost of the images, of the radiometric and geometric corrections and of the classification).

In the two selected areas the NRE is in the order of 0.21, which indicates a rather low performance in terms of cost-efficiency.

4. Conclusions

As far as the generation of crop area estimates the contribution of EO was evaluated for two of the areas (and the main crops cultivated within) selected as use cases in the project AGRICAB. As to the contribution to the third level of application (image classifications to improve accuracy of estimates from the ground surveys) the results were evaluated in terms of RE and cost efficiency. The result indicates a low contribution in improving the estimates and, as a consequence and due to the type of images used, an even lower cost-efficiency.

Nevertheless, the other two levels of application, i.e. the construction and stratification of the sampling frame, and the support to ground surveys, were deemed very important, although it was not possible to further quantify their contribution.

In the future, in order to increase the efficiency in the use of EO data, a multi spectral/temporal approach can be further explored. A minimum of at least two images must be foreseen. A critical issue related to the areas of interest and similar environments is the presence of cloud cover during the main growing seasons. This poses a constraint on the proposed multi temporal approach using optical satellites only. In perspective, a combination of SAR (Sentinel 1) and optical satellites (Sentinel 2) may provide a useful opportunity for this type of applications.

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Sampling transects for crop area estimation with drones.

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ABSTRACT

Small Unmanned Aerial vehicles (UAV), better known as drones, have invaded very quickly the public debate. Besides the headlines on their military use, the potential civil applications are widely discussed. Agriculture is one of the fields in which drones appear to be very useful. In particular many agricultural statisticians would like to understand how much information can be extracted from UAV images and how cost-efficient such images may be.

This paper has several purposes:

- Discussing the cases in which UAV images can substitute field surveys.
- Analysing suitable sampling schemes for such image acquisition.
- Presenting practical implications and limitations in a test by the ITA consortium in Malawi.

Sampling long thin stripes to be surveyed with UAV has a good efficiency in terms of variance, but the feasibility is linked to two conditions that appear to be very difficult to meet: possibility to identify all major target crops on images with 2-3 cm resolution and flight regulations in the country that allow flying long distances far away from the operator. Small traditional airplanes with pilot might be a more realistic approach than UAV for surveys based on a sample of aerial photographs.

Keywords: Crop area estimation, Drones, Area frame sampling, Transects.

1. Introduction

The scientific community is paying attention to Unmanned Aerial Vehicles (UAV) and the possible civil applications of the images they can provide (Floreano and Wood, 2015). The debate on the use of UAV, better known as drones, includes the agricultural applications (Malveaux et al., 2014, Anderson, 2014), and the health aspects of agricultural practices (Capolupo et al., 2014). The limitations imposed by flight regulations are also analysed by the scientific literature (Freeman and Freeland, 2014). The image processing technology is well advanced and should not be a major limitation for practical applications (Zarco-Tejada et al., 2012, Hruska et al., 2014, Liu et al., 2014). Most applications of drone images to agriculture refer to local crop monitoring (García-Ruiz et al., 2013, Duan et al., 2014, Uto et al., 2013), in particular for precision agriculture (Zhang and Kovacs, 2012, Stehr, 2015). The possible application to agricultural statistics is often discussed, but at the time of drafting this paper, we have not been able to find any published paper that specifically addresses the topic.

If we consider the standard approaches to use imagery for agricultural statistics (Carfagna and Gallego, 2005), the requirements for yield estimation or forecasting seem far from the characteristics of low altitude flights because a large number of images along the cropping season is a critical condition and this would be too expensive. The use of images as a covariate in regression or calibration estimators appears also unfeasible at the current stage of the technology because it requires covering a very large area, in principle the whole targeted geographical domain

The most realistic use of drone images is substituting field visits in an area frame survey. At the current status of technology it is reasonable to cover for example an area of 1 km x 1 km with a single flight by mosaicking stripes of about 100 m width with a resolution that can range between 2 and 5 cm. Such resolution may be enough to identify single crops in some cases. The usability of such images to identify single crops depends very much on the type of agricultural landscape. One of the purposes of this paper is presenting the conclusions of a test run by the ITA consortium in Malawi. The conclusions of this test are likely to be useful for many countries in sub-Saharan Africa.

If we assume that most crops of interest, or at least some key crops, in a given region or country can be identified, several points still need to be discussed:

- Is a drone-based survey cost-efficient compared with a standard field survey?
- How can we optimize a sampling plan of spatial units to be observed with drones?

Analysing survey costs on the basis of pilot studies is not easy. The cost per sampling unit tends to be lower when a survey becomes operational (Taylor et al., 1997), but with a very heterogeneous pace. Pilot surveys in developing countries may be more expensive than in developed countries due to difficulties linked to transportation infrastructures and logistics, but the cost can be also very different when a pilot study is paid by an external donor.

The idea of using samples of aerial photographs have been used for agricultural and environmental estimates is not new. It has been applied already in the 70's (Jolly and Watson, 1979), but needs to be revisited taking into account the technological advances.

2. Pilot Test in Malawi.

A test has been carried out by the ITA consortium in Malawi. A subsample of 20 clusters of 4 x 4 points 250 m apart was covered with UAV flights. The leaf shape of maize, by far the most important crop in the country, can be reliably recognised with the 2-3 cm resolution images, but associated crops (less visible than maize) were very difficult to identify and distinguish from weeds. Other crops such as ground nuts, soya and cassava are difficult to discriminate for different reasons including the relevant presence of the intercropping practices and the different phenological stages for the same crop types during the drone overpass. Figure 1 provides an example of image acquired by a drone in the Malawi test. The fields in the right side of the image can be clearly identified as maize, but it is very difficult to identify if the associated vegetation are simultaneous crops or weeds.

Figure 1: *Example of image with 2-3 cm resolution acquired by a drone in Malawi.*

3. Data and Sampling Schemes.

We have made simulations using as pseudo-truth the farmers declarations in the Netherlands in 2012 . The data we have contains approximately 770,000 plots declared by farmers in 2012 in the Netherlands, out of which 345,000 correspond to cropland. The rest corresponds mainly to grassland and a minor part of natural vegetation plots owned or managed by farmers. For the examples based on this data layer we will focus exclusively on cropland. The interest of using this data set is that it behaves very much like the real spatial layout of cropland. The consistency of the data set has been checked by crossing it with the Eurostat point survey LUCAS (Gallego and Delincé, 2010) that has resulted in a nearly perfect match, with the exception of a significant undercover on potatoes. Similar data sets exist in all European Union (EU) member states, but most of them consider these data confidential. The Dutch authorities have considered that these data may be made public if they only contain data that anyone can observe on the field. The layer can be found in http://geodata.nationaalgeoregister.nl/brpgewaspercelen/atom/brpgewaspercelen.xml in a GIS format. It would have been better to use a similar data set for a developing country with a more complex agricultural landscape, but it has not been possible to find such data.

There is a wide variety of spatial sampling schemes for agricultural statistics (Benedetti et al. 2015). In this paper we will limit ourselves to comparing:

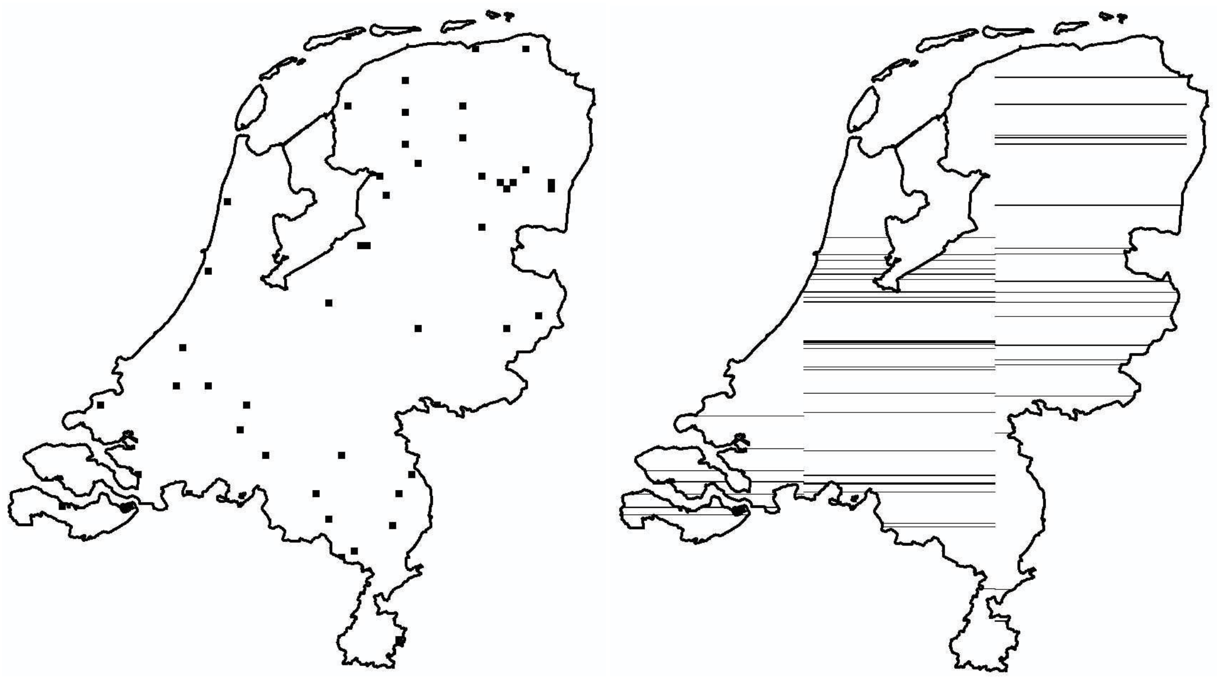
- simple random sampling of points. This is generally not a good choice for the problem we are considering, but we use it as a benchmark.
- Square segments. We have tested segments of 1 km × 1 km and 3 km × 3 km

- Long and thin segments (stripes). We have tested stripes of 10 km × 100 m and 90 km × 100 m that correspond to the same area of the square segments above. Therefore the variance ratio between square segments and stripes may be attributed to the shape and not to the size of the segments.

Long and thin stripes are theoretically better adapted than square segments to low altitude flights. A good quality UAV can fly a straight line of 100 km if the topography is not too complicated. However local or national regulations often forbid such long stripes.

Figure 2 represents the spatial layout of a sample of square segments of 3 km × 3 km and a sample of stripes of 90 km × 100 m. The sample of stripes has been defined with the help of a fixed grid. A large proportion of stripes is incomplete because they are clipped by the country boundary. This is likely to have an impact on the efficiency of the sampling scheme and may need to be reworked with a sampling frame better adapted to the shape of the country. In both cases we have considered simple random samples. Improvements such as stratification or systematic sampling have not been considered in order to focus on the effect of the segment shape.

Figure 2: *Layout of a sample of square segments and a sample of 90 km stripes.*



4. Simulation Results.

For the comparison of variances we use the "equivalent number of points". If a sample of n segments with a given shape and size gives the same variance as a simple random sample of $n \times Q$ points, we say that a segment is equivalent to Q points in terms of variance.

Table 1 reports the equivalent number of points Q of square segments and long stripes for major crops and some less important crops. We can see that Q is generally larger for minor crops. This happens because the spatial auto-correlation is generally higher at short distances for major crops, making clusters less efficient. We can also see that the relative efficiency of stripes compared with square segments is higher when the stripes are very long. This empirical result is fully consistent with the formal link between efficiency of clusters and spatial autocorrelation (Carfagna and Gallego, 1994, Gallego 2012).

Table 1: *Equivalent number of points of square segments and stripes*

		1 km2			9 km2		
	Area (% territory)	*Q* square segment	*Q* stripes	Efficiency stripes	*Q* square segment	*Q* stripes	Efficiency stripes
Maize	7.17	7.2	12.8	1.8	13.8	26.0	1.9
Temporary grass	5.41	6.2	14.1	2.3	14.6	41.8	2.9
Wheat	4.32	4.1	6.1	1.5	6.2	15.2	2.5
Potatoes	4.27	5.7	8.5	1.5	9.0	24.4	2.7
Sugar beet	2.07	8.9	15.1	1.7	18.3	58.5	3.2
Barley	0.84	9.9	18.9	1.9	24.3	69.0	2.8
Flowers	0.65	4.4	6.7	1.5	6.7	20.1	3.0
Orchards	0.51	6.1	12.1	2.0	13.6	43.6	3.2
Pulses	0.19	11.4	25.7	2.2	43.2	115.8	2.7
Flax	0.06	12.6	24.6	1.9	39.3	131.2	3.3

5. Conclusions and Discussion.

Very high resolution images acquired by UAV are a very appealing tool for agricultural statistics. The idea of substituting field surveys with photo-interpretation of geo-referenced images with a resolution of 2-3 cm is attractive, but several limitations appear very strongly:

- The applicability is limited to crops that can be identified on images with a reliability compared to field observations. This is unlikely for associated crops, as in the example of Figure 1.
- National regulations often limit the flights of UAV to the area within the sight of the operator. Square segments of 1 km × 1 km would be feasible, but the statistical efficiency of such segments is not very high.
- A UAV-based survey requires field trips of highly specialized staff and material. The ratio between the cost of field observations in a traditional area frame survey and an UAV-based survey is not easy to estimate with the available information coming from small pilot tests.

For specific food need assessments based on inter-annual changes of maize (assuming maize is the staple food) a sample of UAV-covered stripes can provide a sufficient information if long stripes are compatible with national regulations.

We need to make a reasonable assumption to apply to developing countries with very small plot size the relative efficiency values obtained from data in the Netherlands, where the average field size is around 3-4 ha. We can assume that the spatial correlation structure may be similar if we apply a 1:3 or 1:4 zoom-out. The average field size would become 0.2-0.5 ha, a field size that is much more common in semi-subsistence agriculture. However this “plot reduction” may be not enough to have a landscape similar to a developing country. In particular simultaneous crops are not considered in the results.

The efficiency for long and thin sampling units (e.g. 10 km × 100 m) may be around 2-3 times better than for compact-shaped units (squares). Taking into account the standard operational conditions of UAV (landing near the take-off point), a suitable sampling unit could be a pair of parallel transects of 10 km with a distance of 500 m or 1 km from each other.

When flight regulations are do not allow long distance flights of UAV, small aircrafts with pilot would be an alternative that should be considered. It is less fashionable than UAV and has other requirements (sufficient network of landing fields), but it might be efficient in many cases.

A sampling plan should take into account the orographic characteristics of the surveyed area. A stratification bight be performed to exclude areas with too steep slopes for a smooth operation of UAV. However case by case analysis is needed for an approximate assessment of the potential bias generated by excluding hilly areas.

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Measuring Area, Yield and Production of Vegetable Crops

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ABSTRACT

The horticulture subsector is among the fastest growing agricultural sub-sectors in most Sub-Saharan African countries. Compared to traditional field crops, horticultural crops (or vegetable crops) exhibit several advantages that make them attractive to farmers, both commercial and subsistence. Vegetable crops contribute significantly to food security and income generation for a large segment of the population, particularly women. The growth of this sector can also contribute to the reduction of rising unemployment levels in both urban and rural sectors. In recent years, the horticulture industry has become a noticeable earner of foreign exchange; in fact, some of the horticultural crops provide a viable option for diversification hence widening a country's export base.

However, despite this importance, vegetable crop cultivation has been one of the least statistically explored sectors in many African countries. The quantity of vegetable crops produced each year is largely unknown in most countries. There are a number of country experiences or

isolated studies and surveys on the estimation of vegetables and fruits, but since vegetable crops are often outside of the traditional scope of agricultural surveys and censuses, there is no consolidated and internationally validated estimation methodology.

The survey approach for the estimation of area and production is a challenge due to the large variety of vegetable crops. Issues to be taken into account in horticulture crop production estimate methodologies include (iii) Plant phenology, cultivation and harvesting techniques, (iv) implying crop area and yield measurement issues (i) no normalised concepts and definitions for horticulture crops; (ii) Sampling frame and sampling design.

Therefore, there is a need to develop adequate methodologies to estimate vegetables crops areas, yields and production. The purpose of this paper is to propose a consolidated methodology for estimating vegetable crops area, yield and production addressing the main methodological issues and taking into account lessons learnt from past experiences, from country practices and analysis of data from case studies in pilot countries in the context of African countries. The paper will build on a technical paper prepared in the framework of the Research Programme of the Global Strategy to Improve Agricultural and Rural Statistics.

Keywords: Vegetables, Production, Estimates.

1. Background

Accurate statistics on vegetable crop area and yield and production regularly released and communicated to the public must play an important role in planning and allocating resources for the development of the agriculture sector and food security in Africa. Reliable and timely information on vegetable cultivation is of vital importance to planners and policy makers including governments for planning the development of the sector, private companies for important decision-making related to products purchase, storage, distribution, import, export and other related issues.

The challenges for getting accurate estimates on vegetable crop production are not the same for different regions and countries around the world. In developed countries where vegetable holdings are keeping management records and area planted, production, yield, input are registered, the survey or census for estimating vegetable production remain sampling issues, the variable to be recorded are easy to get from the holders. In countries where value chain is well organized and the bulk of vegetable crop production are commercialised through a well-known limited number of markets, the estimates can be obtained through administrative sources related to market data. Expert assessment is also used for vegetable crop production estimates in some countries. The experiences of some countries below illustrate the different methods:

Some countries like Malta and Mexico are collecting vegetable crop data using administrative records and sources of vegetable crop estimates.

The Mexican agricultural statistics program uses administrative registers to obtain vegetable crop data. In particular, the agriculture information includes the sown area, harvested area, damaged area, observed and estimated harvests, etc. The Ministry of Agriculture (SAGARPA) state offices combine advanced reports on sown and harvested areas during the first ten days of each month and continue to capture this information in order to include the cumulated data in the next month's report. The central office of Ministry of Agriculture provides the rules and the information system for processing the data.

In Malta, to do away with expert advice the Agriculture and Fisheries Unit decided to embark, with the support of European Union, on a survey project using scientific methods in order to provide solid foundations for present and future vegetable crop production estimates (TAPAS project).

Interviewing was carried out during a twelve-week period extending from March to May 2005 and the information collected referred to harvested crop production for the calendar year 2004. The households in the sample were informed individually by mail explaining the scope of the survey and the information it was about to collect. Each farmer was asked to prepare area and production figures for the year 2004.

The final results from the TAPAS Project gave a total crop production of 106,922 tonnes in 2004, with a percentage error of 4.3 given a 68 per cent level of confidence. This production was significantly higher than the volume which passed through organized markets which stood at 44,513 tonnes during the same period. The primary aim of the survey was to establish the level of production which by-passes the market. Table 4.1 shows the percentage comparison between the total production from the survey, and the volume of produce that can be collected directly from administrative sources. It can safely be concluded that there are no direct sales for tomatoes, carrots and vegetable marrows and also administrative sources are very reliable. As for beans and onions this is absolutely the opposite as only a small percentage pass through the official markets. On the other hand, the production of beans and onions are mainly grown by part time farmers and are either consumed on the holding or sold directly. A substantial volume of certain crops, namely sugar melons, water melons, cabbages and cauliflowers are sold directly by the holding and by-pass the official market (TAPAS, 2005).

Table 4.1 Comparison between estimated total crop production (t) and crop production (t) from

administrative sources

	Production (t) TAPAS survey	**Total production (t) from administrative sources**	**%**
Tomatoes	15,047	15,051	100
Onions	5,276	2,254	42,7
Beans	1,990	467	23,5
Vegetables Marrow	3,083	3,046	98,8
Water melons	5,148	4,400	85,5
Sugar melons	4,172	2,871	68,8
Cauliflowers	5,065	3,186	62,9
Cabbages	3,482	2,634	75,6
Lettuce	2,720	2,237	82,2
Carrots	1,612	1,648	102,2

Sources: Fruit and vegetable production/Final report (TAPAS, 2005).

Some countries do not implement a specific sample survey or census for vegetable crops. Accordingly, vegetable crop data are collected together within the framework of an existing agricultural survey or census. Therefore, data on vegetable crops are collected together with other crops like cereals, fruits, etc. In many Europeans countries, the Survey on Agricultural Production

Methods, abbreviated as SAPM, was a survey carried out in 2010 to collect data at farm level on agri-environmental measures in the EU. European Union (EU) Member States could choose whether to carry out the SAPM as a sample survey or as a census survey. The SAPM covered all agricultural holdings (including vegetable crops holdings).

In the case of Africa and Asia, due to the diversity situations of vegetable crops cultivation, it is difficult to collect vegetable data production together with traditional crops.

Some vegetable holdings are usually located in specific areas. In developing countries, they are located in the neighbouring of cities, where it is easy to access markets to sell produce due to perishability of these types of crops. In many countries, most of the vegetable crop plots are located in specific sites, generally near water points in rural areas where water is available for irrigation (AFRISTAT & DNSI, 2004). Therefore, a sample used to estimate the production of a set of crops (including traditional and vegetable crops) is not able to capture in an efficient manner the production of the latter. Sampling bias error could be large considering vegetable crops holdings are not spread enough and could be considered as rare crops. Specific surveys with specific sample designs are necessary for the vegetable crop estimate survey.

The specific case of Africa

The practice of growing vegetable crops is prevalent in almost all African counties. Horticultural crops, especially vegetable crops, serve a dual function as both cash and food crops. The methods and techniques employed by producers for growing and harvesting these crops vary from region to region, according to peculiarities of vegetable crops. Furthermore, the specificity of vegetable crops such as continuous harvesting, successive harvesting, staggered harvesting, the different methods of cultivation and marketing strategies adopted by holders including timing and frequency of harvest for staggered crops pose certain statistical challenges (area and yield measurement) that are not present in traditional crops (cereal and root crops).

One particular challenge is that the growing cycle is often short for vegetable crops compared to traditional ones and vary considerably from one vegetable crop to another. This allows several planning and harvesting occurrences for the same vegetable during a single growing season and different crops rotation during the same growing season. As a result, different crops are often sown and harvested on the same piece of land during the agricultural year. This practice is the main characteristic of vegetable growing. In developing countries, another characteristic is that the farmers are typically small holders and are located near wet zones and big cities due to the perishability of these crops and the lack of storage facilities, and close proximity to major markets.

Another challenge is the application of technology such as fertilizers and irrigation to vegetable crops that affects yield and the number of harvests.

Due to heterogeneity among cultivation techniques, and frequency of harvest, choosing the appropriate observational method for a particular crop can be difficult. The observational method should be chosen based on the crop and cultivation technique including necessity for periodical monitoring. For the purposes of this study, vegetable crops are divided into 5 types with regard to the nature of crop (leaf, root, fruit) and the methods of harvest (single, staggered) requiring a specific method for yield estimation:

1) Leafy vegetables with staggered crop harvest;

2) Leafy vegetables with single harvest;

3) Root vegetables with single harvest;

4) Fruit vegetables with single harvest;

5) Fruit vegetables with staggered harvest.

In these cases, staggered harvest crops refer to crops for which fruits or products do not mature at the same time and for which multiple harvests are required and spread over a period of time. Examples include tomatoes, okra etc. On the other hand, single crop harvest refers to crops that are completely harvested upon maturity and destroyed thereafter. These include pumpkins, cabbage, lettuce, carrot, etc.

2. Objectives

Considering the issues of having a sound methodology for vegetable crops production estimate, the Global strategy to improve agricultural and rural statistics added this domain to the list of research topics to be explored in the research plan. A literature review has been prepared to review the methods used in different countries and regions to produce vegetable crop production estimates and to prepare and implement Field Test Protocol (FTP) and a guideline to support countries. The FTP targeted development countries where technical issues are more acute. Among all existing sources (administrative, expert assessment, census, survey) the FTP targeted to conceive and implement survey methodology in order to assess the technical choices and the results and gather elements to prepare a methodological guideline. The FTP has tried to explore all aspects to have a good survey providing accurate estimating of interested parameters including:

- Necessary adaptation of concepts and definitions for vegetable crop survey
- Appropriate sample frame for vegetable crop holdings:
- Appropriate sample design for effective sample selection for the survey aiming at having accurate harvested area and yield estimates for all significant crops including rare and cash crops
- Appropriate methods for harvested area and yield data collection considering the challenges identified for this kind of crop (continuous planting/harvesting, staggered harvest crop)

The FTP has been applied in Ghana and this paper will try to summarize the methodology adopted for measuring vegetable crop area, yield and production based on a sample survey. The paper will address the primary challenges associated with measuring vegetable crop production. More specifically the pilot has addressed the issue of sample frame and sample design and the issues of having easy and accurate measurement methods for production parameters estimates (area harvested, yield). The FTP puts emphasis on:

- The method for choosing or developing an appropriate frame of vegetable crop holdings, and specific variables to be collected during PSUs constitution and listing of vegetable crop holding as a final sampling unit;
- Considering different measurement methods including farmer inquiry and objective measurement for harvested area and yield estimation for various vegetables;
- Considering yield variability over time for staggered harvested crops and the feasibility for using monitoring method and farmer recall to collect data for yield estimate;
- The use of beds for vegetable cultivation allows to pilot other methods for harvested area and yield data collection in addition to the crop-cutting method;

3. Methodological Approach

3.1. The Scope of the Pilot Survey

The administrative sub-division of Ghana is at first level 10 Regions and at second level 216 districts. The scope of the field test is limited to two districs in two close regions. The scope a the pilot survey is two districts. The district target should be the ones where vegetables growing constitutes an important activity and convenient for testing various aspects of the methodology. The Ada West District in the Greater Accra Region and Keta Municipal District in the Volta Region were chosen. by Statistics Research and Information Directorate (SRID) of the Ministry of Food and Agriculture (MOFA) and are known to be sheltering a large number of diverse types of vegetable holders growing a large number of vegetable crops.

3.2. Methodology of Data Collection

Data could be collected through a sample survey. The absence of a sampling frame for vegetable crops (list of vegetable crop holdings) requires a prior listing operation to constitute an exhaustive list of gardeners. Once this has happened, a sample of vegetable holders will be drawn.
The survey will be implemented in several steps:

- Step 1: Listing of vegetable crop growing areas.

The first step is to list all the horticultural sites. Each site will be enumerated with important variables like geographic position, number of vegetable holders, types of vegetable crops grown. This listing will allow establishing a sampling frame for vegetable sites as PSU. The sample of PSU will be drawn from this frame.

- Step 2: Listing of vegetable holdings and the identification of holders.

A full listing of vegetable holdings will be obtained for each sample of vegetable crop areas. This list will be the Secondary Sampling Unit (SSU) frame. During the listing, information will be collected on farmer name, crops on each parcel and specific date of harvest. The latter is very important: the enumerator will record the exact date of the harvest. A return visit will be done on that date in order to collect information on yield.

- Step 3: First visit

In the second step, the main part of the questionnaire is filled. Data are collected on socio-demographic characteristics of farmers, economic characteristics of the farm including labour, land (size and number of plots, number of beds under cultivation, average size of beds by crop, equipment, production costs, etc.). During this visit, we will identify the beds by crop type and a few beds by crops will be measured to get an idea of their average size.

- Step 4: The Yield Survey

The production of a selected sample of plot will be collected and weighed. In some cases, the enumerator will collect and weigh the total production of a bed or count the number of its plants, calculate the average weight of a plant from a few harvested plants and compute the weight of the production of a bed. In other cases, (for staggered harvest crops), he/she will estimate the production of a bed in a number of measurement units and weigh the contents in order to compute the weight of the bed.

In the large majority of countries (developed and developing countries), a proper system to collect area data on vegetable crops does not exist. Some countries, mostly developing countries, rely on Census of Agriculture to collect these data. Some developed countries use administrative data or expert assessment. Very few countries conduct surveys or censuses for collecting vegetable crops area. It is important to examine which method applies to which country and under which conditions. For instance, in Africa, the vegetable plot has often the form of the bed and since some vegetables are staggered harvest crops, one option is to rely on the statement of the holder to have area and production estimates and that requires a significant effort of memory recall from holders.

If the collection of data on vegetable crops is done within a more comprehensive survey/census, it is possible that the questionnaire design and the general techniques of measurement of area and production for "traditional" could not fit the peculiarities of vegetable crops.

The use of administrative data from different sources, that is to say data which were not collect primarily for statistical purposes, can be difficult when reconciling them to obtain statistical data. This can be more difficult for countries where administrative data are outdated. Global Strategy is elaborating a guideline on how to improve and integrate administrative data in the agricultural statistical system (Global Strategy, 2015).

Due to the large species of vegetable crops, the measurement of yield depends on the type of vegetables. Onetime enumeration is not meaningful for some vegetable crops, since they have several growing seasons within a year. It is important to evaluate the best option between: 1) Providing necessary tools and capacity building to the holder and relying on his statement or 2) Follow-up by several visits, with the physical presence of enumerators. In this last case, it is important to determine with the holder, the exact date for crop harvesting. Some crops are left in the field by the holders and harvested when needed.

The yield depends also to the seed varieties. Only information collected from the field could give clear indication on the yield. Administrative data should be extremely detailed to give all these information, for each crop. Therefore, the use of administrative data to identify yield rate could be a daunting task. However, administrative files could be used to assess the production.

The use of a specific seed can be different within a year; the yield rate also can vary considerably during this period of time. For crops which are grown several times during a year period, if the yield estimates for one growing season is used for another one, the results could be inaccurate.

The main challenge for this kind of survey on horticulture crop is to find the best observation methods giving right and accurate measurements of the key parameter for production estimate (area harvested, yield). It is how to find the easiest, the simplest and most user-friendly method for respondents and enumerators, which are fast to implement and are cost-effective that is a challenge.

The vegetables grown in the region (lettuce, carrot, spinach, mint, celery, etc.) are characterised by short growing cycles (1-3 months) and generally non rain-fed crops allowing the practice of continuous planting/harvesting over the year. Certain vegetables like mint, parsley's main characteristic is that they are successive harvest crops and others like okra and tomatoes for which harvest is staggered can last 1 month or more. Hence measuring the harvest area and yield using objective measurement methods needs to monitor each planting/harvesting occurrence and also each harvest occurrence by the sampled holder for okra and tomatoes.

For the exercise, there was not enough budget and probably no national institution would accept to participate in a pilot survey covering one year in the field. The strategy used in this field test is to reduce the number of visits by the enumerators to the farmers at a minimum possible considering the short time allocated to data collection phase in the field (one month). For the recording of area harvested, the combination of objective measurement during the field visits and the farmer recalls allow to calculate estimates covering the reference period (one year). Considering the general cultivation practice of the vegetable growers using the bed as the principal technique for soil preparation and plant sowing, the bed is an area unit that can be used for harvest area measurement.

The questionnaire is designed to allow recording of a suite of variables needed in order to estimate the area and yield of each type of vegetable crops. The variables to be measured and the appropriate methods of measurement vary according to the type of crop, the mode of harvest (i.e. single harvest, staggered harvests, successive harvests), and cultivation techniques (on bed, full field). For yield measurement, two methods are tested, the random selection of a sample of beds to be harvested and the production weighted in the case the plot is sown using the beds and the use of traditional crop cutting method in case the plot is sown using full field. Table 1 below illustrates the proposed variables to be collected during this pilot by type of crop according to the mode of harvest, and cultivation technique.

Note that for root vegetables and fruit vegetables, the determination of the measurement unit is central to estimating production.

3.3. Sampling Frame

A sampling frame can be built using agricultural or population census frame. Some variables collected during these statistical operations allow to identify the vegetable growers. The use of administrative files of producers registered in official government agricultural support programs. It is an important storage of administrative records that allows, through in-office activities, to obtain enormous quantity of information about the vegetable growers.

The experience and knowledge of the field enumerators or technicians about the producers and plots land located in their work areas could make it easier to identify producers and their agricultural holdings.

Sometimes it is necessary to build a proper sampling frame. For instance, during the pilot test in Ghana, this option was used. In the absence of appropriate registers of vegetable holdings in Ghana, the better sample design is the two staged sample. The use of Enumeration Area (EA) of the Population and Housing Census 2010 was an option but due to the time-lag between the two operations (5-6 years), the risk of having obsolete and inappropriate information about vegetable growers of the EAs for drawing a sample of PSU was very high. In addition to that the need for having more information on the PSU for an effective sample selection required to have a step for the first stage sample frame preparation by the identification and listing of PSUs allowing the collection of important variables to support the sampling selection.

The first stage sampling frame was built by a complete listing of vegetable growing areas (sites) in each district. Variables such number of holdings operating in the site, the types of vegetables grown in the site were collected to be used for the sample selection.

Once the site is selected, then a complete listing of vegetable holdings is done. This list was the Secondary Sampling Unit (SSU) frame. For sample selection purposes, variables were collected on holder name and sex, type of vegetable grown and specific date of the next harvest, number of employees, total acreage under cultivation. This additional information is used to perform effective holdings sample selection and also for operational use to ensure that the area and yield questionnaires are implemented at the right time particularly that yield data collection are planned during the right harvest time minimizing the survey personnel workload and costs of logistics.

During the listing of the PSUs, the following variables could be collected: a) Area Code b) Area Name c) Geographic Location-GPS Coordinates; e) Estimated Number of Vegetable Holders; f) Main water source; f) Types of vegetable crops grown.

The latter variable allows to build a sample, covering all the different crops. The estimated number of vegetable holders allow to calculate the probability of inclusion for the PSUs.

During the listing of SSUs, the following variables could be collected: a) Name of the Holder; b) Gender; c) the Total acreage under cultivation (acres); c) the number of beds (if applicable) d) The crop grown; e) the beginning of the period of harvest.

3.4. Sample Selection

The sample design could be the 2 stages sampling. At the first stage, the vegetable growing areas are selected with probability proportional to size (pps). The variable to be used for the pps sampling could be the number of vegetable growers in the area.

In the pilot test held in Ghana, 102 vegetable growing sites were identified and listed in the two districts (53 for Keta and 49 for Ada). 32 sample sites (PSU) were selected using PPS (16 for each district). The sample rate at first stage is 1/3. In the Ada District, one site was automatically selected since it was the only site where a specific crop, Zucchini, was recorded. The listing of vegetable crop holders in these 32 sites gave a total of 1814 holders. 10 sample holders were selected randomly in each of the 32 sites. The sample size for the field test was 320 holders. The workload of the enumerators and the budget limitation was taken into account in deciding on the sample size. A total of 16 enumerators were available for the field test.

4. Field Implementation and Innovation

The field implementation has allowed to identify several area of innovation:

- For staggered harvest crop, the enumerator can visit the field 3 times during the harvest period. Ideally, at the beginning, at the peak and at the end of the harvest. A harvest diary could be given to the farmer in order to record the production of the farm during the absence of the enumerator. The variables to be collected could be: a) the production on the bed/crop-cutting area in terms of number of measurement unit; b) Number of Harvested Beds; c) The date of the harvest. These variable should be kept simple as possible and well understandable by the farmer. Such collected would be useful to access the variability of the production within a single harvest period and to obtain better estimates of the production.
- The pilot test in Ghana has shown that, the growing of vegetable crops is not fairly distributed in various PSUs. For instance, zucchini was only cultivated in one PSU. During the sample selection, this PSU was automatically included in the sample. The estimation of the vegetable crop production grown in such production is done separately and then add to

the estimation on the remaining sample. This procedure allows avoiding the overestimation of the production for such "rare" crop.

- In order to assess the yield, a number of beds are randomly selected in the case the field is divided in beds. The enumerator will confine the field, whatever is its form, in a rectangle with sizes a and b. He will assign the four corners of the rectangle numbers from1 to 4. Using a calculator, he will select a number between 1 and 4. This number will correspond to a selected corner, which will be considered as an "origin point''. Then, he will select a random number between '0 and a' and between '0 and b', using a calculator. These selected numbers will be the coordinates (a, b) of a point in the field. When the point falls in a bed, this bed is selected. The operation is repeated until 3 beds are selected from this field. The sizes of the three beds will be recorded.
- Due to their correlation with the production, socio-economic variables, like availability of water supply, the demand, the equipment, etc. could be collected in other to assess the production. In the case of the pilot test, stratification was not necessary, since the listing of the SSU present a quite homogenous population. However, when stratifying the whole population of the farms the more recent information for each farm is used. It is therefore necessary, to keep update as possible all the information related to the farms. The listing is highly useful in this case.

5. Concluding remarks

Methodologies for measuring area and production for vegetable crop are under development. For instance, Remote Sensing Data are also used to estimate agricultural production; but their use is still at an early stage. Even in developed countries the use of remote sensing data in horticulture is scarce. However, some studies have been done on its implementation in horticultural census/survey (Avtar & Kamlesh, 2012 and Trout et al., 2008). Apart to the fact that it can be used to assess the area, it could be used to identify the harvest period and provide information on the growth status of crop. This information will facilitate the data collection work (Lee et al., 2014).

The pilot test survey in Ghana is currently under implementation, the result will allow to assess the various methodologies to measure area and production (farmer inquiry vs. objective measurement). It will also allow to access the variability of the production for staggered harvest crop.

However, the field implementation in Ghana done so far has allow to confirm what identified in the literature review about the use of bed for vegetable crop production and the use of a measurement unit for the measurement of the production by the farmer.

An adequate sample design has been also developed in order to estimate in an accurate manner the production. The data collected in the Keta district, will be compare with existing data on the vegetable production in order to assess the methodology.

CROP	Divided in Beds		NOT Divided in Beds	
	Area	**Production**	**Area**	**Production**
Leafy with single harvest • Lettuce • Cabbage • Cauliflower	Randomly select beds and: • Area by inquiry • Area by objective measure (GPS) • Simple geometric calculations for small beds • Number of beds harvested by inquiry over the last 12 months	Randomly select beds and: • Harvest bed, and weigh Or • Count plants • Randomly select plants, harvest and weigh • Production by farmer inquiry • Estimate yield of each harvest by farmer inquiry over the last12 months	• Area by inquiry • Area by objective measure (GPS)	Randomly select crop cutting area • Harvest and weigh • Production by farmer inquiry • Estimate yield of each harvest by farmer inquiry over the last 12 months
Leafy with staggered harvest • Spinach • Mint • Parsley • Celery • Potato leaves	Randomly select beds and: • Area by farmer inquiry • Area by objective measure (GPS) • Simple geometric calculations for small beds • Number of beds harvested by inquiry over the last 12 months	Randomly select beds and: • Harvest bed, and weigh • Production by farmer inquiry • Estimate the number of harvest over the last 12 months by farmer inquiry • Estimate yield of each harvest by farmer inquiry over the last12 months	• Area by inquiry • Area by objective measure (GPS)	Randomly select crop cutting area • Harvest and weigh • Production by farmer inquiry • Estimate yield of each harvest by farmer inquiry over the last 12 months
Root vegetables with single harvest • Carrot • Beet • Turnip • Bulb onion • Shallot • Leek	Randomly select beds and: • Area by inquiry • Area by objective measure (GPS) • Simple geometric calculations for small beds • Number of beds harvested by inquiry over the last 12 months	Randomly select beds and: • Harvest bed, and weigh Or • Estimate number of measurement units • Harvest randomly selected plants, weight measurement unit • Production by farmer inquiry in measurement units • Estimate yield of each harvest by farmer inquiry over the last12 months	• Area by inquiry • Area by objective measure (GPS)	Randomly select crop cutting area • Harvest and weigh OR • Estimate production by farmer inquiry in measurement units • Estimate weight of measurement units by farmer inquiry

Fruit Vegetables with single harvest • Pumpkin	Randomly select beds and: • Area by inquiry • Area by objective measure (GPS) • Simple geometric calculations for small beds • Number of beds harvested by inquiry over the last 12 months	Randomly select beds and: • Harvest bed, and weigh Or • Estimate number of measurement units by farmer inquiry • Estimate weight of measurement unit by harvesting, filling, and weighing • Estimate yield of each harvest by farmer inquiry over the last12 months	• Area by inquiry • Area by objective measure (GPS)	Randomly select crop cutting area • Harvest, and weigh Or • Estimate number of measurement units by farmer inquiry • Estimate weight of measurement unit by harvesting, filling, and weighing • Estimate yield of each harvest by farmer inquiry over the last12 months
Fruit Vegetables with staggered harvest * • Cucumber • Eggplant • Pepper • Hot pepper • Tomato • Okra *Methods are same regardless of whether or not fruit vegetables are cultivated in beds.	Randomly select beds and: • Area by farmer inquiry • Area by objective measure (GPS) • Simple geometric calculations for small beds • Number of beds harvested by inquiry over the last 12 months	Using fruit vegetables already reaped that are present at holding. • Estimate number of measurement units by farmer inquiry • Estimate weight of measurement unit by harvesting, filling, and weighing • Estimate the number of harvest over the last 12 months by farmer inquiry • Estimate yield of each harvest by farmer inquiry over the last 12 months	• Area by inquiry • Area by objective measure (GPS)	Using fruit vegetables already reaped that are present at holding. • Estimate number of measurement units by farmer inquiry • Estimate weight of measurement unit by crop cutting, filling, and weighing • Estimate yield of each harvest by farmer inquiry over the last 12 months

Table 1: *Variables to Be Collected to Measure the Area and the Production According to Each Type of Crop*

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THEMATIC SET

G45

NEW SOFTWARE, APPS AND TOOLS FOR DATA ANALYSIS, INTEGRATION AND MODELLING IN AGRICULTURE STATISTICS

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The Canadian Longitudinal Census of Agricultural File – a Tool to Better Understand Structural Change of Canadian Farms

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ABSTRACT

The structure of the agricultural sector evolves through the responses of individual farms to technological innovation, economic shifts and demographic trends, among other factors. In 2014, the Canadian Longitudinal Census of Agriculture (CL-CEAG) dataset was created to provide an additional tool for micro-level farm analysis. This initiative followed the example of the U.S. Census of Agriculture Longitudinal File. This paper describes the CL-CEAG dataset, the methodology for the record linkage and models of farm exits and farm profitability as examples of analysis using the CL-CEAG. Discussion on the features of the file and on how to access it concludes.

Keywords: Census of Agriculture, longitudinal data, farm exit, farm profitability

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1. Introduction[1]

[1] The authors thank their colleagues for valuable comments and suggestions, in particular Ray Bollman.

1

The primary purpose of the Census of Agriculture (CEAG) is to create a statistical profile of Canadian census-farms[2] at one moment in time. However, given that the CEAG includes the population of census-farms and that it provides a broad range of farm and operator characteristics with a high degree of continuity over time, the CEAG presents a unique opportunity for the creation of a longitudinal dataset for farm-level analysis of structural trends and the lagged impact of policies and external shocks. Thus, following the US example, where the US Census of Agriculture Longitudinal file was created in 1997, linking census records back to 1978[3], Statistics Canada created in 2014 the Canadian Longitudinal Census of Agriculture (CL-CEAG) dataset. The purpose of the paper is to present the CL-CEAG dataset as a new analytical tool, describing in particular the methodology for the record linkage, as well as providing models of farm exits and farm profitability as examples of analysis using the CL-CEAG. Discussion on how the dataset can be accessed while ensuring data confidentiality concludes.

2. Existing longitudinal files for the Canadian agricultural sector

The CL-CEAG micro-dataset complements already existing longitudinal data on Canadian farms from administrative data sources and surveys. Housed at Agriculture and Agri-Food Canada (AAFC), administrative data of from AgriStability and AgriInvest, two Canadian agricultural risk management programs, provide detailed longitudinal farm business revenue and expense data of over 100,000 participating farms, as well as detailed inventory information for about half of these, beginning in 2005. The population is limited to program participants and does not include all Canadian farms. The file does not include farm physical information or farm operator characteristics.

The Longitudinal Administrative Databank (LAD), housed at Statistics Canada, consists of detailed income, social transfer and demographic information of 20 percent of Canadian income tax filers and their families, beginning in 1982. Farm families can be identified as those with a non-zero value for Gross Farming Income and/or Net Farming Income. The LAD has been used to analyze the persistence of negative net farming income and the prevalence of low family income of farm families compared to non-farm families (Culver, 2012; Nagelschmitz, 2007). The file does not include any information on the farm business.

The sample overlap of the biennial Farm Financial Survey, which collects information on farm assets, liabilities, capital purchases, and capital sales, as well as some operator demographic information and program participation information, has been used for analysis, such as of the year-to-year changes in level of farm debt (Culver, 2012).

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[2] In Canada, a census-farm - or “agricultural holding” - is any operation producing agricultural products that are intended for sale, which in addition to farms producing field and livestock products crops also includes mushroom houses and nurseries; farms producing Christmas trees, fur, game, sod, maple syrup or fruit and berries; beekeeping and poultry hatchery operations; operations with alternative livestock; as well as operations involved in boarding horses, riding stables and stables for housing and/or training horses (see http://www.statcan.gc.ca/eng/ca2011/gloss) (See http://www.statcan.gc.ca/pub/95-629-x/2007000/4123857-eng.htm). In this paper the focus is on all census-farms, and we use the term “farm” and “census-farm” interchangeably, always mindful that the majority of census-farms are small operations , which provide at most only a very small contribution to their farm operator’s income.

[3] See Hoppe and Korb (2006) for a description of the US Census of Agriculture Longitudinal file dataset; Ahearn et al (2009) and Katchova and Ahearn (2015) use the file for analysis of farm level dynamics.

In the past, CEAG files have been linked at the micro level in pairs of two succeeding census iterations to analyze the characteristics of exiting, entering and continuing census-farms (Kapitany and Bollman, 1983; Ehrensaft et al, 1984; Bollman and Ehrensaft, 1988; Bollman et al. 1994; Kimhi and Bollman, 1999). In addition, Shapiro et al. (1987) used as sample of micro-linked census-farm records from 1966 to 1981 to examine the dynamics of farm concentration.

The CL-CEAG complements these existing longitudinal administrative and survey data sources, by providing longitudinal data for all census-farms, as well as the possibility of including a wide range of farm and operator characteristics variables in micro-level models examining farm behaviour for up to 25 years.

3. The Canadian Longitudinal Census of Agriculture dataset

The Canadian Longitudinal Census of Agriculture (CL-CEAG) dataset links the micro-data of census-farms across the six censuses from 1986 to 2011, using the unique Agricultural Operation Identifier (AGOPID), which is part of each census-farm record. The AGOPID makes it possible to track the change in characteristics of individual farms over time, as well as to identify census-farm entrants and exits between collection years to measure the dynamics of structural change. The dataset provides a consistent set of industry- and geography-based classifying variables.[4] For the latter, the 2011 Standard Geographic Classification is applied, with the fundamental geographic unit being Census Consolidated Subdivisions (CCSs). CCSs can be aggregated, to form Census Divisions, Census Agricultural Regions, and Economic Regions, providing a high degree of flexibility.[5] The CL-CEAG dataset currently includes a number of variables that describe farm and farm operator characteristics that are consistent over the period covered by the data. Many more census variables can be added as research projects are developed.[6]

The AGOPID is fundamental to the creation of the CL-CEAG dataset and the interpretation of analysis that uses the data. The AGOPID is attached to each census-farm, which has been identified based on the definition of "agricultural holding" (see footnote above) and is therefore included in the Census of Agriculture. The AGOPID is largely based on the location of the farm's headquarter. A census-farm is treated as "continuing" if it responds to censuses under the same AGOPID across census years. By the same token, if a respondent associated with an AGOPID indicates that there is no longer an operation that produces agricultural products for sale or with the intent to sale, the census-farm with that AGOPID is considered to have exited[7].

Changes in farm ownership (whether it be an intergenerational transfer or an arms-length purchase from outside the family), change in operators, or change in headquarter location have the following impacts on the AGOPID: If a census-farm is sold or otherwise transferred as an on-going operation and the new operator's information (i.e. name and age) is available and is associated with the farm's location, the farm is considered continuing and its AGOPID is maintained. However, if a census-farm is bought by another existing farm, the farm is most likely treated as part of the new owner's existing operation and the farm's land, building and inventory are recorded in the Census of Agriculture questionnaires as an expansion of the buyer's farm. In that case, the AGOPID of the

[4] The CL-CEAG dataset includes industry variables of longitudinal farm type based on the North American Industry Classification System (NAICS; http://www.statcan.gc.ca/eng/subjects/standard/naics/2012/introduction#a8).
[5] http://www23.statcan.gc.ca/imdb/p3VD.pl?Function=getVDPage1&db=imdb&dis=2&adm=8&TVD=116940
[6] Some CEAG variables have evolved over time. Where feasible, a consistent variable is created. Some variables may not be found in all years, but may nonetheless be useful for analytical purposes.
[7] Note that a farm is not considered active if all land is rented out.

Table 1. Factors Related to Farm Exit between 2006 and 2011

	Likelihood of exit	Signifi-cance
One-period farm and operator characteristics [Reference in brackets]		
Macro-Region [Ontario]		
Atlantic		
Quebec		
Prairies	++	***
Alberta	+	***
BC		
Farm Type [Grain and Oilseed]		
Beef Cattle	---	***
Hogs	+++	***
Horticulture		
Mixed		
Revenue Class [Under $50K]		
Between $50K and $250K	-	***
Between $250K and $999K	--	***
Over $1M	---	***
Age of 1st Operator [Under 30 years of age]		
30 to 39 years of age	-	**
40 to 49 years of age	--	***
50 to 59 years of age		
60 years of age and older	+++	***
Off-Farm Employment [No Off-Farm Employment]		
Part-Time Off-Farm Employment		
Full Time Off-Farm Employment	+	*
Number of Operators [One operator]		
Two	--	***
Three	---	***
Multi-period Variables (1996-2006)		
Change in Value of Machinery and Equipment (Bottom tercile [reference]		
Middle tercile	--	***
Top tercile	-	***
Change in Farm Size [Bottom tercile]		
Middle tercile	-	***
Top tercile	--	***
Change in Gross Farm Receipts [Bottom tercile]		
Middle tercile	--	***
Top tercile	-	***

Notes: +/- indicates the direction and strength of the influence of the variable on the likelihood of exit and are only reported when statistically significant. *,**,*** indicate significance at .01, .001 and .0001 levels, respectively. For categorical variables, reference groups are noted in parentheses.

purchased farm is terminated and no new AGOPID is created. If a farm is sold and bought but the new operator or head quarter location cannot be identified with the farm under the previous owner, the old AGOPID is inactivated and a new AGOPID is created.

Entry and exit rates generated by the CL-CEAG are qualitatively similar both to entry and exit rates generated by the CEAG going back to the early 1900s of between about 35 and 50 percent over 10 years, and to the U.S. (Bahar and Brown 2014). They are also are in line with manufacturing firm 10-year entry and exit rates of about 40 percent (see Baldwin 1998).

4. Examples of Modelling using the CL-CEAG

Longitudinal datasets are useful tools for many types of analysis. Here we first highlight the use of lagged and multi-period variables in the modelling of farm dynamics, specifically farm exists, and then the analysis of the factors associated with change over time in farm performance (i.e. profit margins). It is important to keep in mind that, while instructive, the results of these simple models presented here should be viewed as correlative and not aimed at identifying causal relationships.

Example A: Farm Exits

Farm exit and entry dynamics in Canada have been modelled with various datasets in the past, including multiple panels of two-period CEAG panel data and a sample of longitudinal CEAG records (Ehrensaft et al. 1984; Kimhi & Bollman, 1999). The CL-CEAG allows the use of micro-multi-period variables of farm dynamics and behaviour on the whole population of census-farms, which could be related to future continuation or exit decisions of census-farms.

Building on Freshwater (2015), we use a logit model to estimate the relationship of farm and farm operator characteristics on farm exits, including three multi-period variables identifying the farms' growth behavior. Table 1 shows the results for census-farm exits between 2006 and 2011, (i.e., of AGOPIDs which existed in 2006 but not in 2011). The first multi-period variable accounts for the change of the value of machinery and equipment between 1996 and 2006, namely the ten years leading up to the anchor year (2006). The change in the value of machinery and equipment is assumed to be partly an observation of investment behaviour and reflective of the medium to long-term business objectives of the farm. The variable was created using terciles rankings within each farm type and farm size group in the anchor year, assigning each farm the value of Top, Middle, and Bottom Tercile, from greatest percent increase to greatest percent decrease in the value of machinery and equipment. The hypothesis is that farms planning on exiting are less likely to increase their investment in years prior to exiting than are farms in the other two categories. We also construct a similar variable of terciles of percentage change for physical farm size, using the number of acres for crop farms and herd size for livestock enterprises between 1996 and 2006, with similar a hypothesis.[8] Finally, a variable for change in annual gross farm receipts between 1996 and 2006 (in 2001 dollars) is included in the model to captures the trend of farm revenues in the years prior to the decision to exit or continue, which may have a different trend than physical size of the operation. In addition to these multi-period variables, the model also includes standard single-period variables in the farm exit model: region, farm type, gross farm receipts, off-farm employment and farm operator age.[9]

Given that the purpose of the paper is to illustrate the use of the dataset, it is sufficient to show the general tendencies rather than exact coefficient. This approach limits the impact of this analysis on the confidentiality of the dataset, as will be discussed further, below. The longitudinal farm growth indicators all have the expected signs with regards to the probability that the farm exits. Farms that were growing are less likely to exit than those that are decreasing in size. At the same time, the single-period variable farm revenue class (using farm gross receipts) is the strongest predictor of farm exits, and operator employment off the farm and the number of operators are also significant variables. The CL-CEAG enabled the modeling of the role of multi-period trends at the census-farm level on farm behaviour.

Example B: Farm Profit Margins

While the previous example shows the benefit of the CL-CEAG in enabling the use of multi-period variables for analysis in traditional regression models, this second example shows how the longitudinal dataset enables the modelling of change of farm attributes over the entire period (i.e. 1986 to 2011). This example models the factors impacting farm profit margins across the period.

The general linear mixed longitudinal model (GLMLM) is used because it is better suited to longitudinal analysis than the more common generalized linear model (GLM). While the GLM assumes that observations are independent of each other, the GLMLM takes accounts the fixed effects impacting observations of each subject, in addition to the random effects of each observation (Breslow and Clayton, 1993).

The dependent variable of the model is 'profit margin', calculated as Total Gross Farm Receipts minus Total Farm Business Operating Expenses plus Interest Expenses divided by Total

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[8] The variables are change in farm acres (for grain, tobacco and horticulture farms); head of cattle (beef cattle farms); and number of pigs (hog farms).

[9] Since 1991, the CEAG allows for multiple operators, with no difference in status, i.e. there is no 'primary operator' designation. However, for this analysis we use the first operator that is identified, and assume that the first operator is most involved in the operator of the farm, i.e. the "primary" operator.

Gross Farm Receipts.[10] In addition to the one-period farm and farm operator characteristics, as in the farm exit model, the model includes CEAG variables associated with two farm management practices as a proxy for adoption of innovation: 'Use of computer for farm management' and 'Use of tillage practices', which references the adoption of no-till technology.

The results of the estimation are as follows. The coefficients of the farm and farm operator variables have broadly speaking the expected signs: Larger farms with older farm operators that dedicate their time to farm operations tend to have higher profit margin, after taking into account their farm type and location.[11] Farms with two operators are more likely profitable than those with either one or three operators. This might be a sign of the most stable farm management and farm size structure, perhaps due to husband and wife partnerships[12]. The variable 'Use of computer for farm management' has a positive and marginally significant effect of farm profit margins, while the variable 'Use of tillage practices' has no significant effect. Census year dummy variables were included in the model to account for external factors, such as market conditions and weather patterns; they were found not to be significant.

The model provides largely an intuitive set of associations. More work is required to develop a fully formed identification strategy. The longitudinal nature of the file, however, opens up several avenues of econometric analysis to pursue this, including the development of internal instruments, for instance using Systems- GMM (generalized method of moments) estimation.

5. Discussion

The CL-CEAG dataset has been developed to provide an additional tool for the analysis of the Canadian agricultural industry, given its broad range of farm characteristics and now the ability to use multi-period and lagged variables to identify the drivers of farm behaviour, including responses to macro-factors, such as changes in the infrastructure and cost of transportation, regional economies, and policies and regulations.[13]

However, the CL-CEAG is not free of limitations: The linking of farm records over survey time, like all firm-based data files, is not always clear-cut. Some changes occurring to the farm business require special consideration and judgement as to whether they represent the death and birth of a new business or the continuation of an on-going farm operation, such as the sale of the farm to new owner but without change of headquarter location or structure of the operation. Also, given the quinquennial nature of the CEAG, farm entries and exits which occur within the five year period are not observed and thus entry and exit rates may be underestimated (Katchova and Ahearn, 2015). In addition, the analysis of multi-period variables or the observation of dynamic trends is limited to those farm businesses that are in existence for at least ten years to be part of three censuses. Lastly, since the primary purpose of the CEAG is to provide information on Canadian

[10] Gross farm receipts include revenues from the sale of agricultural and forest products and agricultural custom work and machine rental, as well as payments from government programs and insurance proceeds. Operating expenses include business costs in the production of agricultural products plus wages and salaries paid to children and spouses. For incorporated farms, operating expenses may also include wages and salaries or rent paid to owner/operators (i.e. shareholders), while labour remuneration owner/operator of unincorporated farms is part of net operating income.
[11] The relationship with employment of other family members is not modeled and might have a different effect.
[12] Detailed results are available from the authors upon request.
[13] For example, Ferguson and Olfert (2015) used information for Census Consolidated Subdivisions in their work on the impact of the elimination of a grain transportation subsidy. Now, with the CL-CEAG the impact of individual farm characteristics can be analyzed.

census-farms at a point in time, the questions are not designed with the longitudinal dataset in mind. However, the development of future censuses might now take the longitudinal CL-CEAG dataset into consideration, so that lagged and multi-period variables could potentially become farm typology indicators.

The CL-CEAG dataset – like all micro-level data – must be managed in a manner that prevents residual disclosure of records, which repeated use of the data with slightly different methodologies can cause. Longitudinal business micro-datasets are inherently at greater risk of residual disclosure than datasets of populations, because the number of records tends to be smaller and the firms (farms) tend to be more easily identifiable than people, especially the larger firms (farms) in a given region or industry. The CL-CEAG is housed in Statistics Canada's Centre for Data Development and Economic Research (CDER), a centralized Research Data Centre at Statistics Canada headquarters that provides strictly managed access to business economic microdata for analytical research. Projects need to go through an approval process and are subject to extensive security requirements throughout the research process[14,15]. Due to the risk of residual disclosure, i.e. identification of respondents through combination of research results, steps have to be taken to limit the effect of published research projects subsequent work. Best practices, such as minimizing the use of descriptive data, have been employed to ensure the usefulness and availability of the dataset into the future.

6. Conclusion

This paper describes the CL-CEAG dataset and provides examples of this new tool for research of the dynamics of structural change of Canadian farms. The aim of Statistics Canada and Agriculture and Agri-Food Canada is that CL-CEAG will encourage much new research.

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Extending the LACO-Wiki Tool for Land Cover Validation to Crop Area Estimation

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ABSTRACT

LACO-Wiki is an open access, online map validation tool that has been being developed by IIASA and GeoVille. Funded by the Austrian Agency for the Promotion of Science and originally as a prototype by the European Space Agency, the application is intended for a variety of stakeholders including map producers and public agencies, such as environment agencies, that need a land cover validation solution for their products. In addition, LACO-Wiki can be used by researchers and students who are interested in learning about land cover map validation and for examining different methods of accuracy assessment. A secondary aim of LACO-Wiki is to become

an open data repository for calibration and validation data as well as a repository for land cover and land use maps, which could become a valuable resource for the remote sensing and research community.

LACO-Wiki provides guidance that takes users through the full validation workflow from uploading the map to be validated, generating a validation sample, initiating a validation session and creating a customized report on accuracy assessment. The system currently allows crowdsourcing of the validation tasks to members of a team or to a wider set of participants where users can generate random or stratified random samples to validate existing maps using publicly available very high resolution imagery (VHR) such as Google Earth and Bing. New functionality is currently being added to allow for the creation of a systematic sample that can be used for applications such as crop area estimation. Following the methodology outlined in Kerdiles et al. (2014), LACO-Wiki will automatically suggest an indicative number of sample points required to calculate the crop area with a user-specified level of confidence. The system is currently being tested on area estimation of wetland rice in Madagascar. In countries where access to VHR ortho imagery and image processing technology are not available or where field work costs (i.e. ground-truthing) are prohibitive, LACO-Wiki could represent a highly reliable, low cost solution specifically for area estimation in categories that can be consistently identified (i.e. stable over time) in VHR images, but also more generally for map validation.

Keywords: LACO-Wiki, Area estimation, map validation, land use, land cover, crowdsourcing

1. Introduction

LACO-Wiki is a web-based platform allowing users to validate land cover and land use maps. It provides users with a sequentially guided interface where they can upload their own land cover and land use maps, generate samples, create validation sessions and obtain customized reports including an accuracy assessment and a confusion matrix. During the validation session, different reference layers can be used including satellite and aerial imagery from Google and Bing, and features from OpenStreetMap. This paper outlines new functionality that is currently being added to LACO-Wiki to allow users to estimate areas of selected classes, in particular cropland classes.

With regard to area estimation methods, Craig and Atkinson (2013) review classical and newer techniques, including censuses, described as rather expensive and time consuming, which can therefore only be used every few years in developed countries or even less frequently in developing countries. Some, site-specific studies have analyzed areas where the reference data are effectively covering the whole area, thus becoming a census (Hollister *et al*, 2004). Statistical sampling is more commonly used in order to reduce costs and allow for quite accurate inference on larger populations (Congalton and Green, 2008). List frame and area frame sampling are sound methods to gather information, each one suffering from particular problems, e.g. maintenance of lists is difficult or small area estimation by area sampling has been poorly done (Craig and Atkinson, 2013). Hence, area frames and list frames are sometimes combined to address these issues. Area frame sampling is used in several countries including the United States National Agricultural Statistics Service (NASS). In Europe, the LUCAS survey, carried out by EUROSTAT and the European Commission Joint Research Center (JRC), employs a point system sampling approach for land cover area estimation. The system is called the Land Use/Cover Area Frame Statistical survey (LUCAS), and is used to estimate areas and change over time of land cover more generally, among other uses (Gallego and Delincé, 2010). Additionally, Kerdiles et al. (2014)

estimated areas of cropland in North Korea by using a similar system, with a systematic sample of points stratified by slope that were interpreted using very high resolution satellite imagery (e.g. from Google Earth). From these sample points, the authors at the JRC were able to estimate the area of cropland in hectares for different slope strata along with the standard error and coefficient of variation. Following the methodology outlined in Kerdiles et al. (2014), LACO-Wiki will automatically estimate an indicative number of sample points required to calculate the crop area with a user-specified level of confidence. In the current paper, we will demonstrate how the system works on area estimation of wetland rice in Madagascar. Additionally, and following good practice recommendations (Olofsson *et al*, 2014), LACO-Wiki allows users control and transparency at each step as well as producing several measures of accuracy and uncertainty.

The next section provides an overview of the LACO-Wiki system and the methodology behind the extension of the functionality for area estimation. Some remarks on the openness and applicability of the tool conclude the paper. It should be noted that the most usual metrics for validating a land cover map also apply to area estimation problems. For example, computing the omission error for a given class is equivalent to estimating the area that should have been classified as that class, but has been allocated to a different one.

2. Tool description and methods

LACO-Wiki can be accessed online at http://laco-wiki.net. For first time users, a brief user registration is required via Geo-Wiki; alternatively, users can log in using their Google+ or Facebook accounts. Once inside the tool, a sequence of 4 + 1 steps can be performed. The four initial steps are sequential but can be revisited at any time.

The first step consists of uploading a map in either vector or raster format (Figure 1). The currently accepted formats are shape files and GeoTIFFs in a WGS84 or ETRS89 LAEA projection. Once a map has been uploaded, the legend can be customized for on-screen display. The system allows users to upload ancillary datasets (RGB images in the supported projections) that could be of use in the validation process.

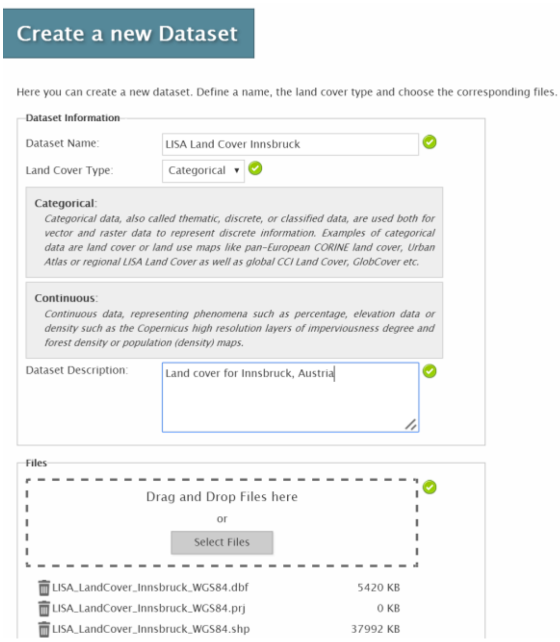

Figure 1. Step 1 – Example showing uploading of a vector dataset

The second step is the generation of a validation sample set (Figure 2). Here users can choose between completely random and stratified random samples for raster data and completely randomized for vector data. In the future, stratified random sampling for vector will be added along with systematic sampling for both types of data sources. The samples can be point, pixel (resolution-dependent) or geometric features (i.e. segments) depending on the type of map that has been uploaded and which sampling method has been chosen. Alternatively, in the near future, a validation sample set created in a previous session or generated in a different tool could be uploaded and used.

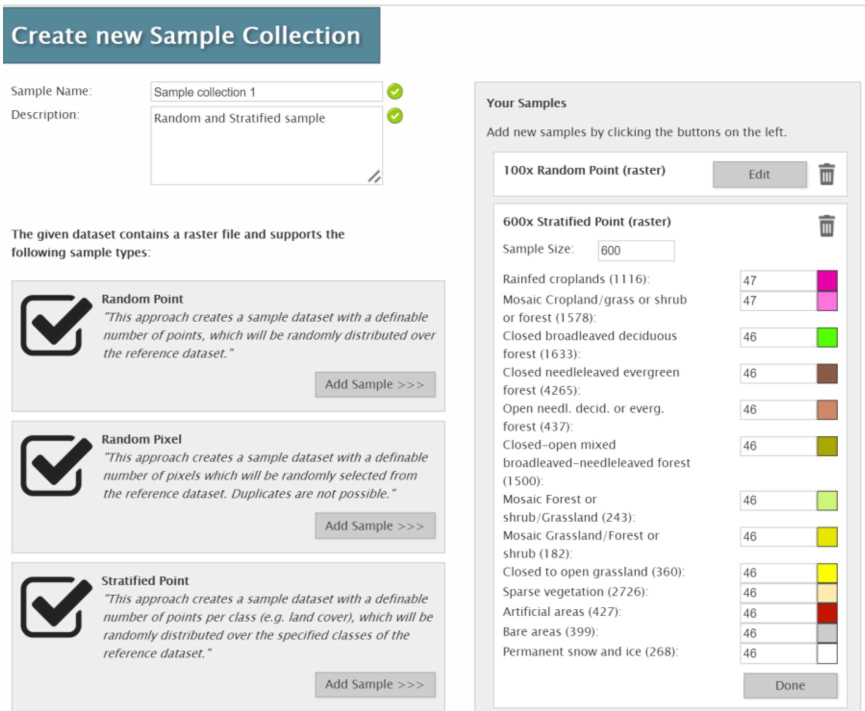

Figure 2. Step 2 – Selection of sampling methods for validation

The third step is the map validation or sample interpretation. With the use of reference data including satellite and aerial imagery from Google and Bing and a feature layer from OpenStreetMap, samples produced during the previous step can be validated. Users can employ the previously defined legends and the validation can be done in two ways: 1) Blind validation, where users interpret the reference data and then decide to which of the available land cover-land use classes the selected sample point, pixel or segment belongs or 2) plausibility validation, where users decide whether the land cover-land use class associated with the point or area of interest is correct or not (Figure 3). In both cases where a segment contains more than one land cover, dominance or majority of one is the deciding factor. In the future a third validation option will be added, called enhanced plausibility, which will allow users to correct the land cover-land use class if they think it is incorrect.

Figure 3. Step 3 – Plausibility validation using reference satellite and aerial imagery

The fourth step is the quality assessment and report generation. Here users can select what accuracy measures they want calculated including user, producer and overall accuracy but also Average Mutual Information (AMI) (Finn, 1993), quantity and allocation disagreement (Pontius and Millones, 2011), kappa (Congalton and Green, 2009) and Portmanteau accuracy (Comber *et al.*, 2012). An excel report is created that includes all this information. It is also possible to download the confusion matrix and the raw data.

More recently, we have been extending the LACO-Wiki tool by adding an additional piece of information and an iterative process as shown in Figure 4.

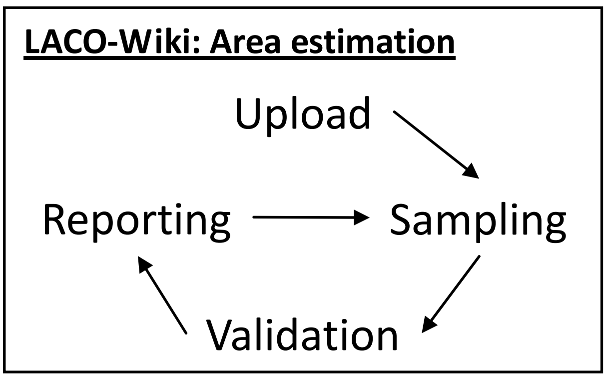

Figure 4. LACO-Wiki iterative process allowing re-sampling after obtaining area estimates reports

The iterative process allows for two-step sampling. The first report produced will include an initial estimation of the area A_c corresponding to each class *c* (e.g. overall cropland) computed by simply multiplying the total map area *A* with the proportion p_c of points classified as *c*.

$$A_c = A\, p_c \qquad \text{with variance} \qquad V(A_c) = A^2 \frac{p_c(1-p_c)}{n-1} \tag{1}$$

If we have a stratification, the estimates are:

$$A_c = \sum_h A_{ch}\, p_{ch} \quad \text{with variance} \qquad V(A_c) = A_h^2 \sum_h \frac{p_{ch}(1-p_{ch})}{n_h - 1} \tag{2}$$

and a coefficient of variation $CV(A_c) = sqrt(V(A_c))/A_c$ usually expressed in percentage.

In general, when a stratification is used for the first time, the available information is not enough to apply the usual Neyman rule for optimal allocation of a sample among strata (Cochran, 1977). A good strategy in this case is allocating half of the foreseen sample in a "reasonable" but subjective way, and applying a more formal optimal allocation to the rest of the sample at a later stage. The "reasonable" allocation applied by LACO Wiki will be based on coarse indications provided by the user on the possible values of p_{ch}. The user is asked about the possible proportion of class c in stratum h suggesting some values: (0, 10%, 20%, 50%, and 80%) and giving the option to provide a user defined value. The user is warned to choose "0" only if they are sure that p_{ch} is negligible. LACO-Wiki will propose a sample per stratum:

$$n_h^* = k^* A_h\, \dot{p}_{ch}(1-\dot{p}_{ch}) \qquad \text{where} \qquad k^* = n^* \frac{A_h\, \dot{p}_{ch}(1-\dot{p}_{ch})}{\sum_h A_h\, \dot{p}_{ch}(1-\dot{p}_{ch})} \tag{3}$$

This first lot allows better tuning the proportions per stratum, obtaining $\ddot{p}_{ch} = n_{ch}^* / n_h^*$ where n_{ch}^* represents the number of points interpreted as belonging to class *c* in stratum *h* in the initial sample.

Now we can make a better allocation of the overall sample of size *n*, provisionally provided by the user:

$$n_h = k A_h\, \ddot{p}_{ch}(1-\ddot{p}_{ch}) \qquad \text{where} \qquad k = n \frac{A_h\, \ddot{p}_{ch}(1-\ddot{p}_{ch})}{\sum_h A_h\, \ddot{p}_{ch}(1-\ddot{p}_{ch})} \tag{4}$$

The additional sample in each stratum will be $n_h - n_h^*$. If the initial selected values for $\dot{p}_{ch}$ were not adequate (i.e. not reflecting actual field conditions), it may happen that $n_h - n_h^* < 0$ for a given stratum. This will lead to an overall sample size slightly larger than foreseen and the user will be warned. The user will be also informed of the foreseen coefficient of variation CV computed by applying formulae (2) with the proportions $\ddot{p}_{ch}$ computed with the initial sample. The user will be asked if the foreseen accuracy and sample size are satisfactory. Otherwise a new value of *n* will be requested and the foreseen CV computed again until an acceptable trade-off is reached. A sequential approach to tuning the sample size and the accuracy is also possible (Carfagna and Marzialetti, 2009), but not implemented at the moment in LACO-Wiki.

For the classes where more samples are required, the system will randomly allocate them to each stratum and steps 3 and 4 would proceed as described earlier, producing a new validation and a report of accuracy and area estimates. If a pre-selected sample has been loaded in step 2, LACO-Wiki will then use this sample and the classification/validation done in step 3 to estimate the area. The results of the area estimation step will be displayed in the report produced in step 4. The system is iterative in the sense that if users are not satisfied with the area estimates obtained or their variability at any stage in the process, they could decide to run a sampling campaign again using the updated variance estimates.

Direct crowdsourcing or team support is implemented in the system since all validation tasks can be shared with several users in order to distribute the work and achieve faster results.

3. Discussion and applicability

The system is currently being evaluated by Madagascan experts and local experts at IIASA as well as local students. An overall agreement between these interpreters will be done and presented at the conference to demonstrate and compare current capabilities of the system. An increase in the accuracy of the area estimated for wetland rice is expected.

This system can be applied to different land cover classes. The main conditions for its applicability are:

- The targeted land cover class can be reliably identified on VHR images. If we think of crops, this may only be true in the case of paddy rice and some permanent crops, such as olive trees or vineyards, but this strongly depends on the complexity of the agricultural landscape. It can be also applicable in many cases to the overall area of arable land, of permanent crops or cropland.
- The dates of the images in Google Earth and Bing are recent enough to accept that few changes have happened between the image date and the reference date. In any case, the estimation obtained is some type of average of the yearly areas of the different dates of the VHR images considered.

LACO-Wiki was designed as a very straight-forward tool allowing users to easily validate their land cover-land use map and estimate the per-class area. As an online independent platform, it allows users from anywhere in the world to achieve fast map validation results. The calculations shown in the tool and the reports produced are standardized and therefore allow for comparison against different methodologies or even between different samples generated using LACO-Wiki.

The essential advantage of the tool is that validation and area estimation can be done entirely without ground-truth information. This is particularly valuable where field campaigns might be prohibitively expensive or where the areas are inaccessible. Additionally, if local knowledge exists, it can be incorporated as an extra layer in the system and visualized simultaneously with the satellite imagery. This would allow the user to produce a more refined interpretation of what land cover or land use exists at a given location.

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Selective editing procedure for the Community Survey on the Structure of Agricultural Holdings

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ABSTRACT

The annual survey on the Structure of Agricultural Holdings (SAH) collects information on agricultural areas for cultivation type, type and quantity of livestock, agricultural production, structure and amount of labour involved in the holding. In the present work we describe and evaluate the results of the selective editing strategy used to identify the influential values of the SAH main numeric continuous variables (reference year 2013).

Keywords: selective editing, influential error, agricultural census, data modelling

1. Introduction

The survey on Structure of Agricultural Holdings (SAH below) collects information on Italian farms about land by type of cultivation, type and amount of livestock, type of production, structure and amount of family and not family labour (ISTAT, 2001). For the first post-census survey (reference year 2013), a new procedure for checking and correcting data has been designed, which integrates different methods and tools for the detection and treatment of different types of non sampling errors in the data. In particular, this work focuses on the description of the selective editing strategy designed to detect the possibly influential errors for the main continuous numeric variables from the survey (farms agricultural surfaces, livestock and some productions).

Within each data editing and correction strategy involving companies (in this case, farms), it is usual to investigate which are the units potentially affected by errors having significant impact (and therefore potential biasing effect) on the final estimates of the main target variables (see for example EDIMBUS, 2007, or MEMOBUST, 2014). One class of particularly effective methods in this area is known as selective editing (Latouche *et al.*, 1992), in which the units potentially affected by influential errors are selected to ensure a more severe control (generally manual/interactive revision) of their nature/source aiming at reducing their potential biasing effect on the final estimates. In the case of the SAH, the selective editing method adopted for the identification of influential errors is based on the latent class contamination models proposed by Di Zio and Guarnera (2013) and implemented in the generalized package Selemix (Guarnera *et al.*, 2013).

The work is structured as follows. Section 2 contains a description of the main features of the overall data editing and correction procedure implemented for the SAH numeric variables. Section 3 contains a brief description of the selective editing methodology and the Selemix software. Section 4 shows the results of applying the method to the most important survey variables of the SAH 2013. In Section 5 the results and efficiency of selective editing process are evaluated. Section 6 contains some concluding remarks and future work perspectives.

2. SAH survey: the data editing and correction procedure

The SAH 2013 responds to EU Regulation No. 1166/2008 of the European Parliament and of the Council of 19 November 2008. It aims to systematically produce statistics on the structure of agricultural holdings and on agricultural production methods. For numeric continuous variables, the final estimates are totals at National and regional level. The theoretical sample of the SAH 2013 includes 42,723[1] companies (D'Orazio, 2013), with a reference population of 1,138,214 companies active in the Country (about 70% of the 1,620,844 recorded at 2010 6th Census of Agriculture). A distinctive feature of this edition of the SAH is that this is the first survey conducted after the 6th General Census of Agriculture, which has made it possible to use the census as an auxiliary source, in order to make more efficient the survey process and more accurate the final results.

The survey was conducted by using web electronic questionnaires. Multiple factors contribute to the complexity of the data editing and correction strategy: the high number of observed variables, their types (both categorical and continuous), the complex relationships (both structural and statistical/mathematical) existing between the variables. With regard to non sampling errors, it is necessary to point out that some of them (for example duplication, skip items, balance) are already identified at the data entry stage, where some consistency checks are carried out at the time of entering information. This strategy ensures more accurate data with respect to a basic set of controls. However, the incompleteness of the controls means that collected data may still remain in situations of non-acceptability or inconsistency, to be properly treated at the subsequent data editing and imputation (E&I) stage.

As known, an error that occurs during collecting or data entry can have both systematic or random nature: these errors can be identified when they entail logical/statistical/mathematical inconsistencies, anomalous values, influential values on the target estimates. In order to identify the various types of error that are potentially present in the target variables (surfaces, livestock and farm productions), a complex procedure of E&I has been carried out. Its main steps are:

[1] In order to meet the Regulation requirements for some domain of interest the number of sample units was increased adding 2.030 small units outside the target population of the SAH: this kind of units are out of the purpose of this paper. The total number of sample units contributing to the estimates keeping into account also events like farms merge or split is 44552.

1 error localization in the phase of identification of the statistical units and/or coverage (errors in identification codes, merge/split of farms compared to the census, membership to the target population,…). This phase will be referred to as pre-editing;

2 identification of possibly systematic errors (in particular unit measure errors) on the basis of a deterministic approach, in order to apply proper automatic corrections;

3 identification of influential errors, with a presumably random nature, through selective editing, for subsequent manual/interactive review;

4 identification and automatic correction of not influential errors, with a presumably random nature, on the basis of a probabilistic approach. In particular, a data-driven type method, implemented in software Diesis (Bruni *et al.*, 2002), has been used.

In the following, the focus will be on the second and third phases of the procedure.

3. The selective editing approach for the identification of influential errors

Let X be a continuous variable and θ a parameter to be estimated on the X's distribution. We define as influential with respect to θ those X values which are potentially affected by a measurement error and have a possibly biasing effect on the θ estimate. Given their statistical relevance, these values need an accurate verification, which is generally performed by manual/interactive revision by well-trained expert clerks. In order to reduce costs and time of such data treatments, they have to be limited to the most critical units. All the residual errors could be eliminated by using less costly automatic data editing procedures. The main objective of selective editing is actually to limit the most demanding activities of data editing (manual reviewing, re-contact, etc.) to those cases where the expected benefit in terms of costs reduction is highest (Lawrence *et al.*, 2000). A score function (Latouche *et al.*, 1992) is used to rank the observed units, so that observations with the highest score are supposed to contain the most potentially influential errors on the target estimates (in the case of the SAH, the variables' totals). A specific value for the score function (threshold) is set in advance, and the m units with score above the threshold are selected for manual editing, where m depends on the expected estimates accuracy. The latter generally corresponds to the allowed residual error on the estimates computed on the not edited data. Since usually the estimates of interest (e.g. totals) involve several variables, a different score function is computed for each variable (local score) and a unique global score is obtained by suitably combining local scores. The selective editing approach allows to reduce not only the overall cost of interactive editing, but also the over-editing effect (that is the resources spent to manually check non sampling errors having low biasing effect on the target parameters estimates).

Typically, the score functions are based on the comparison of the observed values of the target variable with the corresponding predicted values obtained through some (explicit or implicit) model, taking into account the possible sampling weights. A key issue with this approach is that errors tend to be identified with residuals with respect to the assumed model, so that it is difficult to separate the natural variability of the investigated phenomenon from the extra variability due to the presence of errors in data. Moreover, it is not obvious how to define the threshold determining how many units have to be selected for interactive editing. A recent approach (Di Zio *et al.*, 2013 and 2008) tries to overcome this difficulty by explicitly modelling both true (i.e. not contaminated) data and error mechanism. In particular, in order to capture the intermittent nature of the model, a two-component mixture model is used, where the components are naturally associated with error-free and contaminated data, respectively. In other words, errors are assumed to affect only a subset of data in such a way that each unit in the dataset is corrupted by an error with an (unknown) a priori probability. Based on the appropriate conditional distribution, for each observed value the corresponding predicted "true" value is obtained, and the error component is determined as the difference between the observed and the true variable values. In this way, the number of units to be selected for manual revision can be directly associated to the required accuracy for the target estimates. It has to be underlined that the estimation of contamination models can be performed taking into account an appropriate stratification of the population units, that can be different by that one underlying the estimation domains (reference data partitions at the influential errors identification step). In practice, often the estimation domains correspond to a more detailed data partition with respect to the data stratification adopted at the contamination model estimation stage: this depends on the fact that in order to obtain "robust" and reliable estimates, a suitably large number of sampling units is needed in each strata. The described method is implemented in the R package SeleMix (SELEctive editing via MIXture models) available on the website http://www.R-project.org (Guarnera *et al.*, 2013). This package includes functions for the estimation of the model parameters via EM algorithm, computation of prediction of true values conditional on observed values, prioritization of units for interactive editing according to a user-specified threshold. If the analysis is performed on sample surveys, in order to select the most influential errors SeleMix uses the sampling weights. Missing values in the response contaminated variables are allowed. In this case SeleMix can also be used as a tool for (robust) imputation of incomplete data. The covariates included in the model are supposed to be error-free and not affected by non-response, therefore the efficiency of this approach also depends on the reliability of the available auxiliary information.

4. The selective editing procedure for the SAH

The aim of the selective editing approach implemented for the 2013 SAH survey was the identification of the potentially influential errors affecting a subset of key survey variables on firm surface (*Total Agricultural Surface, Utilized Agricultural Surface, Actually Irrigated Surface*) and livestock (*Total Number of Cattles, Total Number of Equines, Total Number of Cattle "Bufale", Total Number of Sheep, Total Number of Goats, Total Number of Pigs, Total Number of Rabbits*), Production of milk. For surface and livestock variables, auxiliary information from the 6th Census of Agriculture (reference year 2011) is available. However, no census information is available on milk produced by dairy cows, sheep and goats. Out of the 42.723 firms included in the SAH theoretical sample, the selective editing models have been applied to the subset of 38.330 respondents which resulted correctly identified (also in a longitudinal perspective) at the *pre-editing* stage[2]. Based on exploratory data analyses and the direct support of area experts, we defined: the contamination model at regional level, the approach to be adopted in order to predict the "true" values (model-based values vs census variable values), and the threshold on the target estimates accuracy. In particular, the choice of the contamination model for each single target variable as well as the specific auxiliary information to be used have been mainly based on the amount of available observed information and on the data characteristics (e.g., high rates of zero values in variables' distributions).

Before applying the selective editing strategy, some preliminary analysis and editing activities have been performed on the data in order to identify and possibly eliminate the systematic and/or measurement errors affecting the target variables. Different latent-class regression models have been developed for the different variables subject to selective editing (*Total and Utilized*

[2] Responding firms consistent with respect to Census units, e.g. splitted units are properly reconstructed in order to match with the Census generating units.

Agricultural Surface, Livestock, Produced Milk, Total Irrigated Surface), using as auxiliary information, when appropriate, the corresponding items observed at the Census of Agriculture and possible related survey variables. As some of the target variables (i.e., *Total and Utilized Agricultural Surface*) are observed in more than one item in the survey questionnaire, all the available information is simultaneously used in the corresponding estimated models. As mentioned, depending on the considered variables, the auxiliary information from the 2010 Census of Agriculture perform differently in terms of accuracy of predictions: i.e., the census provides good auxiliary information for the agricultural surfaces, on the contrary for variables related to the production of milk no reliable information is available from the census, therefore information from the survey itself has been used in order to exploit existing relations among variables for editing purposes. For each target variable, different stratifications are used at the model estimation and at the influential data identification steps, in order to guarantee the robustness of model estimates in each stratum and the efficient identification of influential errors at the most appropriate publication domains. Furthermore, different thresholds have been set for each target variable to properly tailor the balance between the expected estimates accuracy and the costs for manual revisions.

In Table 1, the number of observations identified as influential by variable and by region, is reported. As an example, 183 observations have been selected as influential for the variable Utilized Agricultural Surface (SAU2) and 129 ones for the variable Total Agricultural Surface (SAT2) (about 0.5% and 0.3% of the sample units, respectively): about 250 agricultural firms will have to be manually checked in this case, as there is an overlap of about 80 units in the two sets of potentially influential observations. In general, for the most part of the considered variables, the results highlight a not uniform distribution of potential influential errors in the Italian Regions: this suggests the need of most accurate preliminary data analyses aiming at identifying potential lacks or systematic sources of errors at the data collection and/or at the data entry stages.

5. Evaluation of the selective editing process

In this section the evaluation of the selective editing process with respect to the SAU2 and SAT2 variables is reported. Tables 2 and 3 show, respectively for SAU2 and SAT2, the number of: collected data (A), data corrected (imputed) through automatic or interactive editing procedures (B), data reported as influential (C) and, among them, corrected data using interactive editing (D), by Italian region. Moreover, Tables 2 and 3 show the following percentages:

- imputation rate (B/A): number of corrected information out of the number of collected data,
- rate of influential errors (C/A): number of data reported as influential out of the number of collected data,
- imputation rate by influential errors (D/B): number of data reported as influential and interactively corrected out of the total number of correct data,
- hit rate (D/C): number of data reported as influential and corrected by means of interactive editing out of the total number of data reported as influential.

Table 2 shows that out of the 44,552 SAU2 observed values in the final dataset, 97.18% is not corrected. Complementarily, the imputation rate is 2.82%, while the percentage of cases reported as 'influential' is 0.41% (183 units). Out of these units, only 20 (hit rate = 10.93%) were classified as errors and corrected. For SAT2 (see Table 3), similarly, the 96.53% of the observations is not subject to any correction. The proportion of units reported as 'influential' is 12.29% (129 cases). Out of these, only 24 (hit rate = 18.60%) were classified as errors and corrected.

Table 1: *Number of influential observations, by Region per and target variable*

Region	SAU2	SAT2	CATTLE	EQUINS	CATTLE "BUFALA"	SHEEP	GOATS	PIGS	RABBITS	COW MILK	"BUFALA" MILK	SHEEP MILK	GOAT MILK	IRR1	IRR2	Total (a)
Piemonte	12	4	9	4	2	17	10	**80**	4	7	0	0	0	0	0	144
Valle D'Aosta	17	12	1	1	0	3	0	0	0	0	0	1	3	5	5	32
Lombardia	13	4	0	5	0	6	0	**68**	5	5	0	1	0	0	0	104
Veneto	5	4	3	5	1	4	11	28	8	2	1	0	0	**240**	**431**	586
Friuli-Venezia Giulia	4	3	8	1	1	3	8	12	2	0	0	3	0	0	**77**	114
Liguria	13	4	5	0	0	2	11	0	0	0	0	1	1	**115**	**90**	164
Emilia-Romagna	3	3	0	1	0	2	8	32	1	2	0	1	0	0	44	94
Toscana	5	9	**44**	9	3	**67**	11	10	4	4	0	**25**	1	0	0	171
Umbria	18	9	19	2	1	7	1	10	3	3	1	1	0	0	0	61
Marche	12	5	18	1	0	30	6	1	5	2	0	3	1	54	50	162
Lazio	10	5	**88**	**18**	8	29	6	5	2	5	3	17	0	0	0	178
Abruzzi	14	13	8	3	0	3	7	8	1	0	0	6	0	1	32	80
Molise	13	17	26	3	3	31	4	11	0	4	0	2	0	39	23	130
Campania	3	2	11	1	16	20	8	8	3	8	4	0	1	0	1	78
Puglia	13	12	11	4	1	29	14	6	2	0	0	7	1	**202**	72	274
Basilicata	9	6	0	6	3	**57**	**38**	8	2	0	0	**32**	3	31	7	171
Calabria	4	4	**69**	2	3	**110**	**96**	21	1	0	1	9	0	0	0	280
Sicilia	5	4	**170**	**24**	2	**58**	**71**	2	3	4	0	**60**	**12**	34	0	406
Sardegna	3	1	3	3	1	0	0	37	1	0	0	1	0	81	0	129
Trentino-Alto Adige-Trento	1	1	0	0	0	4	1	0	0	0	0	0	0	0	0	6
Trentino-Alto Adige-Bolzano	6	7	1	0	0	6	3	2	1	0	0	0	1	1	0	22
Total	183	129	494	93	45	488	314	349	48	46	10	170	24	803	832	3386

(a) The Total does not represent the row sum but the number of distinct farms for which at least one influential value has been identified.

Table 2: *Number of observations, by regions. SAU2 variable*

Region	Total (A)	Total Corrected (B)	Influential (C)	Influential Corrected (D)	B/A (%)	C/A (%)	D/B (%)	D/C (%)
Piemonte	2236	82	12	1	3.67	0.54	1.22	8.33
Vale D'Aosta	230	21	17	4	9.13	7.39	19.05	23.53
Lombardia	2090	96	13	1	4.59	0.62	1.04	7.69
Veneto	2877	39	5	0	1.36	0.17	0.00	0.00
Friuli-Venezia Giulia	1152	66	4	1	5.73	0.35	1.52	25.00
Liguria	649	39	13	2	6.01	2.00	5.13	15.38
Emilia-Romagna	2698	82	3	1	3.04	0.11	1.22	33.33
Toscana	2400	14	5	0	0.58	0.21	0.00	0.00
Umbria	1117	32	18	1	2.86	1.61	3.13	5.56
Marche	1716	91	12	1	5.30	0.70	1.10	8.33
Lazio	3231	116	10	1	3.59	0.31	0.86	10.00
Abruzzi	2342	13	14	0	0.56	0.60	0.00	0.00
Molise	974	26	13	2	2.67	1.33	7.69	15.38
Campania	2847	38	3	0	1.33	0.11	0.00	0.00
Puglia	3081	49	13	1	1.59	0.42	2.04	7.69
Basilicata	1749	73	9	1	4.17	0.51	1.37	11.11
Calabria	4181	49	4	0	1.17	0.10	0.00	0.00
Sicilia	5432	240	5	2	4.42	0.09	0.83	40.00
Sardegna	2218	9	3	0	0.41	0.14	0.00	0.00
Trentino-Alto Adige-Trento	524	52	1	1	9.92	0.19	1.92	100.00
Trentino-Alto Adige-Bolzano	808	29	6	0	3.59	0.74	0.00	0.00
Total	44552	1256	183	20	2.82	0.41	1.59	10.93

Table 3: *Number of observations, by regions. SAT2 variable*

Region	Total (A)	Total Corrected (B)	Influential (C)	Influential Corrected (D)	B/A (%)	C/A (%)	D/B (%)	D/C (%)
Piemonte	2236	82	4	0	3.67	0.18	0.00	0.00
Valle D'Aosta	230	21	12	4	9.13	5.22	19.05	33.33
Lombardia	2090	95	4	1	4.55	0.19	1.05	25.00
Veneto	2877	38	4	0	1.32	0.14	0.00	0.00
Friuli-Venezia Giulia	1152	62	3	0	5.38	0.26	0.00	0.00
Liguria	649	32	4	2	4.93	0.62	6.25	50.00
Emilia-Romagna	2698	91	3	0	3.37	0.11	0.00	0.00
Toscana	2400	24	9	1	1.00	0.38	4.17	11.11
Umbria	1117	50	9	2	4.48	0.81	4.00	22.22
Marche	1716	97	5	1	5.65	0.29	1.03	20.00
Lazio	3231	145	5	1	4.49	0.15	0.69	20.00
Abruzzi	2342	22	13	1	0.94	0.56	4.55	7.69
Molise	974	48	17	5	4.93	1.75	10.42	29.41
Campania	2847	50	2	0	1.76	0.07	0.00	0.00
Puglia	3081	65	12	3	2.11	0.39	4.62	25.00
Basilicata	1749	92	6	2	5.26	0.34	2.17	33.33
Calabria	4181	160	4	0	3.83	0.10	0.00	0.00
Sicilia	5432	270	4	0	4.97	0.07	0.00	0.00
Sardegna	2218	18	1	0	0.81	0.05	0.00	0.00
Trentino-Alto Adige-Trento	524	58	1	0	11.07	0.19	0.00	0.00
Trentino-Alto Adige-Bolzano	808	27	7	1	3.34	0.87	3.70	14.29
Total	44552	1547	129	24	3.47	0.29	1.55	18.60

The differences between SAU2 and SAT2 variables are higher for the total number of corrections, than for the number of corrected influential cases. The hit rate values (10.93% and 18.60% for SAU2 and SAT2, respectively) can be interpreted as a measure of 'efficiency' of the procedure adopted in identifying, among the influential cases, actual errors. The low values of the index may be due to the fact that in the estimated models it was considered as auxiliary variable the information (measured in the census) of three years before the survey, so with low predictive power, and that this information could have quality defects. The imputation rate for influential errors exceeds 10% only in Valle d'Aosta and Molise, probably because of the low number of total cases. In Trento, there is only one reported unit as a possible influential outlier.

As a further element of evaluation, Table 4 shows, respectively for variable SAU2 and SAT2, the relative differences between the estimates calculated on the following sets of data: before the E&I phase (Raw), after the step of interactive revision of the influential errors (Semi final), and at the end of the entire process of E&I (Final). The estimates are computed using sample weights adjusted for non-response. In other words, Table 4 shows the impact on estimates obtained using Raw data of the corrections made on the only influential data and of the total corrections, respectively. The impact is measured on total estimates and, therefore, there could be possible compensations for different sign of the data corrections. Out of the (National) Total estimate, the corrections involve a change of less than one percent of the estimate using raw data.

Table 4: *Relative differences between estimates computed using different data, SAU2 and SAT2 variables*

Region	(Semi final-raw)/Raw (%)	(Final-Raw)/Raw (%)
Total SAU2	0.03	0.98
Total SAT2	-0.04	0.09

To better evaluate the impact of the corrections on the data reported as influential, Table 5 shows the sum and the average of the absolute differences between the data flagged as influential and corrected and the relative raw data in comparison with the same measures of the absolute differences between the corrected data but not reported as influential and the raw data. The corrections on the influential data are larger than those on non-influential data: 1.23 times for SAU2 variable and 2.8 times for the SAT2 variable. This underlines the capacity of the selective editing procedure to identify the most influential errors on the final estimates.

Table 5: *Sum and average of the absolute differences, SAU2 and SAT2 variables*

Variabile	Somma	N	Media	A Media/B Media % C Media/D Media %
A. SAU2 |Influent corrected– Raw|	402342	20	20117	
B. SAU2 |Not Influent corrected – Raw|	20179311	1236	16326	123
C. SAT2 |Influent corrected – Raw|	2104088	24	87670	
D. SAT2 |Not Influent corrected – Raw|	47493823	1523	31184	281

6. Conclusions

The aim of the selective editing approach implemented for the 2013 SAH survey was the identification of the potentially influential errors affecting the estimates of a subset of key survey variables to be subjected to a clerical review. For the 2013 SAH, the set of variables considered for the selective editing procedure includes total firm surfaces and livestock, and the auxiliary information is the same set of variables observed at the 2010 6th Census of Agriculture.

The obtained results differ when dealing with surfaces and livestock. Indeed, the variables relative to the total surface of a firm are more stable over the time and generally grant a relevant number of observations. This allowed to apply the selective editing procedure to quite detailed domains of estimates given by the combination of the variables (Region and OTE). The number of influential units to be subject to clerical checks results to be ‘adequate according to the available resources. As far as the livestock is concerned, observed figures changes easily over time. Consequently, the effectiveness of the 2010 6th Census of Agriculture as a source of auxiliary information resulted lower for livestock variables than for surfaces variables. This has probably led to identify a number of 'influential' cases higher than expected and/or desired for the purpose of containment of the interactive control, despite a careful definition of diversified thresholds for different animal types. Also the information on milk production, naturally depending from livestock numbers, has been affected by this instability. Moreover, the concentration of influential cases in some regions for some variables led to hypothesize the presence of systematic factors on the results. Further experiments are therefore needed in order to check on the one hand the effectiveness of the models and of the covariates used for this type of variables, on the other hand the existence of additional and more updated sources of auxiliary information. The assessment of the effects of selective editing procedure was focused on SAU2 and SAT2 variables. The share of cases reported as influential and actually corresponding to errors proved to be quite low. Nevertheless, the average number of identified errors is significantly higher for the cases reported to be influential than for the overall average of correct observations.

Overall, the selective editing process has produced satisfactory results, but its efficacy was lower than expected probably because of both the nature of the data and the absence of auxiliary information with a suitable quality. In subsequent editions of the survey, the use of alternative auxiliary information (other administrative sources, data from the current survey in a longitudinal perspective) will be evaluated. As far as the selective editing procedure is concerned, both a multivariate strategy for modeling data and the use of different thresholds of the estimates of accuracy on individual domains will be analysed. Finally, the results of the present work, will be used to plan the future survey edition with respect to the various phases of the entire process (for example, data recording) to identify and prevent any systematic error causes on the main variables.

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Assessing the impact of infectious disease outbreaks on agriculture and food security: The case of the Ebola virus disease outbreak in West Africa

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ABSTRACT

Assessing the field level impact of Emerging Infectious Disease outbreaks such as the recentEbola virus disease (EVD) on agriculture and food security is challenging because such epidemics restrict access to farms and households, limiting the traditional means of direct measurements and field surveys. Therefore, a simulation model is developed and used to assess the impact of EVD outbreak on the 2014 agricultural production in Guinea, Liberia and Sierra Leone. Model results show that the impact of of EVD on the 2014 agricultural production was relatively small at the national level. However, it is significant at the sub-national level in affected areas. Furthermore, the impact on economic activities and livelihoods severely affected household food security in the main affected areas.

Keywords: Emerging Infectious Disease outbreak, Ebola, agriculture, simulation model, West Africa.

1. Introduction

Emerging infectious diseases (EIDs) are increasing in frequency, posinga significant threatto global economies and public health (Jones, K et al 2008;Pike, J. et al). Joneset al. (2008) found that EID events aredominated by zoonoses (60.3% of EIDs) with the majority of them (71.8%) originating in wildlife, for example, severe acute respiratory virus and Ebola virus. Infectious diseases account for a quarter to a third of all mortality and the outbreakscan easily cross borders and threaten economic and regional stability, as has been demonstrated in last decadeby HIV/AIDS, 2009 H1N1 influenza, H5N1, and SARS epidemics and pandemics as well as the recent Ebola outbreak (Verikioset al. 2011).

EIDs can be classified in two broad categories based on the nature of the outbreak and the main channel of impact. Estimates of the economic cost of outbreaks of the first category follow the standard “cost of illness” approach that focuses on the opportunity cost of resources consumed or lost as a result of disease. One example of such pandemic is HIV-AIDS, the economic cost of which arises mostly from the high mortality and illness caused by the pandemic. By contrast, outbreaks of the second category cause relatively little illness and death but short-lived and severe economic impact, driven essentially by the behavioral effects of these outbreaks. The last outbreak of Severe Acute Respiratory Syndrome (SARS) in 2003, the 1994 plague outbreak in Surat, India, or the 2014 Ebola outbreak in West Africa , fall in this category(Brahmbhatt, M;&Dutta, A; 2008). The SARS outbreak caused significant disruption and economic loss worldwide, and is estimated to have reduced worldwide GDP by USD 40 billion in 2003 (McKibbin, 2004). Similarly, the overall economic loss associated with the 1994 plague outbreak in Surat, India, were put at over USD 2 billion. According to the World Bank, the last Ebola virus disease (EVD) outbreak in West Africa caused GDP growth to fall drastically to 0.5 percent in Guinea from 4.5 percent expected before the Ebola crisis. Similarly, GDP growth fell by more than half, from 5.9 percent to 2.2 percent in Liberia and from 11.3 percent to 4.0 percent in Sierra Leone. The EVD outbreak caused severe disruptions that affect all economic sectors, notably the agricultural and food sector.Avian influenza outbreaks also cause serious disruptions to various economic sectors but the principal impact has occurred in the poultry sector. HPAI of the H5N1 strain has inflicted severe direct economist costs to affected countries, mostly in terms of losses of poultry due to the disease and control measures such as culling birds, with impacts extending not only to farmers but also to upstream and downstream sectors such as poultry traders, feed mills, breeding farms etc. Vietnam and Thailand lost about 15% of the stock of poultry (Brahmbhatt, 2005). The major affected South-East Asian economies have seen direct costs, in the region of 140 million birds culled and the stated costs of containing the epidemic of approximately USD 10 billion. In addition, trade restrictions led to a 36.8 percent decline in South-East Asian poultry trade (World Bank, 2005; Elci, 2006).

Recent years have seen a renewed interest in the analysis of the economic impact of EIDs. In the case of SARS for example, analyses have focused on the macro-economic impact including on GDPs, trade and Government budget, and most studies have highlighted the impact on sectors such as health, tourism, hotels, airlines, IT, etc(Keogh-Brown, M. R.&Smith, R. D.; 2008).Most analysis of the impact of EIDs on the agricultural sector has focused on describing changes in production and other parameters before and after the outbreak. For example, FAO conducted a number of studies on the impact ofHIV-AIDS on the agricultural sector (FAO, 2003), which found that the main channel of impact has been through loss of labour, which affects planted areas and yields resulting in reduced food production and resulting food insecurity.For example, in Zimbabwe, according to surveys conducted in 1997, agricultural output in communal areas declined by nearly 50% among households affected by AIDS in relation to households not affected by AIDS. A similar approach was used by Yalcin et al (2010) to analyze the impact of the highly pathogenic avian influenza H5N1 outbreak among turkey producers.

In case of an EID outbreak with potential serious impact on the agricultural sector, such as the recent Ebola virus disease (EVD) outbreak in West Africa, there is a need during the epidemic to provide an accurate ex-ante assessment of the impact of the outbreak on agriculture, livelihoods and food security, to support the design of effective emergency relief and rehabilitation programmes to minimize the impact of the outbreak on affected populations. However, assessing the impact of EID outbreaks such as Ebola on agriculture is challenging because the disease restricts access to farms and households, limiting the possibility to conduct direct measurements and carrying out interviews.

The purpose of this article is to outline a methodology for assessing the impact of Ebola on agricultural production. Asimulation model, the Disease Impact on Agriculture – Simulation (DIAS) model was used during the last Ebola outbreak in West Africa to quantify its impact on cereal production in Guinea, Liberia and Sierra-Leone. A limited amount of field survey information, where available, was used to fine tune and improve the model accuracy.

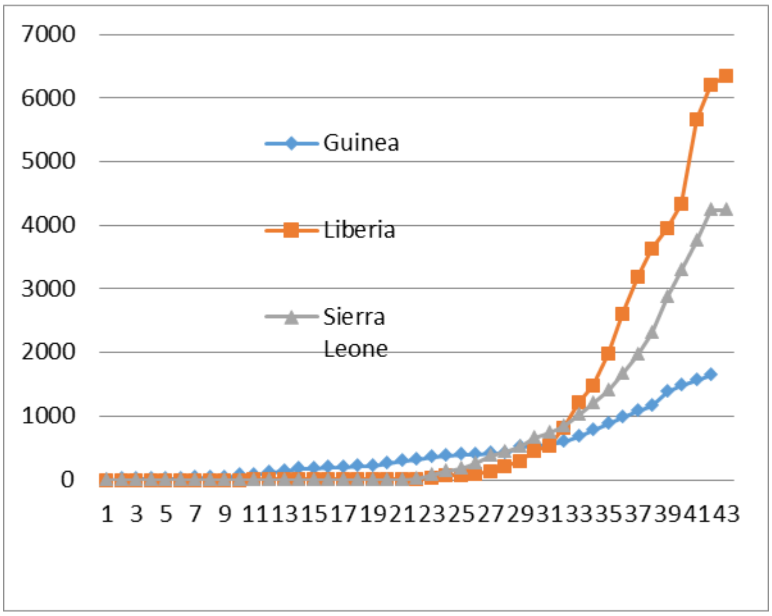
The reminder of paper is organized as follows: section 2sets out the channel of impact of EVD on agricultural production; section 3 outlines the methodology and the data used;section 4 presents and discusses the results. Finally, section 5summarizes the main conclusions.

2. Ebola virus disease (EVD) outbreak and agriculture

As outlined by the World Bank (2014), the impact of the Ebola epidemic on economic well-being operates through two distinct channels. First, there are the direct and indirect financial and human costs of the disease. Second, there are the behavioral effects resulting from peoples' fear of contagion, which leads to a series of disruptive actions and decisions by the population and public actors. These behavioral actions reduce labourforce participation and disrupt several economic sectors including transportation and trade. In the case of recent infectious disease outbreaks such as the SARS epidemic of 2002-2004 and the H1N1 flu epidemic of 2009, behavioral effects have been responsible for as much as 80 or 90 percent of the total economic impact of the epidemic (The World Bank 2014).

The last EVD outbreak in West Africa started in Guinea in December 2013, escalated the fastest in Liberia in early 2014 (see figure 1) and led to a sharp disruption of economic activities. The number of cases in Guinea were high during early part of the outbreak but remained relatively low during later part of the outbreak. In Liberia and Sierra Leone it led to the quarantining of the most affected regions, restrictions of internal population movement, as well as closure of markets. According to the figures from the World Health Organization (WHO), a total of 28 616 confirmed, probable and suspected cases were reported in Guinea, Liberia and Sierra Leone, with 11 310 deaths. The Public Health Emergency of International Concern (PHEIC) related to the outbreak was lifted in March 2016.

Figure1 : Evolution of the EVD crisis: number of cases as of December 2014



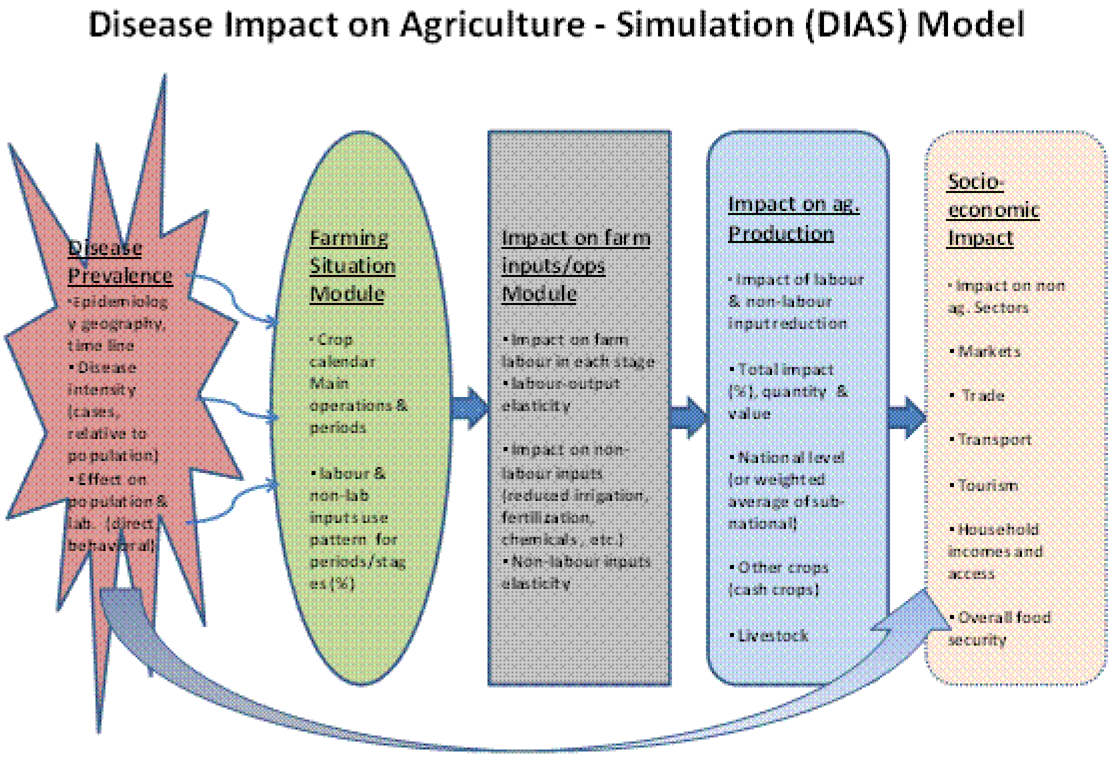
Rice is by far the most significant crop and it is grown on between 80-90 percent of all cereal-cropped area in the three most affected countries; it is virtually the only cereal grown in Liberia. Other food crops include cassava (in all three countries) and maize (in Liberia and Sierra Leone). In addition, the three countries grow cash crops, particularly cacao beans, coffee and rubber, which make up the bulk of their agricultural exports. In general, the EVD epidemic started to spread when crops were being planted and grew during the crop maintenance period, and then expanded rapidly during the critical harvesting period for the staple rice, maize and cassava crops.Farm operations, inputs and then harvestingwere affected in two ways. The main impact was seenthrough reduction in farm labour due mostly to aversion behaviors such as quarantines, border closures, restrictions/ban on people movement, people fleeing infected areas, reluctance to work in usual labour groups, etc. The disrupted/reduced farm labour affected land preparation/planting, crop maintenance/growth (weeding, fencing, application of chemicals, etc.), and harvesting. Secondly, through the labour associated non-labour inputs - reduced use of material inputs such as applied quantities of fertilizer, irrigation, chemicals, etc. Depending on their use and the relative impact these changes affect crop output.

3. Simulating the impact of EVD on crop production: the EVD Disease Impact on Agriculture – Simulation (DIAS) Model.

Quantitatively, the direct impact in terms of the number people infected in relation to the size of the population of the area is extremely small. Much of the impact observed has been of the behavioural type. The development of the DIAS model includes the following steps: (i) converting the relative cases of EVD infection into the impact on farm labour using a logistic function representing the S-Curve, (ii) assigning the labor use pattern and the labour associated non-labor inputs use pattern to each of the three major periods of crop production, (iii) establishingthe elasticity of labour and non-labor inputs and (iv) aggregating the impact of labor and non-labor input changes over different periods of crop production.

The most important component of the methodology is the use of the S-curve to quantify the impact of EVD on farm labour.

Figure 2: Schematic of EVD Impact on Agricultural Production Simulation



3.1. Using a logistic function (S curve) to calculate percentages of impact

Using a logistic function representing the S-Curve, the actual cases per 100 000 were converted to a percentage of population (and thereby farm labour) that may be considered affected. This follows a logic that as the number of cases of infection rise the impact is low at low number of cases but rises rapidly and then flattens out at some point. The formula adapted here is the following[1]:

I = f (X) = S/(1+K^(T+V/2-X)/V))

Where,

I = the percent impact on population (and by extension on labour) for a given value of X.

X = Variable X represents the number of relative cases of Ebola disease, for example per 100 000 of population.

S = Saturation point (maximum potential impact in % of labour disrupted completely, asymptotic limit of the S curve). An arbitrarily chosen value of 1/3 (or 33%) is used here.

[1] Modified from the following presentation of the S-curve:https://akapps.wordpress.com/2011/08/27/simple-s-curve/

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Past studies on HIV infection rates have shown that the saturation points occurred at 39% for Botswana, 33.4 % for Swaziland and 31 % for Lesotho(see Whiteside & Erskine, 2002). A mobile phone survey carried out by the World Bank, with the Liberian Institute of Statistics and Geo-Information Services and the Gallup Organization, in October and November 2014, concluded that " ... 30 percent of respondents indicated that they were no longer working in agriculture compared to the baseline HIES. The majority cited worries about Ebola as the main reason they were not working.".

K = A constant used as a base for the exponential calculations (similar to log to the base 10 or the natural log to base e). It is set equal to 81 as in the original market study. In general, the smaller value of this constant, flatter the s-curve.

T = takeoff point; where on a severity scale of the infections the hyper growth in impact starts. The relative cases of infection at which the curve takes off and rises rapidly. The arbitrarily chosen value of 5 implies that when 500 cases are reported in a nation of 10 million people it will start having a significant general panic and the behavioral impact on population.

V = takeover level; it represents the number of relative cases when almost 90% of the impact is felt, for example at 100 in this case. Thus the steep rise of the curve is experienced between 5 and 100 relative cases.

Labour requirement varies depending on crop development stages. Rice being the predominant crop, the rice crop calendar was used as the main agricultural calendar. To accurately assess the impact of labour shortages at three different crop development stages, the crop calendar that covers about 9 months, was divided into three 3-month periods corresponding to land preparation/planting, growing/maintenance and harvesting in accordance to FAO/GIEWS crop calendar.

Figure 3: FAO/GIEWS average food crop calendar

WFP-compiled WHO data was used to input the cumulative cases. The first cases of EVD were reported in Guinea and Liberia in March 2014 and in Sierra-Leone in May 2014, but Liberia has been the hardest hit country (see figure 1). In Liberia, the incidence was later but steeper, affecting rice growing (labour and other inputs) and harvesting period; In Guinea, cases remained low through growing and harvesting period. Assuming a certain incubation period length of the EVD, the representative cases for each period were taken from the end of that period, i.e. the cumulative number of cases as of the last week in June, September and December for the three periods, respectively. To get the relative impact of the disease, the cases were expressed as per 100,000 people.

3.2. Assigning the labor use pattern to each period of crop production and simulating the impact of labor use reduction

Elasticities are important assumptions that affect simulation results.Hence, the second most critical set of information is about farm input elasticies and input use patterns. Based on relevant literature for various countries of West Africa (Olumbanjo, O and Oyebano, 2005; Kapsos, 2005; Vollrath D, 2009; Olujenyo, 2004), the labor elasticity for rice was set at 0.5 for the three countries.Labour elasticities for maize and cassava were set at 0.47 and 0.3, respectively.

According to Ngeleza et al (2011), the labor use pattern for rice is as follows: 38% of labour is used during land preparation and planting; 38% used during crop growth and 23% in harvesting. Requirement for cassava is typically 28% , 46% and 26% for these respective crop cycle periods. Using these rates of monthly labour use per operation, total labour use per three-month period from April-December was calculated. The labor use pattern for Maize is 59% 35% and 6% respectively.

In addition, the reduction in farm labour would also reduce the use of other non-labour material inputs such as fertilizer, chemicals, irrigation, etc. It is assumed that non-labor inputs such as fertilizer, other chemicals, irrigation etc. are applied during planting and crop growth periodsfor rice and maize. Thus weights of 50:50:0 areselected for the three periods as the pattern of their use during these three periods. Cassava production does not involve much use of these other inputs, hence only labour impact is calculated.

For simplicity the model groups all inputs into two, labor and non-labor. Using the implicit constant unitary elasticity of production such as the one used in the Cobb-Douglas production function, the sum of all input elasticities is assumed to be equal to 1. Given that we already have the labor elasticity value, the non-labor elasticity is simply calculated as one minus the labor elasticity. The elasticity is then applied accordingly to step 6.

Finally the impact of reduction in labour and non-labour, is calculated using their use patter and elasticities and summed across the three periods to get the final impact on crop production.

4. Results

The impact of Ebola was simulated at county or district level for each country and then aggregated at national level. Table 1 shows the aggregated simulation results at country level. Detailed results atcounty or district levels are shown in annex. As expected, rice was the most affected commodity due to its higher labour and inputs requirement. However, the impact on production was not as catastrophic as envisaged at the time of the outbreak. In Liberia, the most severely affected country, rice production is estimated to have declined by 12 percent from the without Ebola scenario (see Table 1). Output dropped by 7 percent and 4 percent in

Sierra Leone and Guinea, respectively. The relatively high level of impact in Liberia as compared to the other two countries affected by EVD, namely Guinea and Sierra Leone, is primarily due to the much higher intensity of the disease transmission. The infections grew rapidly during the crop growth and harvesting periods of the crop cycle. The sub-national level impact is even much higher in the counties hit hard by the disease, such as Lofa and Margibi in Liberia, where losses of paddy crop are estimated in the order of 20 percent and three others, Bomi, Bong, Monte Serrado, above national average. The simulated impact on maize was lower: maize production was estimated to decline by 3 percent and 4 percent in Sierra-Leone and Guinea, respectively.

Similarly, cassava being much less labour and input intensive crop than cereals, the impact on its harvest is estimated to be lower at 5 percent and 1 percent at the national level in Liberia and Guinea, respectively. In Liberia, cassava losses ranged from 1 percent in Grand Gadeh county to over 7 percent in Lofa and Margibi counties. It should be noted, however, that cassava roots can remain under ground and can be harvested as and when needed, hence the reduced harvest this year should not, necessarily be equated with the potential production of the commodity.

Table1: simulation results:

Country	Simulation Model
	Rice
Guinea	-4%
Liberia	-12%
Sierra Leone	-7%
	Maize
Guinea	-3%
Sierra Leone	-4.2%
	Cassava
Guinea	-1%
Liberia	-5%

In parallel to the modelling exercise, FAO and WFP, in collaboration with the Governmentsof Liberia, Guinea and Sierra-Leoneand other partners have carried out field level rapid assessments (RA) including surveys using questionnaires to analyse the impact of the EVD crisis on food production, supply situation and the overall food security. Results from theserapid assessments have largely confirmed the simulation results: For example, results from the Liberian field assessment indicated that rice production would decline by 10-15 percent at national level and up to 25 percent in hardest hit regions. Similarly, field assessments conducted in Guinea estimated a 3.4 percent decline in maize production and a 1 percent drop in maize harvest.

Other economic indicators confirmed that the impact of the EVD outbreak on national food harvest was not catastrophic. For example, price of imported and local food prices remained mostly stable at relatively low levels in all three countries, indicating that supplies were adequate.

The model produces results of with Ebola situation compared to without Ebola situation. These estimates are useful to indicate the extent of potential losses of agricultural production due to the crisis and can serve as a guide for the type of and the areas for response interventions.

5. Conclusions

The analysis presented in this paper suggests that the impact of of EVD on the 2014 agricultural production was moderateat the national level. However,the relatively low level of impact at the national level masks the subnational production and food security impacts. Moreover, beyond its impact on the agriculture and food sector, the EVD has seriously affected all other sectors of the economy with serious implications for household food security in the main affected areas. The mining, manufacturing and service sectors have been the hardest hit. According to the Economic Intelligence Unit (EIU), Sierra Leone's real GDP grew by just 4.6 percent in 2014, compared to 20.9 percent in 2013 before the EVD. In 2015, the effects of the EVD epidemic resulted in a sharp decline of 25 percent. With the EVD largely under control, real GDP is predicted to grow by 1 percent in 2016. Similarly,in Liberia, GDP growth is estimated at 0.9 percent in 2015, owing to the low output for Liberia's main exports and reduced harvests in 2014. A stronger rebound of 4.8 percent growth is forecast in 2016, well above the growth of only 0.5 percent achieved in 2014, but still well below the 6.8 percent forecasted before the Ebola crisis. In all three affected countries, the disruption of food chains due to the closing of markets, road blocks and quarantines, restricted cross border trading, as well as changes in traders' behaviour due to the fear of Ebola, has significantly reduced the income of EVD-affected communities including producers, consumers and traders. Specifically, income generating activities typically led by women, such as small trading, have been hit hard and the ban on bush meat has also deprived many households of an important source of nutrition and income. This has, in turn, negatively impacted on the food security situation of large numbers of people in the affected countries. Overall, about 2.2 million people, including 395 000 in Guinea, 720 000 in Liberia and 1.1 million in Sierra Leone, were estimated to be in need of urgent assistance due to the EVD crisis.

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Annex: - Impact of Ebola on 2014 crop production (tonnes)

Guinea

County	2013 Production	Simulation Model Result	2014 Production estimate
	Rice (Paddy)		
Boke	288,942	-3.1%	279,877
Faranah	306,106	-3.1%	296,602
Kankan	442,933	-3.2%	428,862
Kindia	332,193	-3.4%	320,809
Labe	115,102	0.0%	115,102
Mamou	108,407	-3.1%	105,040
Nzerekore	459,677	-8.4%	421,222
National Production	2,053,359	-3.7%	1,976,754
	Cassava		
Boke	77,841	-0.9%	77,109
Faranah	51,337	-0.9%	50,859
Kankan	347,543	-1.0%	344,235
Kindia	156,322	-1.1%	154,635
Labe	206,686	0.0%	206,686
Mamou	174,517	-0.9%	172,869
Nzerekore	204,678	-2.9%	198,779
National Production	1,218,925	-1.2%	1,204,805
	Maize		
Boke	67,993	-3.1%	65,863
Faranah	78,014	-3.1%	75,617
Kankan	137,284	-3.1%	133,001
Kindia	59,330	-3.3%	57,362
Labe	177,818	0.0%	177,818
Mamou	68,642	-3.1%	66,526
Nzerekore	83,164	-7.3%	77,056
National Production	672,244	-3.5%	648,742

Sierra Leone

	2013 Production	Simulation Model	2014 Production estimate (t)
Rice (Paddy)	1,255,559	-8.0%	1,155,114
Cassava	3,810,418	-3.0%	3,696,105
Maize	40,022	-4.0%	38,421
Sorghum, Millets, other cereals	102,300	-4.0%	98,208

Liberia

County	2012 Production (t)	Simulation Model	2014 Production estimate (t)
		Rice (Paddy)	
Bomi	7,570	-12.0%	6,661
Bong	62,370	-12.8%	54,372
Gbarpolu	16,140	-3.4%	15,588
Grand Bassa	15,500	-7.6%	14,329
Grand Cape Mount	9,140	-4.4%	8,741
Grand Gedeh	13,000	-3.1%	12,601
Grand Kru	10,420	-6.2%	9,771
Lofa	52,660	-20.0%	42,130
Margibi	7,710	-19.6%	6,203
Maryland	9,200	-3.2%	8,906
Monteserrado	7,570	-16.8%	6,295
Nimba	63,080	-7.8%	58,188
River Ghee	5,230	-5.6%	4,939
River Cess	9,100	-5.2%	8,623
Sinoe	8,500	-3.9%	8,165
National Production	297,190	-11.6%	262,570
		Cassava	
Bomi	14,530	-4.9%	13,818
Bong	71,660	-4.7%	68,263
Gbarpolu	14,050	-1.1%	13,901
Grand Bassa	37,080	-3.1%	35,949
Grand Cape Mount	17,910	-1.5%	17,642
Grand Gedeh	20,400	-0.9%	20,210
Grand Kru	28,500	-2.0%	27,920
Lofa	39,300	-7.3%	36,422
Margibi	21,440	-7.3%	19,870
Maryland	32,450	-1.0%	32,133
Monteserrado	21,440	-6.5%	20,056
Nimba	103,860	-3.2%	100,582
River Ghee	20,340	-2.4%	19,862
River Cess	20,500	-2.3%	20,037
Sinoe	21,730	-1.3%	21,438
National Production	485,190	-4.7%	462,584

THEMATIC SET

H46

PLATFORMS FOR DATA DISSEMINATION AND DATA ANALYSIS

Session Organizer
O. Dupriez | The World Bank | Washington, DC | USA

ABSTRACT

The collection of agriculture statistics is an enormous enterprise largely supported by public funds. Access to agricultural survey and census microdata by the research community and other stakeholders is however limited. Opening up access to datasets would lead to increased engagement with stakeholders and in more diverse and innovative use of the data, which would result in better-informed policymaking in adding much value to the data. But disseminating microdata involves solving multiple technical, legal, and ethical challenges.
The past few years have seen the development of multiple standards and tools to preserve, document, catalog, anonymize, disseminate and analyze data in accordance with international best practice. Pushed by a movement towards increased transparency and accountability, government agencies are increasingly taking advantage of these solutions to share microdata. But the agriculture sector lags behind. Session [40] - Platforms for data dissemination and data analysis will focus on identifying and discussing the barriers, solutions and benefits of a more open access to, and use of, microdata from agriculture surveys and censuses.
We welcome submissions on this theme. Specific topics of interest include but are not limited to the following:

- Incentives and disincentives for microdata sharing
  - Costs, risks, and benefits of sharing microdata from agricultural surveys and censuses
  - Evidence of impact of agricultural microdata dissemination
  - Quantification and qualification of the demand for agricultural microdata (uses and users)
  - Respective roles of the public and private, national and international, stakeholders
- Technical solutions
  - Technical requirements for an efficient (shared?) infrastructure to support dissemination of data in the new, global data ecosystem.

LIST OF PAPERS

Dissemination and visualization of agricultural statistics in Malawi: unravelling the potential role of the media community
L. T. Pangapanga | Research for Development | Lilongwe | Malawi
I. P. Pangapanga | Lilongwe University of Agriculture and Natural Resources | Lilongwe | Malawi
DOI: 10.1481/icasVII.2016.h46

Using modern technology to make metadata of agricultural statistics available for data users
M. Waleed | Central Agency for public Mobilization and statistics (CAPMAS) | Cairo | Egypt
DOI: 10.1481/icasVII.2016.h46b

Standards and tools for the dissemination of agriculture microdata: review and improvements
M. Welch | The World Bank | Washington, DC | USA
DOI: 10.1481/icasVII.2016.h46c

DISSEMINATION AND VISUALIZATION OF AGRICULTURAL STATISTICS IN MALAWI: UNRAVELLING THE POTENTIAL ROLE OF THE MEDIA COMMUNITY

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1. ABSTRACT

In this paper, we examined approaches of disseminating agricultural statistics in Malawi. We used a desk research as well as secondary data from the National Statistics Office to review other ways through agricultural data could be disseminated to the public in Malawi. We found that agricultural data is disseminated through two main approaches that is through hard copy publications and website. However, we find that these approaches are traditional and do not meet the needs of the 21 first century era. In current circulations, there is a lack of display of simplified versions of statistical graphs, namely, pie charts, histograms, time-series plots, contour plots, scatterplots, and many more. The focus has largely been on standard line and tabular forms. On the other hand, we find that there are several means through which statistics in agriculture could be made available to the public, namely, radio broadcasting, mobile phones, televisions and social platforms. However, we also identify some interesting limitations that such approaches could have on agricultural data. We lastly combine these approaches with data visualization that could be easily implemented by journalists, spokesperson and other media community. This paper investigate that these other approaches would be easily combine with visual data. In addition, they could likely allow dissemination of technologies that could be transferred to the rural population of which 90% are farmers. In spite of the limitations that the other approaches to data visualization could have in Malawi, this paper suggests that the NSO has to swiftly move into social media as well other formal media dissemination models of agricultural statistics.

Key words: Agricultural statistics, data visualization, technologies, website

1 INTRODUCTION

1. Study Context and the Problem

High quality statistics are essential for designing and targeting policies to reduce hunger, malnutrition, rural poverty, and to promote the sustainable use of natural resources (http://www.fao.org/3/a-mk541e/mk541e03.pdf). Statistics provide the foundation for evidence-based decision-making and play a critical role in measuring and monitoring progress towards national and international development goals and targets. Improving country capacity for the collection, dissemination and analysis of basic agricultural data is essential. A coordinated approach to statistical capacity development, aligned to country strategies and priorities is crucial. In addition, this has to catch up with modern means of disseminating statistics.

In Malawi, agricultural is rural and cornerstone of the economy. It contributes about 40% of total Gross Domestic Product and provides above 80% of employment (NSO, 2016). The agricultural sector could only achieve its intended purpose only if it is disseminated to profit policy making frontier. Besides, technologies in agriculture could be beneficial if its related statistics can be made available to rural farmers. In our rural farmers will require technologies that is able to produce results on the ground.

Dissemination of agricultural statistics is increasing becoming a cost for most developing countries' central statistical systems. In Malawi, the agricultural statistical forum fails to meet annually because of lack of funds (MoA, 2015). This is despite its critical role in sharing successes that are generated in agricultural technology generation and dissemination value chain. Although the Central Statistical Office and the Ministry of Agriculture have attempted to disseminate agricultural data, their focus has been marginal. It has targeted government and donor community members only. The big question has always been do actual farmers know how the technology is fairing when compared within themselves and across communities.

World Bank, through paper written by Boyko and Hill (2009), isolated data as an input into knowledge and wisdom. If this is the case then data generated in Malawi does not result into knowledge and wisdom of farmers that are supposed to implement various technologies on the ground. If farmers are not aware of the modern ways of farming, how are they going to improve on the old tradition methods of farming practices for the better? It should be noted that many national statistical agencies disseminate microdata for public use. Reiter (2004) discussed two data dissemination strategies. The first is remote access computer servers, to which users submit requests for analyses and, in return, receive only the results of statistical analyses, such as estimated model parameters and standard errors. Confidentiality is protected, because the remote server never allows users to see the genuine data. The second is to release synthetic, possibly simulated, data that mimic the relationships in the real data. This approach has low disclosure risks since the released values are not the genuine data. Discussion of these approaches is framed by two key questions. First, to what degree can these approaches protect data confidentiality? Second, how do these approaches affect the accuracy and types of analyses users can undertake? These two questions are relevant for any method of data dissemination, including disclosure limitation techniques used currently by many agencies and organizations. To provide context and motivation, we begin by examining some of these current approaches.

Statistical Offices such as Malawi National Statistical Office cannot be blamed in its totality as disseminationdemands kwachas. However, it can be argued that dissemination of agricultural statistics is becoming costly because of use of traditional approaches to data sharing. On a good note, in the twenty first century, several global organizations such as the World Bank, Food and Agricultural Organization, UN Statistics Division, Organization for Economic Cooperation and Development (OECD) Global Strategy and others are developing technologies that can enhance dissemination of statistics at a very much reduced cost (http://www2.stat.duke.edu/~jerry/Papers/dissemination.pdf). For example, FAO induced development of CountrySTAT with financial support from Bill and Melinda Gate Foundation. It provides decision-makers with a one-stop Centre for easy access to statistics across thematic areas such as production, prices, trade and consumption (FAO, 2013). However, in most countries, the Country STAT is still idle as data is not regularly updated by the Central Statistical Offices and Ministries of Agriculture, Forestry and Energy. In this paper, we explore approaches that can be affordably used to cut costs on disseminating agricultural statistics. This is based on the call by Reiter (2004) that wide access to public use microdata has undeniable societal benefits

2. Research Methodology

In this paper, we first adopt a meta-analysis, which is a desk based research exploration, of tools of disseminating agricultural statistics. In other words, we adopted a revelatory case study approach following Fitzgerald and Fitzgibbon (2014). We basically review publishable articles of the Food and Agricultural Organization publications, World Bank technical papers, and World Class Universities that have provided a thorough discourse on data dissemination approaches. We have reviewed data disseminated through the following reports: Integrated Household Survey and Agricultural Production Estimate Surveys. Second, we combined desk research with secondary household survey data from National Statistical Office (NSO), phone and face to face key interviews with agricultural data custodians and media houses in Malawi. Lastly, this study had a discussion with statisticians at the NSO and Ministry of Agricultural on how the media could be partnered for easy publication of agricultural statistics.

2 DISCUSSIONS

Agricultural Statistics Stakeholder Analysis

Statistical Office and the Ministry of Agriculture are the major custodian of agricultural statistics in Malawi. These providers of agricultural statistics have varied policies on the dissemination of statistics (Kambewe and Banda, 2011). While some tend to be more comprehensive policies, other providers have simple policies. For example, NSO is governed by Statistics Act and detailed dissemination policy macro and microdata (NSO, 2013; 2014). NSO disseminates through two major methods, website and hard copy publications. Only basic tables without a link to micro-data set are disseminated by the Office. The reports are distributed for free to selected stakeholders. This in itself introduce bias and discrimination of who to access data from the data mother body. The following are the publications that the National Statistics Office provides a link on its website or in hard copy report forms (see Table 1):-

Table 1: Data Publications from the National Statistical Office

Publication	Outputs	Mode
Monthly Statistical Bulletin	Prices, agriculture, finance, industrial, production, transport, and external trade	*Report*
Quarterly Statistics	External trade, agriculture, industrial, production, transport, finance and prices	*Report*
Malawi in Figures	Short summary of available statistics	*Report*
Statistical Yearbook	Annual summary of all available statistics covering all economic and social sectors	*Report*
Statistical Data Bank	Databank of statistics for the country (monthly, quarterly and annual series)	*Website*
Malawi Socio-Economic Database	Presentation of Socio-Economic Indicators including agricultural data	*Website*
African Statistics Day	Presentation, Dissemination	*Report*
Agriculture Inputs Subsidy Survey	Recipients of subsidized agricultural inputs and the impact on the economy	*Survey Report*
National Census of Agriculture&Livestock	*Crop production, acreage, yield, livestock and land tenure*	*Report*

Furthermore, the NSO promotes dialogue with data uses through what is termed the National Statistical System. It regularly meet with sectoral officials and with members of the media. In agriculture, the NSO has developed and supported statistical user-producer technical working groups in the areas of agriculture through Agricultural Statistical Forum and Quarterly Agricultural Production Estimate Survey Meetings.

The Department of Climate Change and Meteorological Services considers data it produces as a public good which can be given free of charge. Summarized data can be accessed while access to raw data e.g. daily data is limited and access depends on how it will be used. Data can be sold to profit making organization such as contractors and insurance companies. The pricing is on cost recovery basis. For other organizations, the Director of the Department of Climate Change and Meteorological Services can give a waiver. Data given by the Department cannot be shared with other users.

The Department of Forestry does not have a policy regarding data dissemination. It normally releases its data through annual reports which are submitted to its parent Ministry, the Ministry of Natural Resources and Environment around June every year so that it is in time for the planning of the new government financial year.Agriculture and Fisheries data of the Ministry of Agriculture is for public use although there is no clear policy on that. Various reports (annual and quarterly) are prepared and meetings are held to disseminate the information. Annual meetings for the Ministry are held and progress of the previous year and plans for the following year are disseminated.

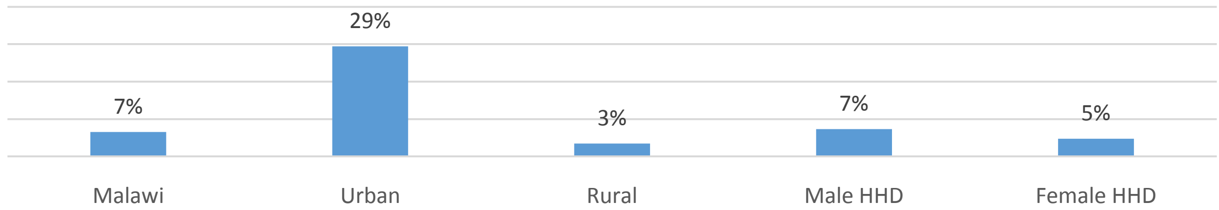
Statistical Database Platforms in Malawi

Malawi has various online databases for disseminating official statistics, namely, MASEDA, CountrySTAT, Data Portal, MDGs; Trade Portal and others. The NSO has a web-page http://www.nso.malawi.net. It is linked to the Malawi Socio-economic database (MASEDA) http://www.maseda.mw/ and the CountrySTAT website http://www.countrystat.org/mwi. The website has latest reports on National Census of Agriculture and Livestock (2006/07), Integrated Household Survey, Micro, Small and Medium Enterprise Report, Welfare Monitoring Surveys (Annual), latest statistical flashes (food crop prices) and Statistical Bulletins.

As regards to the data storage, most raw data is stored in SPSS or Stata format. Recent data is now being archived through the International Household Survey Network toolkit like the National Census of Agriculture and Livestock and the Population and Housing Census data sets. It can indicated that only 7% of

Malawians have access to internet (NSO, 2015) which means that the internet is only accessed by few individuals that are likely to be non-farming households. As shown by figure 1 below, only in the urban area are households able to access internet.

Figure 1-Proportion of household with access to internet in Malawi



The Ministry of Agriculture and Food Security also has a website, http://www.moafsmw.org/. This website is linked to the National Statistical Office website and a number of other government websites. The site has data on livestock census, farmers clubs, fertilizer consumption, fish statistics, rainfall, tobacco sales, farm gate price data and crop production data. However, the data on the website has not been updated in recent years. The Ministry disseminates its statistics through meetings, bulletins, leaflets and E-mail. The main products from the Ministry of Agriculture & Food Security are the Annual Agriculture Production Estimates which are disseminated at various for a (see Table 2).

Table 2-Types of disseminating agricultural statistics in Malawi

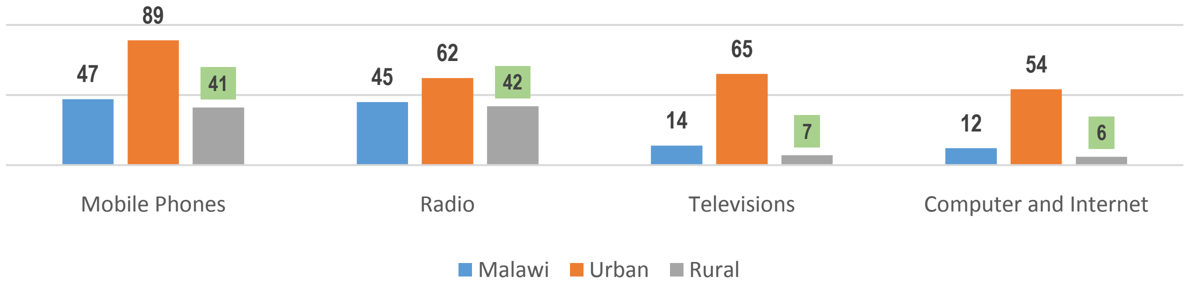
Data Type	*Data Dissemination Methods*
Crop estimates (Crop production, acreage, yield)	Publication
Tobacco Statistics	Annual reports, media and press releases and Website: www.tccmw.com/
Sugar Statistics	Press Release and Annual Reports
Smallholder Coffee Statistics	Annual Reports
ADMARC Purchases	Annual Reports
Livestock Census	Annual Reports
Horticultural Commodity Prices	Biweekly E-mail reports and through the Annual Agricultural Statistical Bulletin
Retail prices	Biweekly E-mail reports and through the Annual Agricultural Statistical Bulletin
Farm gate prices	Biweekly E-mail reports and through the Annual Agricultural Statistical Bulletin
Fishery statistics	Annual Agricultural Statistical Bulleting
Consumer Price Index	Stat flashes, Press Releases and Monthly, Quarterly and Annual Report
Trees planted	Annual Reports
Wood removals	Annual Reports
Daily weather forecasts	E-mail, on the web and the media
Malawi 10=day Rainfall and Agromet Bulletin	E-mail, on the web and the media
Seasonal Forecasts	E-mail, on the web and the media

National Statistical Office (2015) reported that above half of household in Malawi cannot afford internet services and 31% of households are reported that they do not know how to use internet. This implies that use of website in Malawi is challenged by barriers such as affordability, availability as well as technological know-how.Nevertheless, about 77% of individuals in Malawi are able to access social platforms such as Facebook and WhatsApp that do not require heavy tech-know (MACRA, 2016).

Data Visualization

Organizations of all types and sizes generate data each minute, hour and day. Everyone from decision makers to call center workers and employees on production lines hopes to learn things from collected data that can help them make better decisions, take smarter actions and operate more efficiently. Regardless of how much data you have, one of the best ways to discern important relationships is through advanced analysis and high-performance data visualization. If sophisticated analyses can be performed quickly, even immediately, and results presented in ways that showcase patterns and allow querying and exploration, people across all levels in organizations can make faster and more effective decisions.

Figure 2-Proportion Distribution of Households' Access of ICT equipments in Malawi



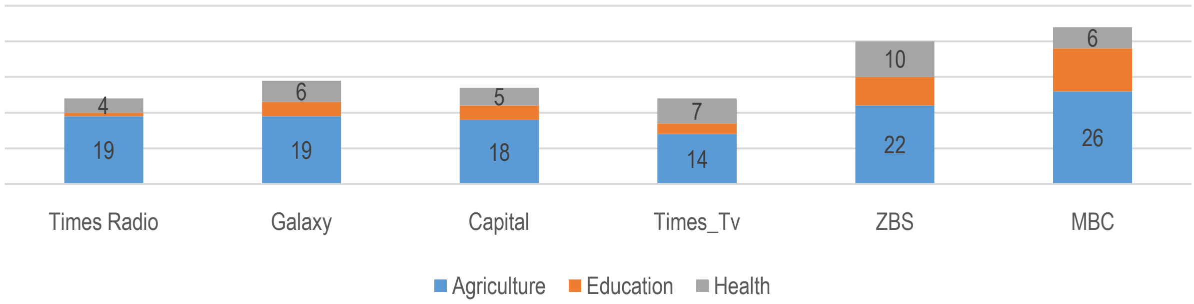
In today's on-the-go society, you may also need to make the results available quickly via mobile devices, and provide users with the ability to easily explore data on their own in real time (SAS, 2014; See Figure 2).

The Media Community

In collaboration with Malawi's National Statistical Office, media personnel, spokespersons from the national statistical system line ministries and sectoral statisticians from various Ministries were brought together to participate in the workshop titled 'Communicating Data through Visualization'. Some of the Ministries that were invited included Agriculture, Trade and Industry, Environmental Affairs, Energy, Mining, Forestry and Fisheries. The workshop aimed at promoting statistical literacy, ensure statistical materials target the right audience, foster networking amongst journalists and government spokespersons and ensure citizens understand better on the statistical information. Some participants highlighted how the workshop de-mystified data for them and taught them how to use official data sources and present information in a visual way.

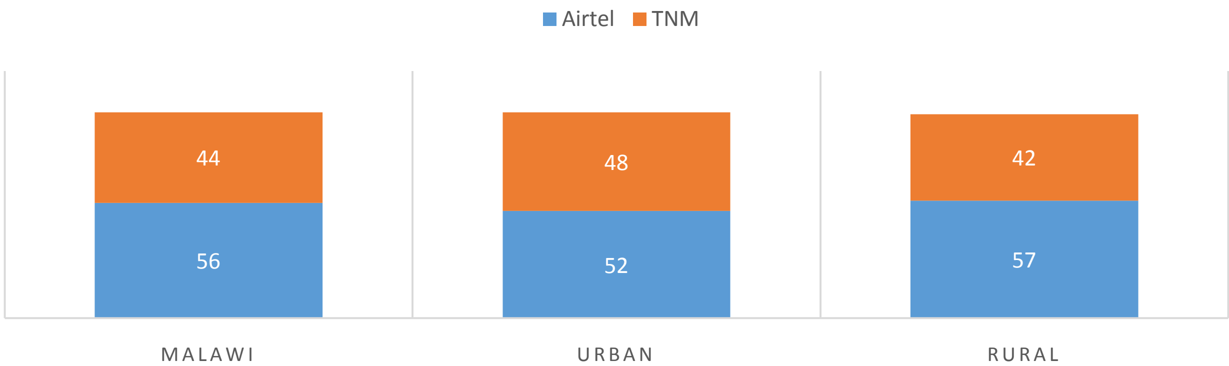
In terms of coverage of issues by the media, it is noted that out of main thematic areas of government, agriculture top the airtime given to broadcasting. This is a space that the Malawi statistical System can take in disseminating agricultural data and technology transfer. Figure 3 depicts issues that are broadcasted by Radio Stations in Malawi.

Figure 3-Issue based programmme by Radio stations



In terms of mobile service provider, we only find two providers that is Airtel and TNM (see Figure 4). This means dissemination of data can be channeled through any of these to households as well as individuals. MACRA (2015) found that about half of the population that owns mobile phones use dual sim which means they have access to both Airtel and TNM line. The growing popularity and global reach of Social Media like Facebook and Twitter presents an interesting new data source for social and economic research. Social Media and related methods and technologies, for example crowd sourcing and social collaboration, can also serve as a new data collection approach (Jug, 2014)[1].

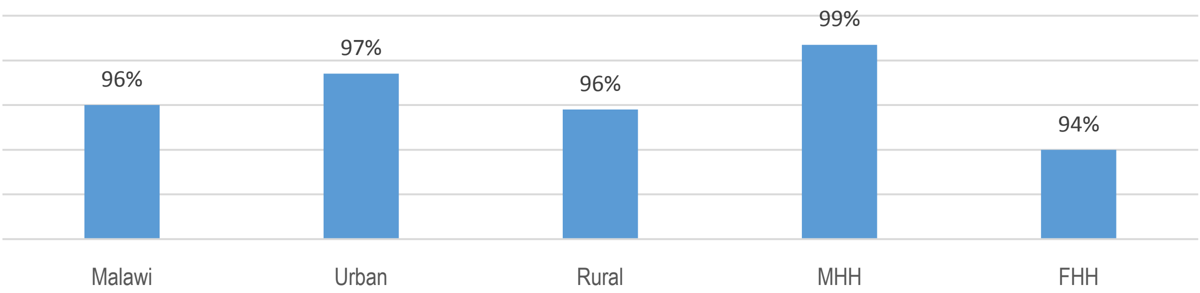
Figure 4-Proportion Of Individuals By Phone Service Providers



It is indeed imperative for the Malawi Central Statistical System to train the media community because of its coverage with the public. For example, Figure 5 shows that above 40% of the population in Malawi, urban and rural areas have a radio. This can imply that households listen to news that can be broadcasted on the radio. Assuming radio stations broadcast messages about agricultural technologies, almost 90% of the population in urban and rural areaslisten to radio programmes (NSO, 2015).

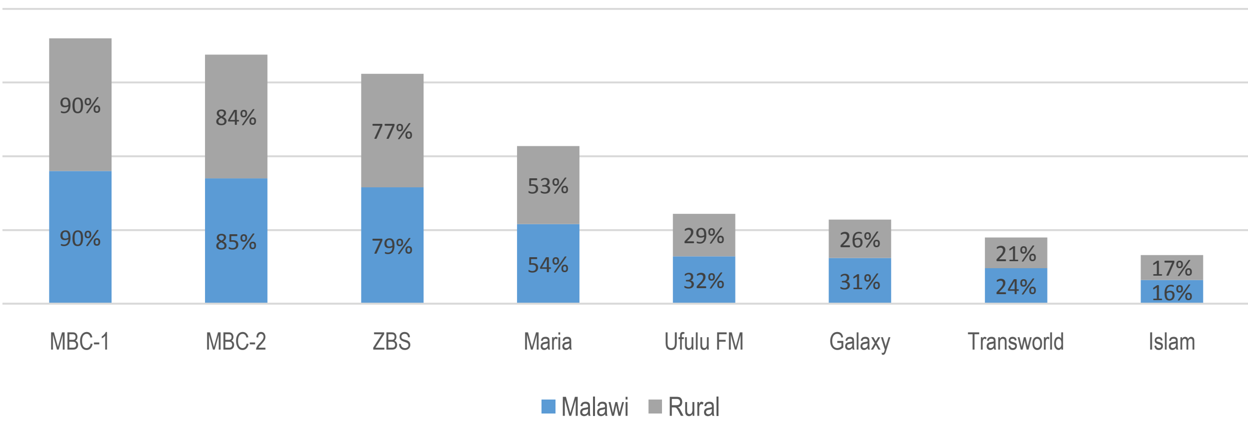
[1]Jug M. (2014). Information revolution: from data to policy action in low income countries: how can innovation help? PARIS21. France.

Figure 5-Proportion of households that listen to radio



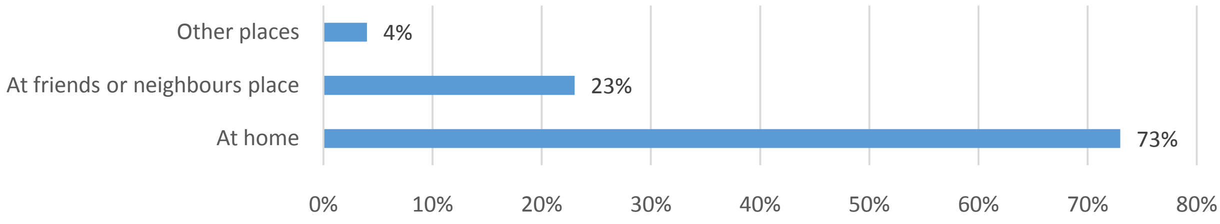
This is also vindicated by radio stations that reach out to households with new agricultural technologies. Nevertheless, among radio stations, Malawi Broadcasting Corporations (MBC) Radio 1 and 2 reach to most households in Malawi than other radio stations (see Figure 6).

Figure 6-Proportion of households that are reached by national radio stations



We however observed the multiplier effects that are generated when having or listening to the radio stations. Figure 7 shows that 73% of households listen from radio at home. This can be implied that about 4.6 people (NSO, 2008) at household level benefit from a single radio broadcasting. What is very interesting is that almost one in four households in Malawi listen from radio at neighbors or friend place. This also increases the multiplier effects from 4.6 people within a household to more than 9 individuals among households that may likely be reached out by national radio stations.

Figure 7-Proportion of households' multiplier Effects due to listerning to radio with others



In terms of newspaper, in Malawi, we have only two major Prints, namely, National Newspapers and Blantyre Daily Times. These newspaper circulate about 36000 prints in a day. They reach out to about 262000 households in a week that is on accumulative basis (see Table 3). However, most newspaper, do not include modern forms of statistical graphs, namely, pie charts, histograms, time-series plots, contour plots, scatterplots, and many more. And these could display an array of economic, social, medical, and physical data (Friendly, 2005). The focus has largely been on standard line, bar, and tabular forms over other types of data visualizations (Strecker, 2012)[2].

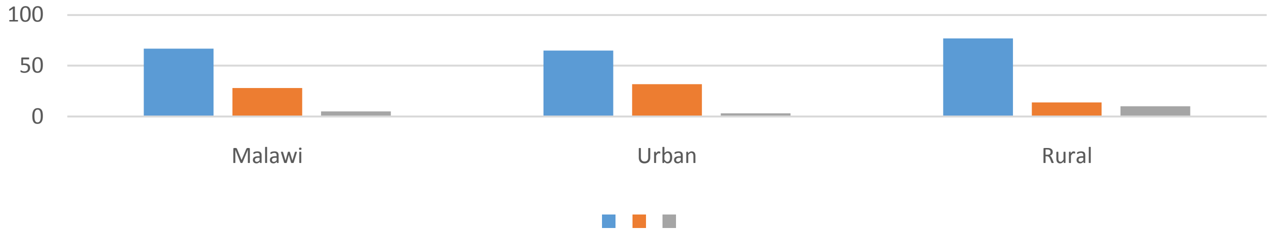
Table 3-Circulations by National and Daily Times newspapers in Malawi

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
National Newspaper	16,000	16,000.00	16,000.00	16,000.00	16,000.00	25,000.00	12,000.00
Daily Times Newspaper	20,000	20,000.00	20,000.00	20,000.00	20,000.00	30,000.00	15,000.00
Total Circulation	36,000	36,000.00	36,000.00	36,000.00	36,000.00	55,000.00	27,000.00
Households Reached	36,000	36,000.00	36,000.00	36,000.00	36,000.00	55,000.00	27,000.00
Individuals Reached	180,000.00	180,000.00	180,000.00	180,000.00	180,000.00	275,000.00	135,000.00

Figure 8 shows households that subscribe to pay tv by location. It can be observed that 67% of households in Malawi subscribe with DSTv while only 5% subscribe with Zuku tv. In rural areas, we find a higher proportion of households subscribing to DSTv while only 10% subscribe to Zuku Tv. This may imply that dissemination of agricultural statistics through Televisions should be able to target pay tv that most households subscribed to.

[2]Strecker J. (2012). Data Visualization in Review: Summary. IDRC

Figure 8-Proportion of households with access to Televisions that subscribe to pay Tv by location



3 LIMITATION

Strecker (2012) highlighted that data visualizations in practice in most designs remain generally clear, but are generic. She stressed that there appears to be a lack of understanding about how to tailor design choices to ensure that visualizations are communicating a more focused and compelling message. In other words, most data visualization are generally at a novice level. More attention should be paid to the following three areas to help improve the effectiveness of the data visualizations currently being created:

- Document consistency: coherent color schemes and chart graphics should be selected and remain through the entire document.
- Titles and decks: supporting text should be used to draw attention to the main message or take-away of the visualization.
- Design choices: colours, positioning, and size should to be carefully incorporated into designs to help draw the reader's attention to the most important data points.

Refinements in these three areas would significantly strengthen the data visualizationsand would help improve their ability to communicate effectively. For example, most participants at the training organized by NSO spotted that they had a limited understanding of data visualization principles, but demonstrated strong enthusiasm for its potential and a willingness to learn and further engage with these tools. Therefore, they requested further knowledge and skills development around how to strategically use data visualizations (Strecker, 2012).

Brescian and Eppler (2008) results of field studies confirm and substantiate most of the concepts already collected from the literature. They have also surfaced a few new relevant issues on limitation of visualization, such as:

- the potentially misleading perception of reliability of a visualization (visualizations may appear more convincing and sound than they really are),
- the (multiple) implicit meanings inherent in visualizations (leading to ambiguous interpretations),
- the high prerequisites for diagram interpretation (a visualization's efficacy depends on the user's previous experience and visual literacy).

- The cause of a visualization disadvantage can be twofold: the designer(s) or the user(s) (that is, their interpretation) (Tufte, 1986). The designer can intentionally or unintentionally introduce mistakes or drawbacks in a visualization.
- Previous studies have demonstrated that visualization is costly to produce in terms of time and other economic resources (money, equipment, know-how, etc.). In this context, various authors emphasize the need for quantifiable measures of the quality of a visualization in order to determine whether it isfit for use (van Vijk 2006).
- The interpretation of a visual form can depend on the familiarity of the observer and on his or her previous experience with it.
- Visualization is actually one of the biggest barriers to insight because it places the burden of discovery on the user, hence any tool that places burden on the analyst is a game-stopper.
- Data visualization is defined as the study of the visual representation of data, meaning information that has been abstracted in some schematic form, including attributes or variables for the units of information. "Humans are better equipped to consume visual data than text.
- Given today's explosion of big data, Statistical Offices need more advanced methods for leveraging data methods that don't rely solely on tribal knowledge, personal experience or best guesses.

4 CONCLUSION AND POLICY RECOMMENDATIONS

In this paper, we examined approaches of disseminating agricultural statistics in Malawi. We used a desk research as well as secondary data from the National Statistics Office to review other ways through agricultural data could be disseminated to the public in Malawi. We found that agricultural data is disseminated through two main approaches that is through hard copy publications and website. However, we find that these approaches are traditional and do not meet the needs of the 21 first century era. On the other hand, we find that there are several means through which statistics in agriculture could be made available to the public, namely, radio broadcasting, mobile phones, televisions and social platforms. However, we also identify some interesting limitations that such approaches could have on agricultural data. We lastly combine these approaches with data visualization that could be easily implemented by journalists, spokespersons and other media community. In current circulations, there is a lack of display of simplified versions of statistical graphs, namely, pie charts, histograms, time-series plots, contour plots, scatterplots, and many more. The focus has largely been on standard lineand tabular forms over other types of data visualizations. This paper notes that other approaches would be easily combine with visual data. In addition, they could likely allow dissemination of technologies that could be transferred to the rural population of which 90% are farmers. In spite of the limitations that the other approaches to data visualization could have, this paper suggests that the NSO has to swiftly move into social media as well other formal media dissemination models of agricultural statistics.

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Using Modern Technology to Make Metadata of Agricultural Statistics Available for Data Users

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ABSTRACT

Egypt's agriculture sector remains one of the most productive in the world, despite the small percentage of arable land, irregular and insufficient water supplies and problems with waterlogged and highly sainted soil. Although farmers do not have to pay for water used in irrigation, government drainage efforts have proved insufficient to counter problems in the sector's performance.

so Reliable and timely information about agriculture statistics such as crop area, crop production and land use is great importance to planners and policy makers for efficient agricultural development and for taking decisions on procurement, storage, public distribution, export, import and many other related issues.

Based on the above prospective this paper will discuss types of users for agricultural statistics , the experiences of CAPMAS (National statistics office in Egypt) in documentation Metadata of annual Bulletin of crop areas and plant production (ABCAPP) using Micro data Management Toolkit and disseminate it using National Data Archive (NADA) and the benefits which returns on users.

Keywords: Micro data Management Toolkit; National Data Archive (NADA); Dissemination; Crop areas; Plant production.

1- Importance of agriculture in Egypt

We can summarize importance of agriculture in Egypt in the following points:

1.1 Agriculture is considered a source of livelihood for a large proportion of people and food security.

1.2 In Egypt as most developing countries Agriculture is still a large proportion of GDP.

1.3 There are large numbers of households in Egypt involved in agricultural activities.

1.4 Most farms are small and performance depends on decisions taken by millions of farmers unlike industrial sector.

1.5 Agricultural production is unpredictable because of its heavy reliance on weather, particularly rain.

1.6 Food shortages may lead to political unrest.

1.7 **Agriculture in Egypt is different from other sectors for these reasons:**

1.7.1 Nature of agricultural production is different due to (Seasonality, Geographic spread, Risks and uncertainty: climate change, market forces, Source of technical change (depend on research by Government agencies).

1.7.2 Farm households both as producers and consumers.

1.7.3 There are intrinsic linkages with other rural economic activities such as agro-forestry, fisheries at the household level which are difficult to segregate. Studying or collect data on them together makes sense.

2- TYPES of USERS for AGRICULTURAL STATISTICS

The Official statistics are intended for a wide range of users including governments (central and local), research institutions, professional statisticians, journalists and the media, businesses, educational institutions and the general public. There are three types of users for agricultural statistics: those with a general interest, business interest or research interest (universities, consultants and government agencies). Each of these user groups has different needs for agricultural statistical information.

2.1 Users with a general interest

Users with a general interest include the media, schools and the general public. They use agricultural statistics in order to be informed on a particular topic such as "Crop statistics, Livestock numbers, Holder's legal status and ownership form ...etc ", to observe trends within the society of a local area, country, and region of the world.

2.2 Users with a business interest

Users with a business interest include decision makers and users with a particular interest for which they want more detailed information. For them, agricultural statistics are an important reference, providing information on the phenomena or circumstances their own work is focusing on. For instance, those users will take some agricultural statistics into consideration before launching a product which depended on agriculture, or deciding on a specific policy or on a marketing strategy. As with the general interest users, this group does not usually have a good understanding of statistical methodologies, but they need more detailed information than the general users." Annual and permanent crops: Sown areas, harvested areas, production, yield'.

2.3 Users with a research interest

Users with a research interest are universities, consultants and government agencies. They generally understand something about statistical methodology and want to dig deeper into the facts and the statistical observations; they have an analytical purpose in inventing or explaining interrelations of causes and effects of different phenomena. In this field, official statistics are also used to assess a government's policies such as:

2.3.1 The eradication of hunger, food insecurity and malnutrition;
2.3.2 The sustainable management and utilization of natural resources (land, water, air, climate and genetic resources) Reduce Rural Poverty.
2.3.3 Enable inclusive and efficient agricultural and food systems.
2.3.4 Increase resilience of livelihoods to threats and crises.

3- Documentation Metadata of annual Bulletin of crop areas and plant production(ABCAPP) using Micro data Management Toolkit and disseminate it by using National Data Archive (NADA).

3.1 Definition Meta data

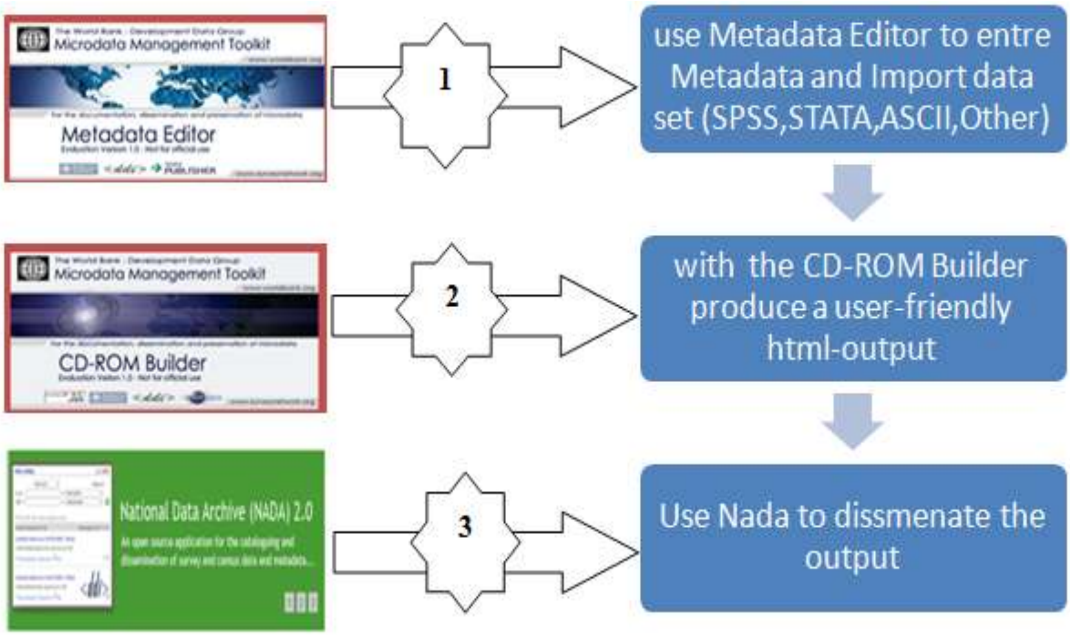
A very simple definition of metadata is that it is any information that helps users find, understand and use data and information. It is also referred to as documentation. Metadata helps us judge the quality of a survey and whether it meets their needs. It is also important for long term preservation.
The metadata should explain what was measured and how it was measured.

3.2 steps of using Toolkit in Documentation Metadata for annual Bulletin of crop areas and plant production (ABCAPP) 2012/2013

3.2.1 Use Metadata Editor to Document survey data in accordance with international standards (DDI-DCMI).
3.2.2 Use CD-Rom Builder to Generates user-friendly outputs, such as CDs, websites, for dissemination and archiving.
3.2.3 Use National Data Archive (NADA) For viewing metadata in website.

The following Figure summarized steps of using Toolkit :

***Figure 1 : Steps of Using Toolkit in Documentation Metadata** for (ABCAPP)*



3.3 Using NADA in Dissemination metadata for The annual Bulletin of crop areas and plant production 2012\2013

NADA is an open source microdata cataloging system, complaint with the Data Documentation Initiative (DDI) and Dublin Core's metadata Initiative (DCMI). It serves as a portal for researchers to browse, search, compare, apply for access, and download relevant census or survey datasets, questionnaires, reports and other information.

The NADA is designed to facilitate the process of releasing micro data to the user community, and support the analysis of this data by the provision of standardized information about the data (metadata). Proper micro data management utilizing the NADA software can have the following advantages for data producers:

3.3.1 Increased quality and diversity of research.
3.3.2 Improved reliability and relevance of data.
3.3.3 Reduced duplication of data collection activities.
3.3.4 Improved visibility of survey institutions as their data becomes more frequently.
3.3.5 Increased donor and public confidence in the survey data producers.
3.3.6 Improved publishing and dissemination efficiency of for data producers.
3.3.7 More efficient access to survey information such as reports, tables, and micro data.

The national statistical office in Egypt used NADA for Dissemination metadata for Agriculture surveys. The following figure shows that Metadata for the annual Bulletin of crop areas and plant production 2012\2013 in the website of CAPMAS.

Figure 2 : Data Catalog for the Bulletin of crop areas and plant production

For more details visit website of CAPMAS:
http://www.capmas.gov.eg/Pages/ShowPDF.aspx?page_id=http://www.censusinfo.capmas.gov.eg/Metadata-ar-v4.2/index.php/catalog/

3.4 Metadata for *the annual Bulletin of crop areas and plant production* (ABCAPP)

The following point some examples about metadata for (ABCAPP) from website of CAPMAS:

3.4.1 Objective

Provides users with indicators about (Holding location, Holder's legal status and ownership form, Data on the holder and composition of his/her household, Land tenure and land use (including areas under major temporary crops),Livestock numbers, Main purpose of production, Ownership and use of agricultural machinery, Land structure, Crop statistics ,Annual and permanent crops: Sown areas, harvested areas, production, yield.

3.4.2 Period of Data Collection :

Agricultural year beginning from the first of November and ends in October next year.

3.4.3 Data Sources

3.4.3.1 Ministry of agriculture

3.4.3.2 Central Administration of Agricultural Economics.

3.4.3.3 Research Institute for Lands, Soil , Water

3.4.3.4 Agriculture Departments in the Governorates.

3.4.3.5 website of Euro stat http://epp.eurostat.ec.europ.eu
EU POPA-Eurostat-Agriculture and Fishery

3.4.4 Methods of data collection

3.4.4.1 Interview

3.4.4.2 E-mail.

3.4.5 Indicators about crop areas and plant production

3.4.5.1 The total cropped area reached 15.48 million feddan in 2012/2013 versus 15.57 million feddan in the previous year, an decrease of 5.0 %.

3.4.5.2 The total cultivated area reached 8.94 million feddan in 2012/2013 versus 8.80 million feddan in the previous year an increase of 1.6 %.

3.4.5.3 The total area of wheat reached 3.38 million feddan in 2012/2013 versus 3.16 million feddan in the previous year an increase 6.9%and amount of wheat crop production reached 9.46 million tons in 2012/2013, versus 8.80 million tons in the previous year, an increase of 7.6%.

3.4.5.4 The total area of rice reached 1.42 million feddan in 2012/2013 versus1.48 million feddan in the previous year an decrease 3.7%. and amount of rice crop production reached 5.72 million tons in 2012/2013 versus 5.91 million tons in the previous year, an decrease of 3.2 %.

4- CONCULSION

Using modern Technology to Make Metadata of Agricultural Statistics Available for Users by NSO is very important, because metadata helps them to:

4.1 Find the data they are interested in. Without names, abstracts, keywords, and other important metadata element it might be difficult for a researcher to locate specific datasets and variables. Any cataloguing and resource location system—whether manual or digital—is based on metadata.

4.2 Understand what the data are measuring and how the data have been created. Without proper descriptions of the survey design and the methods used when collecting and processing the data, the risk is high that the user will misunderstand and even misuse them.

4.3 Assess the quality of the data. To know whether data are useful for a research project, researchers need information about the data collection standards, as well as any deviations from the planned standards.

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Standards and tools for the dissemination of agriculture microdata: review and improvements

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ABSTRACT

Large public and donor investment has led to an increase in the collection of microdata from surveys, census and administrative data. Preservation, discovery and access to these data are uneven and differ greatly by country and type of data. Extensive work by governments and the international community, through networks such as the International Household Survey Network (IHSN) and the Paris21 Accelerated Data Program (ADP), have provided the standards, guidelines and tools that have made it possible for many countries to preserve and disseminate microdata. One area, which is lagging, is in access to agriculture microdata. Agriculture microdata often possess both the characteristics of a household survey as well as an establishment survey, which can make the safe release of the data challenging. The paper discusses the tools developed by the International Household Network (IHSN) and the World Bank for microdata dissemination and includes recommendations on metadata standards as well as a discussion on guidelines and tools available for statistical disclosure control. Standards used for the documentation, preservation and dissemination of a typical household survey may not fit all types of data needed for the generation of agriculture statistics. The paper makes suggestions as to how the standards and tools could be improved to better suite agriculture surveys and in addition, non-survey sources of data for agriculture statistics.

Keywords: Metadata Standards, Disclosure Control, Dissemination, Tools

1. Introduction

There is a global movement towards more open access to data. Large public and donor investment has led to an increase in the collection of microdata from surveys, census and administrative sources. Many agencies provide access to aggregate, tabular or time series data. The preservation, discovery and access to the microdata underlying these sources are uneven and differ greatly by country and type of data. The release of the underlying microdata is important as it allows researchers and policymakers to replicate officially published results, provide feedback for improvement of future surveys, generate new insights into issues, avoid duplication of surveys and provide greater returns to the investment in the survey process.

Extensive work by governments and the international community, through networks such as the International Household Survey Network (IHSN), coordinated by the World Bank, and the Partnership in Statistics for Development of Statistics in the 21st Century (Paris21) have provided standards, guidelines and tools that have made it possible for many countries to preserve and disseminate microdata. These programs have resulted in the documentation of thousands of surveys by countries and agencies across the world. While these programs have ensured substantial improvements in the preservation of data and dissemination of good quality metadata, many agencies are still reluctant to allow access to the microdata. This is particularly true of agriculture microdata. The Global Strategy to improve Agricultural and Rural Statistics (2010) identifies six common areas where agriculture statistics in developing countries face problems. The last two are of particular interest in the context of this paper.

- Limited staff and capacity of the units that are responsible for collection, compilation, analysis, and dissemination of agricultural statistics.
- Lack of adequate technical tools, statistical methodology, and survey framework to support data-production efforts.
- Insufficient funding allocated for agricultural statistics from development partners and national budgets.
- Lack of institutional coordination, which results in the lack of harmonized and integrated data sources.
- Lack of capacity to analyze data in a policy perspective, which results in a significant waste of resources, as large amounts of raw data are not properly used.
- Difficulty for data users in accessing existing data with no metadata or indication of quality.

The Global Strategy acknowledges that building and maintaining technical capacity is a difficult task and requires a long-term plan. One of the recommendations includes that capacity building should include support to the dissemination of results. This could be extended to, or more specifically state, that capacity building to support microdata dissemination should be built. One of the key benefits of dissemination of the microdata is that it widens the pool of experts immediately who can analyze the data to gain the best and timeliest insights possible. It is not possible for the staff of statistical offices to respond to all analysis requests. Releasing the microdata frees up capacity for core activities by allowing users of the data to generate their own analysis.

In order to ensure that the released microdata are properly used they should be released with detailed metadata, which describes the full survey process, the data and any assessments of quality.

The following sections discuss the tools developed by the World Bank\IHSN to help countries and agencies disseminate microdata and discusses, and advocates for, the use of an international standard for the documentation and creation of metadata for survey data called the Data Documentation Initiative (DDI).

2. A Standard for Microdata Documentation

There are a number of reasons commonly cited for why the creation and agreement on standards has benefits. These include allowing the interoperability of systems, lowering the cost for developing tools, improving quality. The most commonly used standard for the description and documentation of survey data is the Data Documentation Initiative (DDI). The DDI had its origins some 20 years ago at the University of Michigan and is now an international standard developed by a large community of practice. The standard is used by most social science archives around the world as well as by a large number of international and country agencies that collect and disseminate survey data.

The DDI standard provides a structured checklist of what needs to be documented to fully understand the entire survey lifecycle, the microdata and its quality.[1] The comprehensive and structured nature of a survey documented according to the DDI standard helps agencies preserve data and makes it easier for users to understand what the data are measuring and how the data were created.

The DDI is comprised of two standards. The DDI Lifecyle and the DDI Codebook.[2] The Lifecycle accommodates the advanced documentation of the survey lifecycle from the conceptualisation of the survey through to analysis. The complexity of the DDI Lifecyle has meant that its uptake has been limited to only a few advanced archives and agencies. This led the World Bank\IHSN to champion an effort to simplify the standard. The DDI Codebook is based on feedback coming mostly from developing countries and as a result, the DDI Codebook is a more bottom-up standard.

The relative ease with which the DDI Codebook can be understood made it possible for the World Bank and IHSN to easily develop tools and guidelines for preservation and documentation of surveys. As a result, the standard is now being implemented in 130 national agencies in 88 countries, and 18 international or other organizations. National Statistics Offices concerned about preservation of their data and institutional memory combined with the World Bank\IHSN have documented over 5000 surveys using the DDI standard.

The standard is suitable for the documentation of any type of survey or census data and as such is suitable, and has been widely used, for the documentation of agriculture surveys and agriculture census data.

Looking forward, the core elements of the DDI Codebook will likely remain the standard of choice for the documentation of surveys from most of the agencies currently using it. Given though that the standard was designed for survey and census data and given that many agricultural statistics are now being generated from other sources of data or are merged with other types of data it will be necessary to adapt or add to the current standard in order to accommodate these sources. Examples

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[1] The Quick Reference Guide for Data Archivists produced by the IHSN gives a description of key fields in the DDI and how the World Bank\IHSN have implemented it.
[2] The DDI Alliance: http://www.ddialliance.org/

of other sources of agricultural statistics are administrative data, remotely sensed data, satellite imagery, cadastral surveys, and time series data.

The DDI Alliance are currently working towards a new version of the DDI (DDI 4). The World Bank is working with the DDI alliance to ensure the standard meets the changing needs of users in developing counties, while still maintaining its relative simplicity for implementation. DDI 4 will incorporate all the elements from DDI Codebook and DDI Lifecycle in a simpler view. It will make it easier to use DDI for geospatial, administrative and time series data. This will be a major benefit to much data used for agriculture statistics. DDI 4 will come with a feature called profiles which will allow the user to pick a subset of elements for specific types of data. For example, for geospatial data, a DDI template (schema) could be created only for geospatial data or a combination of schemas could be created for multiple data types.

3. Tools for Documentation and Dissemination

The previous section discussed the needs for, benefits of, and the successes, which the World Bank and IHSN have had in rolling out standards for the documentation of microdata. A large part of the success in the adoption of the DDI by so many agencies has been the availability of easy to use free tools for the documentation and dissemination of surveys using the DDI standard.

The typical DDI document consists of an XML schema. While it is possible to write a DDI document directly in XML this is not easy nor convenient. To make the creation of DDI documents quick and easy requires software tools that allow the creation of DDI documentation without the user having any knowledge of XML. DDI documentation can be transformed into multiple human readable formats such as PDF reports and web based pages. The DDI lends itself most powerfully to the creation of online searchable catalogues. The World Bank and IHSN have been using and supporting a freeware DDI compliant editor as well as an open source online DDI compliant survey cataloguing and dissemination platform since 2006.

3.1 A DDI editor

The World Bank and IHSN contributed to the development of a DDI compliant metadata editor (The Nesstar Publisher) produced by the Norwegian Social Science Data Archive (NSD). This is Windows based software, which supports multiple languages. It is offered as Freeware by the NSD and has been the key vehicle through which the World Bank and IHSN have implemented the DDI standard since 2006. The availability of this easy to use free editor has led to the preservation and documentation of thousands of surveys, which might otherwise have been hidden or lost.

While the Nesstar Editor will continue to remain available for the near future, it is not anticipated that the NSD will develop the Editor any further. Given the earlier discussion on the need for further development of the DDI standard to incorporate other types of data there is a need to plan for and develop a new editor that can accommodate the new standard and new sources of data. While some advanced data centres have developed their own editors and some commercial editors are now available; there remains a need for the availability of a free, commercial-quality DDI compliant editor. To solve this problem The World Bank have begun the process of developing a new DDI editor. The new editor will support future versions of DDI and will have the added ability to support other standards such as Geospatial ISO 19139 and Dublin Core as well as custom designed schemas. The new editor will run on multi-platforms and will be distributed as open source software. The flexibility of the new editor combined with World Bank and IHSN support to countries is expected to broaden the ability for new types of data (relevant to the generation of data such as those used for agricultural statistics) to be documented, described, preserved and ultimately disseminated.

3.2 A Dissemination Platform

Data have their broadest use and utility if they can be discovered and used by a broad range of users. The most cost effective and efficient way to do that is to display the information online in such a way that makes it possible for users to discover, browse, search and download the metadata and microdata from a single online platform. Some advanced agencies have built their own custom microdata and metadata catalogues, and there are commercial products designed specifically for survey microdata available.[3] The success, which the World Bank and IHSN have had in helping countries, build capacity for the dissemination of data and DDI compliant metadata has however come through making available free (open source) catalogue software developed by the World Bank and supported by the IHSN partners. The software is called the National Data Archive (NADA). It is a multi-platform DDI compliant open source PHP application. The NADA allows users to browse, search, filter and download metadata and microdata. It also comprises a full featured secure administrative interface that allows managers of the system to apply access control polices at the survey level and to monitor and administer requests made by users. The full list of countries and organizations that the World Bank and IHSN have supported in implementing the NADA platform can be found in Appendix 1.

The NADA platform was originally designed to support only the DDI standard and survey and census microdata. User feedback and requests from users have always guided the development path of the NADA platform. The needs of users have changed over time as statistics are generated from new sources or combinations of sources of data. This is especially true of agricultural statistics where data come from many sources and where new data sources are augmenting or replacing survey and census data as a source. To address changing needs the World Bank have begun the development of new version of the NADA. The new version will accept and facilitate, in addition to new and existing versions of DDI, the display and dissemination of multiple metadata standards and data types. Of importance to agricultural statistics, this includes administrative data, time series data and geospatial data.

3.3. Tools for privacy protection

The release of microdata is important, as it allows researchers and policymakers to replicate officially published results, generate new insights into issues, avoid duplication of surveys and provide greater returns to the investment in the survey process.
The release of microdata poses privacy challenges to the producer. Agriculture microdata in particular often possess both the characteristics of a household survey as well as an establishment survey, which can make the safe release of the data more challenging.

The dissemination of agriculture microdata is poor in developing countries. One of the key reasons why these data are not widely distributed relates to the difficulty many countries face in applying statistical disclosure control (SDC) or privacy protection measures to the data. See the review by the Global Strategy to improve agricultural and rural statistics (2014).

[3] Two of the best known commercial products are the Nesstar Server and products from Colectica

While the release of microdata poses often-difficult disclosure control problems this is not the case for all types of data related to agriculture statistics. There are many examples where data from agriculture surveys have been released. One of the prime examples is the LSMS-ISA data produced by the World Bank. Also, a review of data catalogs in many developing countries shows that developing countries are successfully disseminating agriculture related data[4]. Where the data do present challenges for privacy there may be technical solutions and tools that could overcome some of these hurdles and allow the release of traditionally more sensitive microdata.

These strategies usually involve a combination of enabling legislation, the application of appropriate access terms and statistical disclosure control (SDC) methods.[5]

The World Bank and IHSN programs have provided considerable guidance to countries on the creation enabling legislation and dissemination policies for microdata dissemination. This has addressed part of the problem. Countries consistently list the lack of capacity and knowledge of SDC methods for privacy control as a remaining barrier to greater release of microdata. This is particularly the case for many types of agriculture data.

To help address this problem the IHSN, PARIS21 (OECD), Statistics Austria and the Vienna University of Technology and the World Bank has contributed to the development of an open source software package for SDC, called sdcMicro.

The package was developed for use with the open source R statistical software, available from the Comprehensive R Archive Network (CRAN) at http://cran.us.r-project.org. The package includes a comprehensive suite of methods for the assessment and reduction of disclosure risk in microdata. For users who are familiar with R, sdcMicro offers a very powerful and free tool to treat microdata for safe release. For those users who are not familiar with R the World Bank and the IHSN are developing a graphic user interface for sdcMicro that will remove much of the need to know R and free users to simply apply the methods as required. This should be available towards the end of 2016.

The proper implementation of SDC methods requires expertise and experience in Statistics and in the area of SDC. Many advanced agencies have expertise in this specialized area, but this is much less the case in developing agencies. The provision of the free tools will go a long way to improving the ability of agencies to apply SDC methods, but without guidance and capacity building uptake may still be low. To this end, the World Bank and IHSN have produced a number of guides to the SDC process and the practical application of the sdcMicro package. [6]

It should be stressed that SDC is only one part of the data release process, and its application must be considered within the complete data release framework. The level and methods of SDC depend on the laws of the country, the sensitivity of the data and the access policy (i.e., who will gain access) considered for release. The provision of the free SDC package and guidelines create an enabling environment for unlocking more microdata including agriculture microdata.

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[4] See appendix 1

[5] For an in-depth summary of access polices, and dissemination of microdata files see The IHSN working paper written by Dupriez and Boyko (2010)

[6] See: http://www.ihsn.org/home/software/disclosure-control-toolbox

4. Conclusion

The success which the World Bank and its IHSN partners have had in assisting countries and agencies build capacity for the documentation, preservation and dissemination of microdata has, in large part, been due to a strategy of building, disseminating and supporting free tools. The thread linking the success of the tools has been the existence of an easy to understand and implement international standard – DDI.

These tools, and the support for them, have improved the accessibility to good metadata and microdata for thousands of surveys. There are still countries that despite having the necessary platforms and tools for dissemination do not release microdata for all or certain types of surveys. Agriculture microdata are one of the data types that are not widely disseminated and where solutions need to be found in order to maximize the investment in the collection of these data and for improvement in surveys and policy. A commonly mentioned reason for not distributing microdata from agriculture surveys has been privacy protection. To help solve this problem the World Bank and the IHSN have supported the development of a free tool for the implementation of SDC methods and developed guidelines to support this. This lowers the barriers to release and opens the door for more countries to release microdata.

With increasing amounts of data for agricultural statistics coming from sources other than surveys and census there is a need to adapt current tools and standards to incorporate these new sources. The World Bank and IHSN are constantly improving the available tools to ensure they accommodate the changing needs of producers and users of data. The World Bank is also actively working with the DDI alliance to ensure that documentation standards remain accessible and relevant.

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Appendix 1: NADA Catalogues around the World. Distribution of agriculture data through NADA catalogues

	Agriculture			Agriculture	
NADA Catalog	**Metadata Available only**	**Meta & Microdata Available**	**NADA Catalog**	**Metadata Available only**	**Meta & Microdata Available**
Angola / Instituto Nacional de Estatística (INE)			Liberia / Liberia Institute of Statistics & Geo-Information Services (LISGIS)		
Benin / INSEA			Malawi / National Statistics Office (NSO)		X
Bhutan / National Bureau of Statistics (NBS)			Mali / Institut National de la Statistique (INSTAT)	X	
Bolivia / Instituto Nacional de Estadística (INE)	X		Mauritania / Office National de la Statistique (ONS)		
Botswana / Statistics Botswana			Mauritius / Central Statistics Office (CSO)		
Burkina Faso / Institut National de la Statistique et de la Démographie (INSD)		X	Mexico / Instituto Nacional de Estadística y Geografía (INEGI)		
Burundi / Institut de Statistiques et d'Etudes Economiques du Burundi		X	Mongolia / National Statistical Office (NSO)		
Cambodia / Cambodia National Institute of Statistics (NIS)			Mozambique / Instituto Nacional de Estatistica (INE)	X	
Cameroon / Institut National de la Statistique (INS)		X	Namibia / Namibia Statistics Agency (NSA)		
Cape Verde / Instituto Nacional de Estatística (INE)			Nepal / Central Bureau of Statistics (CBS)	X	
Colombia / Departamento Administrativo Nacional de Estadistica (DANE)	X		Niger / Institut National de la Statistique (INS)		X
Costa Rica / Instituto Nacional de Estadística y Censos (INEC)			Nigeria / National Bureau of Statistics (NBS)		X
Cote d'Ivoire (Ivory Coast) / Institut National de la Statistique (INS)			Peru / Instituto Nacional de Estadística e Informática (INEI)	X	
Dominican Republic / Oficina Nacional de Estadística (ONE)			Philippines / National Statistics Office (NSO)		X
Ecuador / Instituto Nacional de Estadistica y Censos (INEC)		X	Rwanda / National Institute of Statistics Rwanda (NISR)		X
Equatorial Guinea / Instituto Nacional de Estadística (INEG)			Saint Lucia / Central Statistics Office		
Ethiopia / Central Statistical Agency (CSA)		X	Senegal / Agence Nationale de la Statistique et de la Démographie (ANSD)		
Gambia / Gambia Bureau of Statistics (GBoS)	X		Sierra Leone / Statistics Sierra Leone (SSL)		
Ghana / University of Cape Coast (UCC)			Somalia / Puntland-Ministry of Planning and International Cooperation		
Ghana / Ghana Statistical Service (GSS)		X	Somalia / Somalia-Ministry of Planning and International Cooperation		
World Food Programme (WFP)			South Africa / University of Cape Town / DataFirst		
World Bank - Microdata Library			Sri Lanka / Department of Census and Statistics (DCS)	X	
International Household Survey Network (IHSN)			Sudan / Central Bureau of Statistics (Arabic Language)		
Secretariat of the Pacific Community (SPC)			Sudan / Central Bureau of Statistics (English Language)		
Guinea / Institut National de la Statistique (INS)		X	Togo / Direction Général de la Statistique et la Comptabilité Nationale		X
Guinea-Bissau / Instituto Nacional de Estatística (INE)			Tunisia / Institut National de la Statistique (INS)		
Honduras / Instituto Nacional de Estadistica (INE)	X		Uganda / Uganda Bureau of Statistics (UBoS)		X
India / Ministry of Statistics and Programme Implementation (MOSPI)		X	United Republic of Tanzania / National Bureau of Statistics (NBS)		X
Indonesia / Badan Pusat Statistik (BPS)		X	Uruguay / Instituto Nacional de Estadística (INE)		
Jordan / Department of Statistics (English Language)			Vanuatu / Vanuatu National Statistics Office (VNSO)	X	
Jordan / Department of Statistics (Arabic Language)			Viet Nam / General Statistics Office (GSO)	X	
Kenya / Kenya National Bureau of Statistics (KNBS)			West Bank and Gaza / Palestinian Central Bureau of Statistics	X	
Laos / Lao Statistics Bureau (LSB)		X	Zambia / Central Statistical Office (CSO)		X

THEMATIC SET

H47

MEASURING THE USE OF AGRICULTURAL STATISTICS FOR DECISION-MAKING

Session Organizer

P. Gennari | Chief Statistician | Food and Agriculture Organization of the United Nations (FAO) | Rome | Italy

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The National Agricultural Statistics Review: Collaborative partnerships supporting the Australian agricultural statistical system

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ABSTRACT

Australia's agriculture, fisheries and forestry industries make an important contribution to Australia's economy, society and natural resources. The productivity, competitiveness, sustainability and profitability of these industries are enhanced by having access to timely, high-quality and reliable statistics to inform decision-making by both government and industry. Similarly, at the micro level, individual businesses use statistics to inform their management and investment decisions. Over time the Australian agricultural statistical system has evolved to support the information needs of decision-makers across government, industry and the broader community.

However, there has been criticism that the current Australian agricultural statistical system is deficient in providing quality, timely data to meet these needs. Like all national statistical offices, the Australian Bureau of Statistics (ABS) faces the ongoing challenge of meeting diverse user needs in an environment of fiscal constraint. In this context, it is essential that the datasets produced within Australia's agricultural statistical system are targeted at the highest priority needs and are produced, disseminated and used in the most effective and efficient way.

The ABS and the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) are the principal producers of agricultural statistics in Australia. The two organisations initiated the National Agricultural Statistics Review (NASR) to hear directly from statistical users and producers across government, industry and the research sector about these issues, and to identify potential solutions. The NASR provided valuable stakeholder insights, and has identified a pathway to establish a contemporary, best practice Australian agricultural statistical system for the future. The NASR has enhanced the relationship between the two agencies and paved the way for further collaboration to provide stronger and more effective leadership across the system. Additional opportunities for partnerships have also been identified with other statistical users andproducers to better coordinate effort and investment, and to work collaboratively to improve data quality and reduce respondent burden.

This paper will briefly examine the context through which the NASR was initiated and its links to national policy in Australia. The paper will briefly explore the NASR process and the positive impacts of collaboration and partnership with a wide variety of stakeholders from across the agricultural sector. As the NASR has progressed into its implementation phase, the final section of the paper will outline progress against actions recommended during the review, and the additional outcomes and opportunities that have emerged as a result of continued engagement across the agricultural statistical system.

Keywords: statistical system; policy; collaboration.

1. Background

1.1 The two predominant producers of agricultural statistics in Australia are the Australian Bureau of Statistics (ABS), and the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES). ABARES, a science and economics research bureau located within the Australian Government Department of Agriculture and Water Resources (DAWR), collects, analyses and disseminates a range of agricultural information to support government policy development and industry bodies across the agricultural industry. As Australia's National Statistical Organisation (NSO), the ABS has traditionally produced a range of data on the production and value of agricultural commodities and on the land management practices used by farmers, to inform information needs and support policy, programs and decision-making processes across the agricultural sector. The ABS also produces a range of natural resource and energy statistics, including environmental-economic accounts.

1.2Outside of ABS and ABARES, agricultural statistics and information are also produced by a range of other organisations including other Australian Government and state/territory agencies, industry bodies, and academic research institutions. These statistics include not only data directly collected via surveys, but also administrative datasets collected as a by-product of other processes – for example data collected under the Government's legislated agricultural levies system, and data collected through trade records and biosecurity databases.

1.3The evolution of Australian agriculture in the past few decades has been accompanied by increasing concerns regarding land and natural resource use and growing interest inthe sustainability of agricultural production.Thishas amplified the pressure on the national agricultural statistical system to meet a range of emerging information needs whilstat the same timeresponding to demand for more accurate, timely and detailed data from industry stakeholders. A report by the Australian Farm Institute in early 2013 identified a range of concerns with the availability and quality of Australian agricultural statistics, including those produced by ABS and ABARES (Potard, 2013). A number of these concerns had also been reflected through stakeholder consultation conducted by ABS and ABARES as part of their respective stakeholder engagement programs. Stemming from these criticisms both agencies recognised an opportunity to collaboratively review the agricultural statistical system and jointly act to address emerging challenges.

1.4In July 2013 the National Agricultural Statistics Review (NASR) was initiated as the first review of Australia's agricultural statistics system which was jointly undertaken by ABS and ABARES. The Review considered all aspects of the national agricultural statistical system, assessed its ability to inform decision-making and identified opportunities to improve the system both now and into the future.

2. Undertaking the National Agricultural Statistics Review

2.1 The purpose of the review was to assess the agricultural statistical system in Australia and its adequacy for informing decision-making in the agriculture, fisheries and forestry industries both now and into the future. The review aimed to identify:

- the priority information needs of stakeholders;
- where information needs are not being met by existing sources of data;
- overlaps and inconsistencies in data; and
- opportunitiesto improve efficiency in the national agricultural statistical information system.

2.2 For the purposes of the review, 'agricultural statistics' was broadly taken to mean the data, information, statistics or other knowledge that could be used to provide insights into agricultural activity (which for the purposes of the review, included fisheries and forestry activity) (ABS, 2014). The agricultural statistical system was considered to consist of:

- agricultural statistical assets;
- the statistical infrastructure underpinning these assets – including standards, frameworks and classifications; physical systems; and coordination and governance frameworks; and
- stakeholders – including users, producers, custodians and providers of agricultural statistical assets and information.

2.3 The NASR was undertaken in two phases over 2013 and 2014, and featured extensive stakeholder engagement in recognition of the critical importance of stakeholder contributions in identifying potential issues with the agricultural statistical system and ways to address them. These stakeholders included not only government agencies (at both the Australian Government and state/territory government levels) but also industry bodies, farmer representative organisations, academic and research institutions, and the broader community.In total across the two phases of the review's consultation, 43 organisations participated in a series of targeted forums, and 42 formal submissions were received throughout the consultation process.

3. NASR final report

3.1 The NASR Final Report summarised the review's findings as regards to the current state of the agricultural statistical system and its capacity to inform stakeholder needs both now and into the future.

3.2 Findings from the review indicated that generally the Australian agricultural statistical system is effective in informing government and stakeholder information needs. Stakeholders reported that about two-thirds of the statistical assets they usemostly met their needs (ABS, 2015:39). Throughout the consultation phase of NASR, stakeholders indicated that the majority of the statistics they used were generated by national or state or territory government agencies, and that the agricultural statistics were a valuable asset.

3.3However,a number of deficiencies and stakeholder concerns were identified throughout the review, that if addressed would improve the capacity of the system to more efficiently meet current and emerging needs. These deficiencies were identified through an assessment of the Australian agricultural statistical system against a set of best practice principles that characterised well-performing statistical systems internationally. These deficiencies were found to be driven by a set of systemic issues, namely:

- A lack of strong governance and coordination across the statistical system to effectively coordinate the contributions of stakeholders and ensure a planned and coordinated approach to statistical production;
- The agricultural statistical system has evolved in a somewhat reactive manner, without a central plan or strategy to guide investment, leading to potential duplication and inefficiency;
- An over-reliance on surveys and an under-utilisation of alternative data sources such as administrative sources, leading to areas ofhigh respondent burden, potential data quality issues and higher costs;
- Under-utilised opportunities to harness innovative new technologies (e.g. 'big data') and statistical methods to produce statistics more efficiently and with reduced burden; and
- The need for a culture of open data to make the best use of existing sources.

3.4 The Report recommended a number of actions to address these systemic issues and stakeholder concerns identified through the review, and to position the Australian agricultural statistical system to better align with international best practice. These recommendations included:

- The establishment of mechanisms to improve coordination and governance across the statistical system, including targeted and purposeful engagement to consult, provide direction, and encourage better coordination of government statistical collection activities; and an annual calendar of statistical activities to improve transparency and encourage coordination of statistical activity;
- The establishment of a Foundation Dataset that applies existing frameworks to organise and present data from multiple sources that will assist toidentify the highest priority information needs across the entire statistical systemto better target investment and plan future statistical activity;
- Encouraging stakeholders to explore alternative data sources to surveys, including through establishing an Administrative Data Initiative to explore greater use of administrative data across the statistical system;
- Adoptingnew and emerging technologies in statistical use and production, including making greater use of internet-based surveys, and encouraging more coordinated approach to invest in innovative new technologies and methods throughout the statistical cycle that will reduce burden and improve data quality; and
- Establishment of a one-stop portal for agricultural statistics to maximise the value of existing data sources and encourage a culture of open data.

4. NASR progress to date

4.1 The NASR recommendations articulated a pathway for ensuring the Australian agricultural statistical system continues to meet information needs in the most efficient and effective way possible. In addition, the collaborative approach taken to the review by ABS and ABARES, and the goodwill and relationships built through the review's extensive engagement process have generated additional benefits. These include stronger relationships between ABS and DAWR/ABARES; and stronger relationships between ABS, ABARES and other stakeholders in the agricultural statistical system. At the same time, the NASR has generated expectations amongst statistical users, and these need to be carefully managed within the context of available resources.

4.2 The NASR report recommendations were aspirational in nature, however, and while warmly accepted in principle by the two agencies, their implementation has required some pragmatism and prioritisation. Some of these have been addressed through natural program developments, for example the adoption of an 'e-form first' strategy for the 2016 Agricultural Census. Since the release of the final NASR Report in mid-2015, while continuing to explore opportunities across all the recommendations,ABS and ABARES have focused their collaborative efforts on a number of priority actions including the implementation of structured, purposeful engagementprocesses for the purposes of greater coordination and governance; the concept of a foundation data framework; and exploration of potential high-value administrative sources.

4.3**Coordination and governance:** As noted above,findings from NASR demonstrated a clear gap in effective governance and coordination of the national agricultural statistical system. Stakeholders clearly identified throughout the NASR engagement process the high value they placed on opportunities to be continually engaged with ABS, ABARES and other representatives from across the agricultural industry to discuss a range of statistical issues and opportunities. As stakeholders endorsed the statistical leadership of ABS and ABARES within the system,both agencies are maintaining a high level of engagement across industry groups and related stakeholders, such as government organisations with responsibility for natural resource management. To make the most effective use of time and resource, and ensure the engagement processes are focussed on specific actions or issues, ABS and ABARES will convene regular summits and other events targeted at specific audiences and topics.

4.4An example of this coordination and governance role is the recent Agricultural Statistics Roundtable,convened with stakeholders from industry Research and Development Corporations (RDCs) and government agencies, jointly led by ABS and ABARES. The focus of the Roundtable was to explore alternative data sources and technologies that could be utilised to increase the quality and accessibility of data, and ultimately begin to reduce survey burden on farmers. Many industry groups within Australia, including RDCs, are custodians of large amounts of data, either through statistical collections or by-products of other activities. Discussion during the Roundtable highlighted the work already being undertaken by industry groups leading collaborative projects to generate and utilise existing datasets. The focus of these industry led projects align with themes contained in the Enduring Goals for Australian Agriculture framework, focussing on areas such as agricultural supply-chain efficiencies, management of natural resources, and sustainability of farming practices.

4.5As well as providing valuable information sharing opportunity for attendees, at the conclusion of the roundtable ABS identified six key actions where the organisational statistical leadership role could be employed most effectively to support or deliver outcomes to enhance existing data sources. These actions are currently being developed by ABS and ABARES, but broadly include:

- Supporting industry collaboration to develop and implement common data standards and data sharing protocols to improve quality and accessibility of existing data sources;
- Exploring the potential of farm management systems, satellite technology and precision agriculture to contribute to official statistics;
- Engaging in viable pilot projects with industry to use administrative data to replace survey content;
- Demonstrating the value of environmental economic accounting as a framework for information relating to sustainable agriculture;
- Establishing a collaborative project with ABARES to extract statistical value from the agricultural levy process; and
- Exploring potential to combine and consolidate surveys across industry and government.

4.6**Foundation data frameworks:** The NASR recommended a Foundation Dataset for Australian Agriculture be established to inform the Enduring Goals for Australian Agriculture, address data gaps and better target future investment across the national agricultural statistical system. This recommendation recognised the utility of agreed information frameworks to help focus and prioritise the collection and dissemination of agricultural statistics, and ensure a direct relationship to policy requirements.

4.7To assist in focussing the Foundation Dataset concept as a foundation data framework for agriculture, the ABS is applying the System of Environmental-Economic Accounting, including the sub-system for Agriculture, Forestry and Fisheries (SEEA-AFF) to the Enduring Goals for Agriculture. This enables analysis of the relationships and linkages between the Enduring Goals that provide the core elements of the foundation data framework. In this way the SEEA and the Enduring Goals can be used together to produce meaningful indicators to meet a range of industry and policy needs.,

4.8The SEEA-AFF has potential to inform a range of policy issues relating to agriculture and the environment, including:

- understanding trends in natural resource use by activity, such as agriculture or forestry;
- addressing information gaps relating to sustainability risk for investors;
- understanding the competing demands for resource use from different activities, for example use of land and water;
- exploring the potential productivity benefits arising from improved farm management practices in specific regions or commodities; and
- understanding the potential economic and environmental impacts of climate events and bio-security risks on particular industries or products.

4.9**Agricultural administrative data initiative:**The NASR proposed an Administrative Data Initiative to develop methods for broader use of administrative data sources within the agricultural statistical system. This initiative will include examining legislative, privacy and commercial barriers to the use of data collected by governments and industry with the objective of reducing survey burden on farmers, and implementing a "collect once, use many times" approach. Two potential areas of action have been identified by ABS and ABARES to progress this initiative:

- Utilisation of levy data: Following the release of the report of the Senate Committee inquiry into the agricultural levies system in mid-2015, ABS and ABARES have been working together to advocate for the statistical value of levy data to be recognised in any legislative change. As a consequence an amendment to the Primary Industry Levies and Charges Collection Act was introduced to Parliament in 2016 which enabled not only RDCs, but also ABS, to access levy data for statistical purposes. If this amendment is enacted, it poses an important opportunity for ABS, ABARES and RDCs to work collaboratively together to harness the statistical value in this important data source and explore the potential for it to supplement or replace survey collection, thereby reducing burden.
- Microdata and Data Integration: ABS has an increasing focus on enabling access to microdata (unit record data) and on data integration projects while maintaining privacy safeguards. The Business Longitudinal Analytical Data Environment (BLADE), held by the ABS, is an important example of a data integration methodology ABS has developed to enable greater access to business data for statistical purposes. BLADE enables integration of ABS business survey data with administrative data sources, such as tax information, using the ABS Business Register as the integrating spine. BLADE is designed to support analysis of the micro economic drivers of business performance, competition and productivity and provide innovative

responsive solutions to client data needs. Already ABS and ABARES are discussing how this might support ABARES analyses of the sector.

5. Next steps for a whole of sector approach

5.1 As a result of the NASR consultative process, NASR outcomes and ongoing work between ABS and ABARES, both agencies continue to be well-positioned to exercise joint statistical leadership across the Australian agricultural statistical system, marshalling support from and coordinating activity with a range of other stakeholders in both government and industry.

5.2 However to ensure that policy directions for Australian agriculture are maintained and supported long term through the provision of relevant statistical information, and to fully address the systemic issues identified through NASR, an increasingly whole-of-government approach will be needed. The combined demand for agricultural commodity data, as well as complementary information on environment, landand natural resource management, will lead to increasing pressure on the national agricultural statistical system to ensure statistics are collected and disseminated as efficiently and effectively as possible to continue to support evidence based decision making.The recent Roundtable was a step in this direction, where opportunities for collaboration were identified and currently being implemented into the ABS work program.

5.3 There are challenges in responding to the directions established through the NASR, however. Reducing dependence on surveys and transitioning to new data sources while maintaining key time series and the credibility of official statistics will require creating of new methodologies and statistical infrastructure. The increasing diversity of information needs and potential sources will also stretch the capacity and resources of the current statistical system.

5.4 To meet these challenges, further leveraging the collaborative relationships built with stakeholders across government, industry and the wider community will be critical. NASR has provided a model for a partnership approach to developing strategic, system-wide solutions to existing and emerging agricultural, land and other environmental policies. However, it is not feasible, or desirable, that the ABS as Australia's NSO lead or deliver in its entirety the leadership and statistical data required in achieving this goal.

5.5In an environment of fiscal responsibility, ABS is best placed to focus its capabilities on producing and disseminating critical data to support the highest-priority information needs, and on its statistical leadership role. This role includes coordinating the efforts of other users and producers of statistics, finding ways to unlock the value of administrative and other data sources for public good, developing and promoting standards and quality requirements, and providing the supporting capabilities for complex statistical products such as data integration.

6. Conclusion

6.1 Maintaining Australia's natural wealth, including the land on which agriculture occurs, is an ongoing challengefor government and industry both now and into the future. Meeting this challenge requires increasingly more complex information,which is putting pressure the national agricultural statistical system and leading to concerns at the capacity of the system to meet these demands. In this context ABS and ABARES took the opportunity to jointly undertake the NASR and identify and address these concerns.

6.2 While the challenges remain, the NASR has laid the foundation for joint coordination and statistical leadership across the national agricultural statistical system, with all stakeholders having a part to play. In this context and in collaboration with ABARES, the ABS, as Australia's NSO, will look to re-align and renew its role of statistical leadership, coordination and integration of high priority statistical information. As this occurs, other stakeholders will need to assume greater responsibility for the collection of relevant and valued statistical data to ensure the Australian national agricultural statistics system remains agile and policy relevant.

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Inevitability of Interdisciplinary Statistical Laboratories for Food and Agricultural Research in Developing Countries: The case of Pakistan

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ABSTRACT

The economy of Pakistan is predominantly dependent on Agriculture, which is the largest sector of the economy and contributes about 21% to the Gross Domestic Product. Most of the population depends on agriculture either directly or indirectly as it accounts for half of the employed labor force and is the largest source of foreign exchange earnings for the country. The Agricultural sector is also one of the key determinants of social welfare. As such, agricultural productivity growth is essential for poverty reduction and the provision of food for the existing population. Due to its importance, agriculture poses various policy implications for policy makers and researchers. However, there exist several deficiencies in agricultural research. A survey study is conducted about the actual statistical facilities in agricultural research in Pakistan and found that there is no proficient system for the proper designing of experiments, data collection, statistical analysis, or interpretation and communication of results. Furthermore, the sector lacks an adequate mechanism for statistical advice to improve research projects or proposals, which are the basic ingredients in promoting food and agricultural research. Even those agricultural centers that have statistical facilities are either not functioning properly or lack sophistication with the use of statistical programs and packages. Agricultural universities/faculties/colleges are facing a broad deficit of adequate and highly qualified statistical personnel, except for a few statisticians on executive boards with many responsibilities. Agricultural and food research institutes and centers in Pakistan are not provided with expert statisticians. Both policy makers and researchers need timely and accurate official statistics, ranging from the data of annual rainfall to an average annual temperature, and statistical models and analyses that apply these data for planning purposes to make better decisions and policy. Thus, there exists a need to integrate the work of agricultural scientists

with statisticians. Hence, in this paper we propose to create a statistical collaboration laboratory to play this vital role in integrating statistical knowledge with agricultural research. The tentative name of this statistical laboratory will be the "**P**akistan **La**boratory for **S**tatistical **C**ollaboration (PLASCO)." The main objectives of PLASCO will be to provide an integrated platform for statisticians and researchers to collaborate to advance agriculture; to train the next generation of statisticians to become useful agricultural statisticians; to build the statistical capacity of agricultural researchers through collaborations with statisticians, seminars, workshops, conferences, and refresher courses; and to create a healthy statistical computing environment with access to statistical software. This laboratory will create bridges between statisticians and researchers (non-statisticians) from various departments and will play an important role in improving the quality of agricultural research. The support and mentorship provided to agriculture researchers at the laboratory will improve their ability to design experiments, collect and analyze data, and interpret and communicate the results. Establishing such a laboratory will require financial resources and commitments from agricultural researchers and administrators at the agriculture and food institutes in Pakistan. National and international funding agencies will be contacted and briefed about the importance of the project and how it will be conducted. Mutual funding from more than one agency may be possible if all the agencies adhere to a mutually agreeable standard. Moreover, because of the great need for improved statistics in agricultural research, many laboratories will be established on the same standard throughout Pakistan. This is not only a single project but can serve as a laboratory test case and a role model for other developing countries.

Keywords: Statistical Capacity Building, Agricultural Research, Research Integration, Statistical Collaboration Laboratory

1. Introduction

Pakistan traditionally is a country with an agricultural economy. The majority of its population (about 70%) heavily depends on agriculture or related activities with strong backward and forward linkages. Moreover, the food security for the masses and raw material production for domestic agro-based industries are also relying on this sector. As the largest sector of the economy, it contributes 20.9% for the Gross Domestic Product (GDP) and 43.5% of the employment (Economic, 2015). This sector has four sub-sectors namely: crops, livestock, fisheries, and forestry. It is also mentioned in the draft report of "Agriculture and Food Security Policy" that Pakistan's Government is really interested in value added growth of the agriculture sector in terms of domestic and export markets. According to the Ministry of Planning and Development, the agriculture sector needs to grow at 5 percent to reduce poverty and ideally should reach the growth targets of 7-8 percent to improve the national economy of Pakistan (MNFSR, 2016). A positive relationship between agricultural growth and GDP exists such that a one percent increase in the agriculture growth rate can bring a 0.34% increase in the GDP growth rate (Hussain & Khan, 2011).

This agrarian economy is moving towards industrialization with an advancement in technology and adoption of modern trends in agriculture. Therefore, there must be precise consultations, collaborations, and policy recommendations to lay down the foundation for agriculture-led growth in the country. On the other hand, several deficiencies exist in the agricultural research system of the country. There is no proficient system for the proper designing of experiments, data collection, statistical analysis, and communication of results. In addition, this sector lacks an adequate mechanism for seeking statistical advice to improve research projects or proposals, which are the basic ingredients in promoting food and agricultural research. The agricultural and food research institutes and centres are working in Pakistan, but there is a lack of expert statisticians in these institutes and centres. Both policy makers and researchers need timely, relevant, and accurate official statistics, ranging from the data of annual rainfall to an average annual temperature, and statistical models and analyses that apply these data for planning purposes and making better decisions. Thus, there exists a need to integrate the work of agricultural scientists with statisticians.

The current paper is a review of an attempt to bridge the relationship between statisticians and non-statisticians (researchers), especially agricultural researchers, with the proposal of creating a unique kind of statistical collaboration laboratory to play a vital role in the integration of statistical knowledge and capacity building with agricultural investigations. The trained statisticians of this laboratory will collaborate with agricultural researchers to provide innovations and ultimately solutions to raise the incomes of impoverished farmers. This idea of developing statistical collaboration laboratories in the agricultural research system was also proposed by Msemo and Vance (2015a). They describe that this type of laboratory can be considered to be a collection of statisticians that emphasizes building relationships with researchers that are collaborations rather than just consultations. The trained statisticians of such laboratories focus on helping their clients to answer their research or business questions (colloborations) rather than helping them just answer their statistics questions (consultations). Another beneficial feature of such laboratories is their ability to build statistics capacity by training young statisticians and to create new statisticial knowledge via research on applied problems (Vance 2015).

This is not an empirical study, rather it is a brief analysis of one of the problems plaguing agricultural research in Pakistan and a proposal of a potential solution to increase agricultural productivity in Pakistan. We are not attempting to reform the current agricultural research institutes. Instead we are proposing to introduce an innovative model to improve the essential statistical aspects of agricultural research. This model, if successful, will spread organically throughout the agricultural research enterprise to improve collaborations between statisticians and agricultural researchers and will, ultimately, lead to increased agricultural productivity and improvements in the livelihoods of Pakistani farmers.

Sections 2 and 3 in this paper describe the problems and current state of the agriculture sector in Pakistan. Section 4 describes the proposed model of a statistical collaboration laboratory to become part of the worldwide LISA 2020 network. Section 5 concludes with some of the challenges facing the agriculture section of Pakistan and our attempts to overcome them to achieve our goal of improving agricultural productivity through the creation of unique kind of statistical laboratory.

2. Problems of Agriculture Sector in Pakistan

The agricultural sector of Pakistan is the backbone of the country's economy. But the growth of this sector is facing many problems. This is the reason of very low per acre yield as compared to other developed agricultural countries, and it is true that the magnitude of the agricultural problems undoubtedly crippled the economy. In 1947, the share of this sector to GDP was 53% which has shrunken down to around 21% last year. These problems of the agricultural sector can be categorized into four main and 28 subsections as below in Table 1 (Mughal, 2016).

Table 1: Problems in the agricultural sector

Techno-Economic Problems	**Natural Problems**	**Socio-Economic Problems**	**Financial Problems**
Limited cultivable area	*Various plant diseases*	Consumption oriented	Lack of credit

Water logging and salinity	Natural calamities	Farmer's litigation	Poor financial positions of farmers
Slow growth of allied products	Scarcity of HYV seed	Joint family system	*Instability in market price*
Low per hectare yield	Under utilization of land	*Illiteracy and Ill-health*	Shortage of agricultural finance
Inadequate infrastructure		Political instability	
Uneconomic land holdings			
Old methods of production			
Inadequate supply of agriculture inputs			
Lack of irrigation facilities			
Inadequate agricultural research			
Lack of R&D and neglect in education & training of farmers			
Problem of land reforms			
Defective land tenure system			
Subsistence farming			
Low cropping intensity			
Improper crop rotation			

According to the Minister of Finance, Ishaq Dar, the Ministry of National Food Security and Research (MNFSR) has been running without a national agriculture policy since its creation in 2011. Both the World Bank and the Asian Development Bank pointed out that agricultural growth will miss its annual target of 2.7 percent due to a drop in cotton output, which partly offset the improvement in sugarcane and rice crops. Minister Dar also stressed that in order to meet the challenges of food insecurity and malnutrition, it was imperative to employ the latest technological advancements and innovative techniques to improve the productivity of this sector (Dar, 2014). The draft report of “Agriculture and Food Security Policy” has been submitted by this ministry to the Government of Pakistan (MNFSR, 2016). The above problems of the agriculture sector and their possible solutions are mentioned in this draft. The statistical laboratory we propose in Section 4 can play a very important role in most of the recommended solutions especially in those in italics in Table 1 above.

3. Current State of Agriculture Research and Statistics in Pakistan

Some important structural changes have taken place in the agriculture section in the recent years especially in the important subsector of livestock. This sector is contributing a great amount to agricultural GDP. Fisheries and forestry were also minor contributors to agricultural GDP in the past but are now growing rapidly. Cotton is also becoming as important as wheat in terms of value added, with a one-fifth share of total earnings. However, the rice and sugar crops have fallen from a 20 percent share in the early 1970s to 15 percent today.

The Food and Agriculture Organization (FAO) reported in the report of the Nineteenth Session of the Asia and Pacific Commission on Agricultural Statistics that Pakistan had a history of conducting the agricultural census every ten years since 1960 (FAO, 2003). Five agricultural censuses in Pakistan have been successfully conducted in 1960, 1972, 1980, 1990, and 2000. The latest, which is the sixth one in the series, was conducted in 2010 by the Pakistan Bureau of Statistics (PBS) of the Government of Pakistan with the objectives to generate basic information on the structure of agriculture; to develop detailed basic information about the agricultural resources, state of their utilization, and to find out the degree of acceptability of modern farming practices among the farming community for the purpose of regional, provincial and national development, planning, and research in the field of agriculture; to collect information about livestock population; and to fulfill data needs of the international agencies like FAO which require the country's information for a worldwide study of agricultural resources in order to formulate international policies in matters relating to the supply of food and raw materials on sustainable basis (PBS, 2010).

The first author conducted a telephonic survey study to know about the actual statistical facilities in agricultural research in Pakistan and found that there is no proficient system for the proper designing of experiments, data collection, statistical analysis, or interpretation and communication of results. Currently, Pakistan has a total of 92 agricultural research institutes, including 15 agriculture, animal, and textile universities; 4 agricultural facilities; 6 agricultural colleges and institutes; 64 agriculture research centers; and 3 other agriculture-related educational departments.

The research conducted, techniques taught, and skills imparted in these institutions rarely extend down to the level of small farmers. For example, farmers need to know how to make optimal use of land, how to use fertilizers and pesticides, and what amount of water is exactly useful and necessary for any crop. Lack of management on the part of farmer is another huge problem.

There are no statistical collaboration laboratories in the country similar the one proposed in Section 4. Even those agricultural centres that have statistical facilities are either not functioning properly or lack sophistication with the use of statistical programs and packages. Furthermore, agricultural universities/faculties/colleges are facing a broad deficit of adequate and highly qualified statistical personnel, except for a few statisticians on executive boards with many responsibilities. Agricultural and food research institutes and centres in Pakistan are not provided with expert statisticians. It is indicated that in the research institutions of Pakistan, a diverse nature of data are generated from various discipline, so the actual insights of these processes can only be well understood by applying the most relevant statistical techniques with advanced statistical programs. The correct interpretation of results obtained needs sufficient knowledge of statistical methods (Hussain, Murshid, & Safeeullah, 2014). It is also observed that a variety of statistical techniques have been used in published articles, but the frequency of advanced statistical methods applied was quite low as compared to journals in more advanced countries (Akhttar, Shah, Rafiq, & Khan, 2016). These gaps can be filled through this proposed laboratory by enhancing the basic skills of junior statisticians by imparting trainings, short courses, and workshops.

Improvement in agricultural research and education is a continuing requirement for development, not only for developing better seeds, improving cultivation methods, and better using other inputs, but also for finding out the best combinations of inputs for conditions in Pakistan. Unfortunately, this area has not received great attention and suffers from financial deficits and lack of skilled personnel. Moreover, there is lack of extension services which is very important in providing farmers with systematic access to new innovations in farming practices, multiple cropping, and use of physical inputs. This can be done through arranging dissemination seminars and other related activities through the proposed statistical laboratory. In order to raise the potential of agricultural production, continuous improvement in the research for agricultural growth is necessary. The specific areas of research include the development of high yielding, short duration, disease and drought resistant varieties of major food and cash crops in Pakistan tailored to the situation prevailing in different areas of the country.

4. Proposed Model of a Statistical Collaboration Laboratory

The LISA 2020 Program was created to build statistics capacity and research infrastructure in developing countries to help scientists, government officials, businesses, and NGOs use data to solve real-world problems and make decisions. In this program, statisticians from developing countries are trained to effectively communicate and collaborate with non-statisticians and helped to create statistical collaboration laboratories modeled after the University of Colorado Boulder's Laboratory for Interdisciplinary Statistical Analysis (LISA) at their home universities or institutions. These new statistical collaboration laboratories foster education in collaborative statistics and promote the proper application of statistics and data science to solve real-world problems (Vance, 2015b). This is important because, when implemented in Pakistan, the statistical laboratory will enable Pakistani agricultural researchers to collaborate with local statisticians to solve local problems and generate real-world impact for the agricultural sector.

The LISA 2020 network is based at the University of Colorado Boulder in USA and is comprised of four statistical collaboration laboratories in Africa and one in Brazil (Msemo & Vance, 2015) (Awe, Crandell, & Vance, 2015) (Goshu, 2016). The program's goal is to create a well-connected network of 20 statistical laboratories in developing countries by the year 2020, including a statistical laboratory in Pakistan to help agricultural researchers better apply statistics. The proposed model is detailed below.

4.1 Pakistan Laboratory for Statistical Collaboration (PLASCO)

Though many details remain to be worked out, we propose to create the **P**akistan **La**boratory for **S**tatistical **Co**llaboration (PLASCO) at Nuclear Institute for Food and Agriculture (NIFA), Peshawar, Pakistan a subsidiary institute of Pakistan Atomic Energy Commission. The overall vision of PLASCO will be to promote effective collaborations between statisticians and agricultural researchers that lead to improvements in agricultural productivity in Pakistan. The mission of PLASCO will be to train statisticians and data scientists to become effective interdisciplinary collaborators, provide research infrastructure for the agricultural sector to enable and accelerate high impact agricultural research, and engage with the agriculture community to improve statistical skills and literacy widely.

Currently, agricultural researchers in Pakistan may receive statistical support from isolated statistics professionals working in various places. PLASCO will be one point of consolidation of statistical resources to act as a bridge between statisticians and other researchers across the country. We envision PLASCO helping to achieve the following objectives:

i) Serve as a center for researchers and statisticians to collaborate to solve agricultural research problems and answer agricultural research questions.
ii) Enhance the existing statistical support services which are difficult to find due to their distribution in different regions.
iii) Develop new statistical methods to address emerging problems in science and technology.
iv) Raise the level of statistical skills and literacy through seminars, workshops, and short courses.
v) Become a source of statistical software for agricultural researchers to access.

4.2 Outline of Proposed Implementation Plan

A statistical collaboration laboratory is, in essence, a collection of technically trained statisticians who are also well trained in the essential non-technical skills of communication and collaboration to effectively work with researchers to answer research questions. It will be directed by a Ph.D.-level statistician and supported by other Ph.D. and M.S.-level statisticians as funding availability and demand from researchers dictate. A major source of statistical expertise and workforce in PLASCO will be statistics M.S. and Ph.D. students who are trained to collaborate with agricultural researchers in the designing of experiments, data collection, statistical analysis, and communication of results.

PLASCO will also be a center for applying statistics in agricultural research, and as such will require physical space for collaboration meetings between statisticians and researchers; workshops, short courses, and training seminars in various topics in statistics, and a computer lab equipped with sufficient computers and modern software for statistical analysis of agricultural data.

We envision that several agencies will be recruited to sponsor and fund PLASCO, including the Pakistan Science Foundation (PSF), Pakistan Agricultural Research Council (PARC), Pakistan Atomic Energy Commission (PAEC), Higher Education Commission (HEC), Pakistan Academy of Sciences (PAS), International Food and Agriculture Organizations. NIFA will be primarily responsible for executing the implementation plan and for operation and maintenance of PLASCO.

Leadership from the LISA 2020 Program will provide advice and logistical assistance to PLASCO. For example, members of the LISA 2020 network will provide software recommendations and trainings to build the capacity of the young statisticians in PLASCO. Decision making regarding implementation of this project will be carried out by the local official of NIFA in consultation with the LISA 2020 leadership.

After developing a final implementation plan, the equipment, materials, and commodities necessary for PLASCO will be arranged by NIFA via the support of proposed funding agencies. Likewise, NIFA will host and sustain this laboratory.

Because much of the infrastructure and physical space required to create and run PLASCO will be provided by NIFA, the budgetary requirements of PLASCO are relatively minimal. Initially, PLASCO will engage a full-time Ph.D.-level statistician to direct and manage the statistical laboratory, costing approximately US$ 12,000/annum. It will require an administrative assistant and an accountant to coordinate the lab’s activities, costing approximately US$ 12,000/annum. It will require several statistics students to work in PLASCO to gain practical training and experience. These students will be paid a nominal sum of approximately US$ 4,800/student/annum. PLASCO will also require the purchase of new equipment such as a multimedia projector and white screen for presentations and workshops; five computers, monitors, and associated software; statistical books and manuals; equipment for internet connectivity; and a backup electrical generator, costing approximately US$ 13,000, for a total estimate of US$13,000 in start-up costs and approximately US$ 48,000 in annually recurring costs.

5. Conclusion

Pakistan is an agriculture country but the agriculture sector is still facing many challenges. Therefore, the use of modern techniques, provision of credit facilities, basic infrastructure, and agricultural research facilities are needed to overcome them. We believe that some of these issues would be resolved through the creation of the proposed statistical collaboration laboratory (PLASCO). The statisticians within PLASCO will be trained to effectively collaborate with agricultural researchers of all types, including agronomists and agricultural economists, to respond to the practical needs of the agricultural sector in Pakistan. This laboratory will provide an integrated platform for statisticians and researchers to work together to advance agriculture; to build the statistical capacity of agricultural researchers through collaborations with statisticians, seminars, workshops, conferences and refresher courses; and to create a healthy statistical computing environment with access to modern statistical software. This laboratory will create bridges between statisticians and researchers (non-statisticians) from various departments and will play an important role in improving the quality of agricultural research. Establishing such a laboratory will require financial resources and commitments from agricultural researchers and administrators at the agriculture and food institutes in Pakistan. National and international funding agencies will be contacted and briefed about the importance of the project and how it will be conducted. Moreover, because of the great need for improved statistics in agricultural research, many laboratories may be established in the future on the same standard throughout Pakistan. This is not only a single project but can serve as a laboratory test case and a role model for other developing countries.

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The (Under)utilization of Agricultural Statistics in Tanzania and Uganda Evidence and Innovations

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ABSTRACT

Official statistics, and the underlying datasets, are essential for stakeholders to take informed decisions. National Statistical Officers (NSOs), however, often have little systematic information on the use of official statistics by stakeholders. This makes it challenging to appreciate whether investments to improve the quantity and quality of official statistics are generating good returns or, rather, whether they represent a net cost for taxpayers. The lack of the feedback on the use of official statistics also prevents NSOs to allocate their scarce resources more efficiently, i.e. to generate statistical products that better suit the information needs of stakeholders.

This paper first analyses the extent to which public and private sector stakeholders in Tanzania and Uganda use official agricultural statistics as provided by the National Bureau of Statistics (NBS) and the Uganda Bureau of Statistics (UBOS) respectively. It builds on data of an online survey implemented by NBS and UBOS in the first quarter of 2016. Results show that stakeholders use only a minor share of the agricultural data collected by the NSOs. The paper then proposes two innovations to enhance the utilization of agricultural data and statistics, which have been tested and implemented using household level livestock data in both Tanzania and Uganda. The first is to complement investments that improve the quantity and quality of official statistics with investments that collect the information needed for decision-makers to design and implement policy reforms. Collecting data to depict, monitor and evaluate the situation on the ground, which is what official statistics largely do, is in fact not sufficient on its own to generate evidence to find effective ways to improve it. The second innovation is on data utilization: data can be disseminated not only in NSOs' reports and as statistical software files but also in simple spreadsheets with embedded statistical commands, which suit the need of stakeholders. This approach empowers stakeholders and is implementable with a more efficient allocation of NSOs' available resources.

Keywords: agricultural data utilization; data dissemination; evidence-based decisions

1. Introduction

The importance of strengthening the evidence base for policies and investments cannot be over-stated. Target 17.18 of the UN Sustainable Development Goals aims to "*increase significantly the availability of high-quality, timely and reliable data … relevant in national contexts*", and target 17:19 to "*develop measurements of progress on sustainable development*". The UN Report "A World that Counts: Mobilising the Data Revolution for Sustainable Development" reads: "*Data needs improving. Despite considerable progress in recent years, whole groups of people are not being counted and important aspects of people's lives and environmental conditions are still not measured*" (UN, 2014).

A number of initiatives and investments are currently being implemented for improving the quantity and quality of data for decision-making. Cases in point are the Partnership in Statistics for Development in the 21st Century (PARIS 21); the Global Strategy to Improve Agricultural and Rural Statistics (GSARS); the Living Standards Measurement Studies – Integrated Surveys on Agriculture (LSMS-ISA); and the May 2016 Bill & Melinda Gates Foundation's commitment to provide national statistical offices with USD 80 million in the next three years to collect gender-related data (BMFG, 2016). Underpinning these investments is the assumption that the generated information will contribute to better decision-making. However, there is so far little systematic evidence on the use of official statistics by stakeholders. This makes it difficult for National Statistical Officers (NSOs), and for other interested stakeholders, to appreciate whether investments to produce quality statistics are generating good returns; the lack of the feedback on the use of official statistics also prevents NSOs to improve the way they allocate their (scarce) resources.

This paper first analyses the extent to which public and private sector stakeholders in Tanzania and Uganda make use of official agricultural data and statistics, as produced by the Tanzania National Bureau of Statistics (NBS) and by the Uganda Bureau of Statistics (UBOS) respectively. It builds on an online survey on the utilization of NSOs agricultural data and statistics implemented by NBS and UBOS in the first quarter of 2016. Results suggest that stakeholders use only a minor share of the agricultural data collected by the NSOs, and notably only the statistics published in NSOs reports and websites. The paper then proposes two innovations to enhance the utilization of agricultural data and statistics, which have been tested and implemented using household level livestock data in both Tanzania and Uganda. The first is to complement investments that improve the quantity and quality of official statistics with investments to collect the information needed for decision-makers to design and implement policies and investments on the ground. Collecting data to portray, monitor and evaluate the situation on the ground, which is what official statistics largely do, is in fact not sufficient on its own to generate evidence to find effective ways to move forward. The second innovation targets data utilization: microdata can be disseminated not only in NSOs' reports and as statistical software files but also in simple spreadsheets with embedded statistical commands, which suit the need of stakeholders. This approach empowers stakeholders and is implementable with a more efficient allocation of NSOs' available resources, provided of course that all ethical and legal issues associated with microdata dissemination are successfully addressed

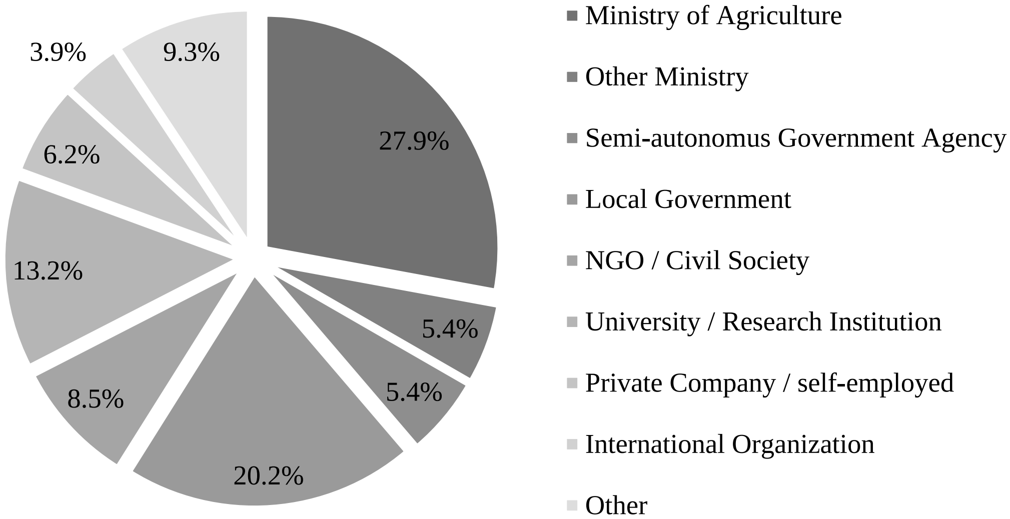
The next section presents the NBS and UBOS survey on stakeholders' utilization of agricultural data and statistics. Section 3 illustrates how NBS and UBOS innovated to improve stakeholders' utilization of livestock data and statistics in Tanzania and Uganda respectively. Section 4 presents conclusions.

2. The (under)utilization of NSO's agricultural data and statistics

In February and March 2016, the Tanzania National Bureau of Statistics and the Uganda Bureau of Statistics joined forces to undertake an online survey among agricultural stakeholders to appreciate their utilization of official agricultural data and statistics. The survey collected information on respondents' affiliation; relevance of agricultural data; sources of data; purpose of using the data; available statistical-related software; outputs produced; ease of access and ease of use of agricultural data; and other.

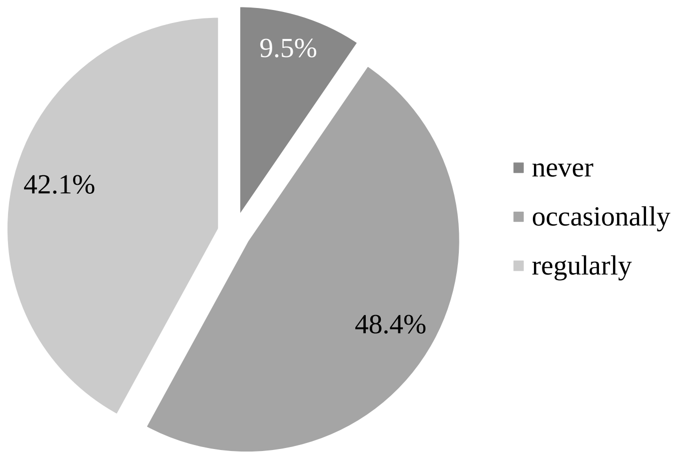
NBS and UBOS sent an email with a hyperlink to the survey to 491 potential respondents, of which 263 in Uganda and 228 in Tanzania. The target population included all UBOS and NBS agricultural-related contacts for which an email address was available. 149 stakeholders or 30 percent of the target population completed the survey, which is an expected response rate for online surveys (Nulty, 2008; Shih and Fan, 2008). Respondents largely include staff in national and local governments responsible to invest taxpayers' money for agricultural development (fig.1). In particular, 59 percent of all respondents work for the public sector, including the Ministry of Agriculture (27.9%); Other Ministries (5.4%); Semi-autonomous Government Agencies (5.4%), such as the Dairy Development Authority; and Local Governments (20.2%). Other respondents represent the private sector, the civil society, the academia, and international organizations.

Fig. 1. *Survey respondents by affiliation*



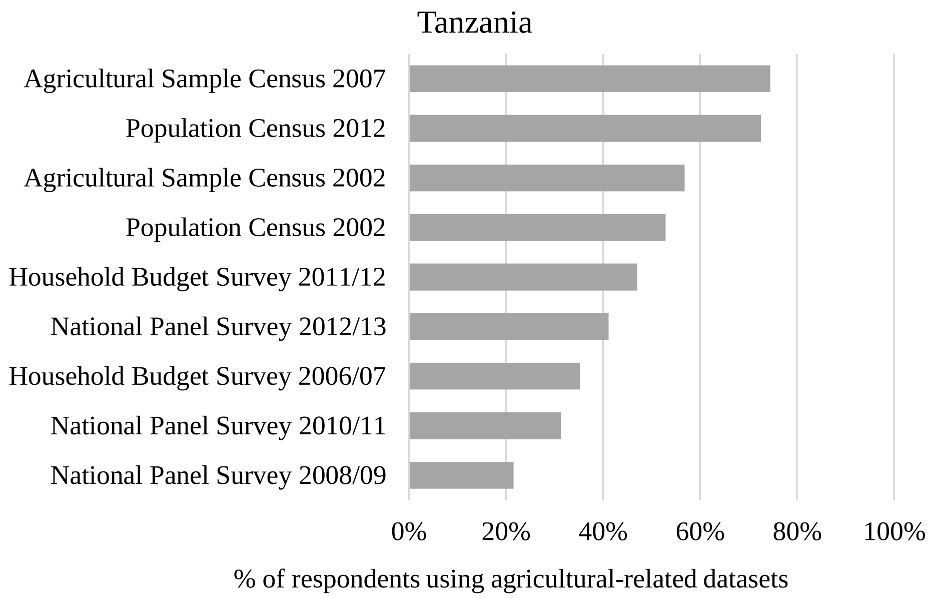
Respondents highly value NSOs' agricultural data and statistics: 76 percent and 35 percent of them indicate that agricultural data and statistics are "very important" and "important" for their work respectively. At the same time, 90 percent report to utilize NSOs' agricultural data and statistics: 42 percent use them on a regular basis, that is at least four times per year or more; and 48 percent use NSOs' agricultural data and statistics occasionally, i.e. less than once per quarter.

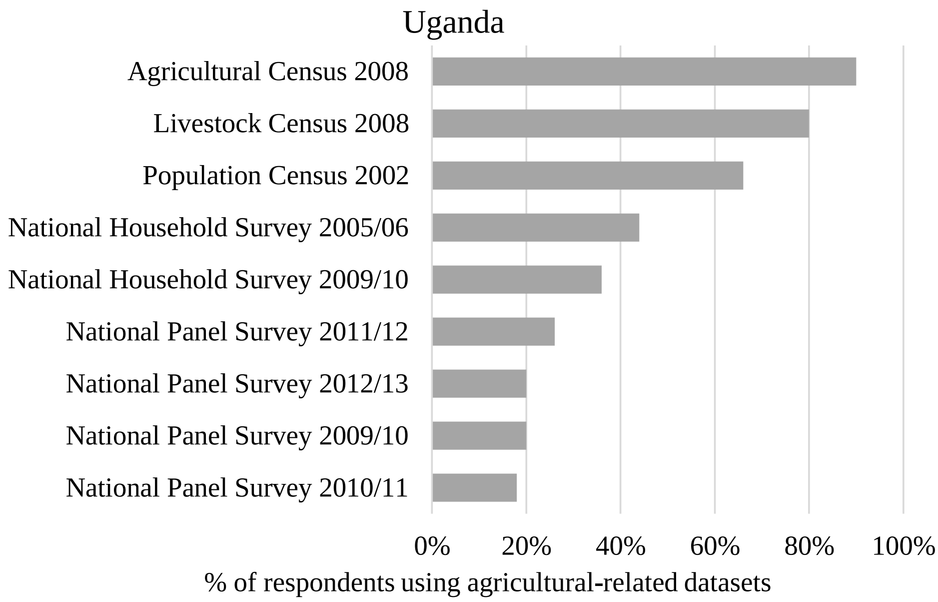
Fig. 2. *Frequency of use of NSOs' agricultural data and statistics*



Respondents primarily use census data, with 70 percent and 81 percent on average utilizing data either from the Population and Housing Census or the Census of Agriculture (Livestock) in both Tanzania and Uganda respectively. Fewer respondents utilize data from sample surveys, notably an average of 35 percent in Tanzania and 27 percent in Uganda.

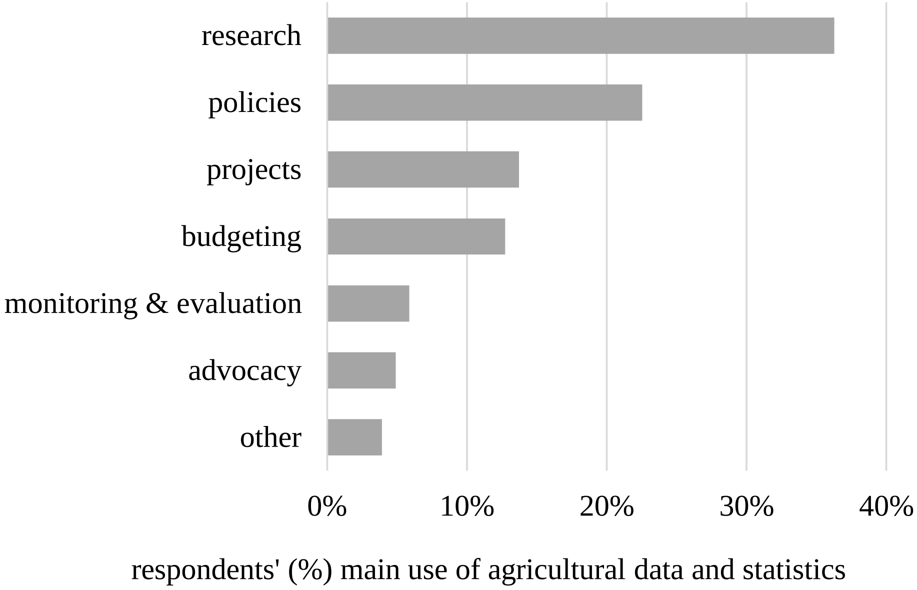
Fig. 3. *Main agricultural data and statistics utilized by stakeholders*





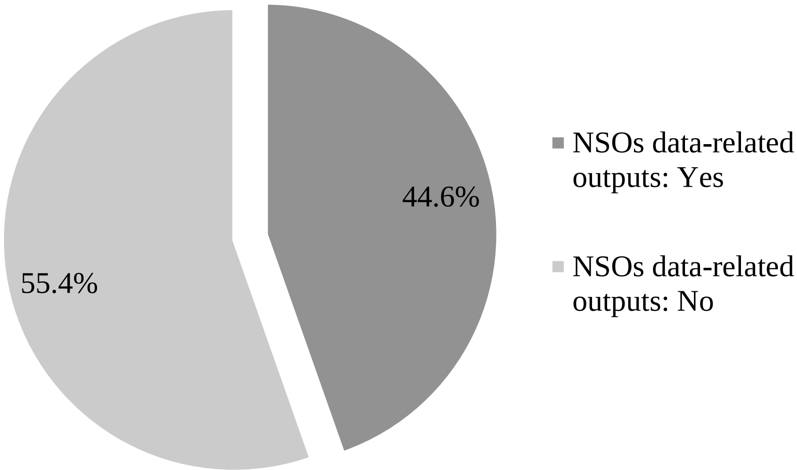
Research is the main single purpose for using official agricultural data and statistics (35% of respondents). However, the use of agricultural data and statistics for designing policies and projects, budgeting, monitoring and evaluation accounts for 55 percent of all uses. This is consistent with the finding that about 59 percent of all respondents are employed by the public sector.

Fig.4. *Purpose for using NSO' agricultural data and statistics*



The survey results also reveal that 45 percent of the respondents contributed to some outputs that build on NSOs' agricultural data and statistics, while 55 percent did not contribute to any. This is consistent with the evidence that about 42 percent of all respondents claim to use NSOs' agricultural data and statistics with regularity.

Fig.5. *Share of respondents producing outputs based on NSOs' agricultural data and statistics*



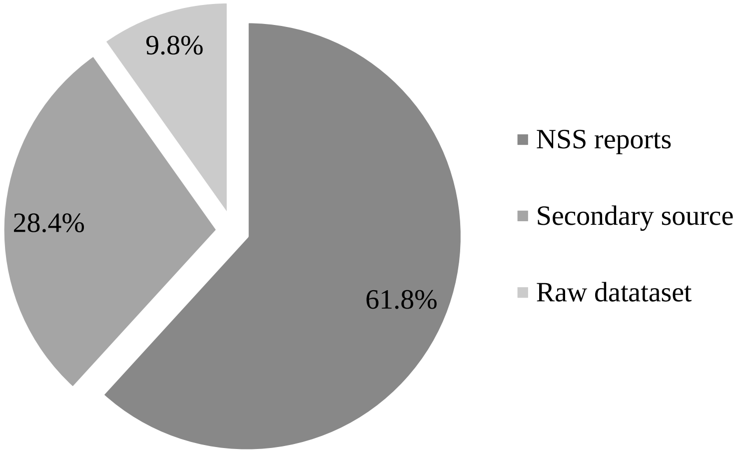
The story so far is one of a good use of NSOs' agricultural data and statistics. However, a closer look at the survey data reveals not only that over 58 percent of stakeholders do not make use or only occasionally use available NSOs' agricultural data and statistics (fig.2), but also that they only use a minor part of the collected data. Fig.6 displays stakeholders' source of NSOs agricultural data and statistics, including NSOs' reports; secondary sources, such as papers and documents that build on NSOs' data and statistics; and raw datasets. The figure indicates that 62 percent of all respondents find agricultural data and statistics in NSOs' reports; 28 percent find them in secondary sources; and 10 percent access the raw datasets for different use.

The Census Reports admittedly comprise a detailed analysis of the collected data – largely because Censuses gather relatively few information – but provide information only on those aspects of agriculture that change slowly over time. This information is valuable for policy makers when complemented with more detailed and frequent data on agricultural production practices, including on non-structural variables such as on type of fertilizers used or crop yield. Sample surveys are the tool that provide this information to decision-makers. The issue is that NSOs' reports of sample surveys only contain statistics for few of the collected data. For example:

a) The NBS Report of the Tanzania 2011/12 Household Budget Survey presents one table on land ownership by plot size and one on land ownership by type of tenure (NBS, 2014). The underpinning dataset, however, also includes information on the use of the plot (e.g. cultivated, rented out; etc.); on income from renting; on the value of in-kind production; on soil type; on the quality of the soil type; on irrigation; and on the value of the land parcel. Unless stakeholders analyse the raw data, all this latter information remains unexploited; and
b) The UBOS report of the 2011/12 National Panel Survey (NPS) includes two tables and one graph on animal rearing, which all focus on livestock ownership (UBOS, 2013). The NPS agricultural questionnaire, however, includes about 80 questions on livestock. Unless stakeholders analyse the raw data almost all of the collected information on livestock is not used for decision-making.

The evidence that only 10 percent of the stakeholders access and use NSOs agricultural datasets (fig. 6) indicates, therefore, that official agricultural data and statistics are largely unutilized for decision-making. This is an issue also because stakeholders often participate in survey design and would be eager to analyse available data. The implication is, at least for the agricultural data of Tanzania and Uganda, that the budget allocated for data collection and dissemination is not supporting a wide use of the data. The NSOs should innovate to facilitate the use of agricultural data and statistics by policy-makers and other stakeholders, thereby ensuring that the resources allocated for data collection are an investment with good returns for society and public at large.

Fig.6. *Source of agricultural data and statistics by share of stakeholders*



3. Innovations to enhance the utilization of agricultural statistics

Since 2011, NBS and UBOS have been collaborating with the Tanzania Ministry of Agriculture, Livestock and Fisheries (MALF), the Uganda Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) and the FAO Livestock in Africa: Improving Data for Better Policies Project to increase the quantity and quality of livestock data available to decision-makers, while at the same time ensuring their use for policy purposes. There are two major lessons out of this process:

a) The first is that investments to improve the agricultural (livestock) statistical system generate good returns particularly when complemented with investments that generate the information needed for decision-makers to design and implement policies and investments on the ground. Collecting data to portray, monitor and evaluate the real situation on the ground, which is what official statistics largely do, is in fact all but sufficient to generate evidence to find effective ways to improve it; and
b) The second lesson is that NSOs can adopt simple and low-cost methods to disseminate entire or selected sections of complex datasets to stakeholders, which allows them to perform their own statistical analysis. In particular, as in most cases stakeholders only perform explorative data analyses, disseminating data in simple spreadsheets with embedded statistical commands is an effective way to empower them.

3.1. Evidence-based decision-making: beyond official statistics

"*The real value of data is that they can track performance and serve to indicate to decision-makers whether they have met their specified targets or not. While this is, of course, vital, they do not help decision-makers understand what they need to do in order to improve their performance going forward*" (UK Statistics Commission, 2007). This simple fact is poorly understood: investments to improve the statistical system, in fact, are rarely complemented with investments to generate data and information for decision-makers to effectively design and implement policies on the ground. For ease of clarity, let's assume that the decision-maker is the Ministry responsible for the agricultural sector; and that the Ministry's overarching goal is the design ex-novo of a comprehensive agricultural sector policy and associated investment plan. To this end, data and information needs span five main domains (Pica-Ciamarra and Baker, 2014).

a) ***Agriculture, economic growth and poverty reduction***. Data and information are needed to show that the development of agriculture, and in particular a given new initiative in the sector, contributes to one or more broader socio-economic development goals of the country. Statistics representative of the agricultural as a whole, of typologies of farmers and production systems, are necessary to this end. Official statistics serve this purpose, such as living standard measurement studies, agricultural / farm surveys and household budget surveys;

b) ***Productivity constraints***. Identifying the binding constraints that prevent different types of farmers from making efficient use of their productive resources is indispensable in identifying priority areas for policy reform and investment. Such constraints could include, for example, inadequate access to seeds and fertilisers, or animal disease prevalence. The agricultural census and/or sample farm and agricultural surveys are excellent sources of data to identify typologies of farmers and their productivity constraints;

c) ***Policy and investment priorities.*** Moving on from constraints, identifying their root causes is essential for establishment of policy and investment priorities. For example, the root causes of animal diseases could be a low vaccination rate; poor application of vaccines and drugs; use of counterfeited drugs; broken cold chain; uncontrolled animal movements across districts; contaminated water points or animal feed; uncontrolled livestock-wildlife interaction; and other. The NSOs are neither mandated nor expected to provide regular data and statistics on all the possible determinants of animal diseases, or of any other constraint for that matter. Indeed, it would be an inefficient use of resources for NSOs to regularly collect data on, for example, all possible intrinsic and extrinsic determinants of even one animal disease – including "living" agents such as viruses, bacteria, and other; "non-living" agents, such as temperature, nutrients, and other; and the multidude of climate, soil and man-driven causes. Only when animal diseases are identified as a main development constraints, therefore, decision makers should invest resources to identify their root constraints: they need to opportunistically engage and exchange information with a multitude of stakeholders, as well implement *ad hoc* statistical surveys targeting some detailed information that cannot be efficiently generated on a regular basis by the NSOs. This is necessary to identify policy and investment priorities;

d) ***Policy and investment design.*** Once the root cause of a constraint has been identified, decision-makers need data and information on the pros and cons of alternative policy instruments for easing and/or removing the root causes of one or more binding constraints. Data and statistics to identify the first best policy instruments are not immediately available, as the implementation of policy reforms usually co-occurs with some form of institutional change – new ways of doing things – which calls for changed behaviors of both implementers and beneficiaries. For example, it could be difficult to say ex-ante whether the system of animal health services is better improved through hiring additional animal health workers, or through providing transport allowances to existing extension agents. Stakeholder consultations and experimentations on the ground, possibly supported by some scientific data collection or survey, assist policy makers in gathering the information needed for identifying the first best policy instrument; and

e) ***Monitoring and evaluation***. Monitoring and evaluation are necessary to ensure that policies and investments be properly implemented and to provide guidance on adjustments. NSOs' data and statistics are a major source of indicators for both monitoring behavioral changes (e.g. farmers' utilization of extension services) and evaluating their impact (e.g. crop yields).

It should be clear from the above that official statistics, while an essential component of the decision-making process, provide on their own little guidance to policy makers to design and implement policies on the ground. And that any rational decision-maker, either for the public or the private sector, has little incentives to analyse NSOs' data and statistics unless s/he is sure that resources are also available to fill her/his information needs along the entire decision-making process. In Tanzania and Uganda, before embarking in any improvement of the agricultural (livestock) statistical systems, NBS, UBOS, MALF and MAAIF agreed to jointly generate all the evidence needed along the entire decision-making process, i.e. to complement investments to improve the agricultural (livestock) statistical system with investments to generate the additional information needed to design and implement effectively policies on the ground. This approach provided major incentives for the Agricultural Sector Lead Ministries (ASLMs) responsible for livestock to allocate more time and resources to analyze NSOs' livestock data and statistics.

3.2. Data dissemination in spreadsheets with embedded statistical commands

A major challenge encountered in the process towards the design of evidence-based agricultural (livestock) policies and investments was the difficulty for staff in the Ministries responsible for livestock to analyze NSOs' datasets, and in particular the livestock section of both the Tanzania 2012/13 National Panel Survey (TZ-NPS) and the Uganda 2011/12 National Panel Survey (UGA-NPS). Breeding scientists, feed specialists, veterinarians, epidemiologists and the like are rarely trained to thoroughly analyse household and agricultural survey data.

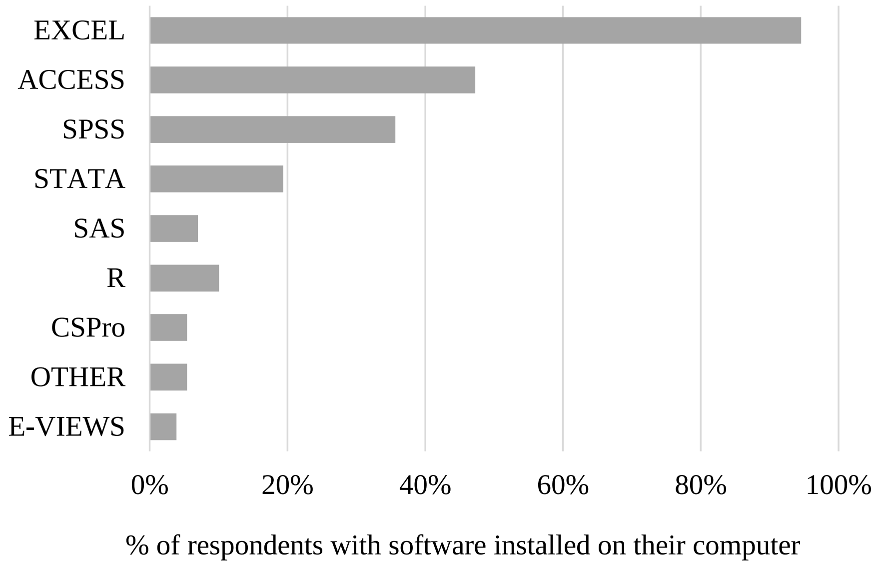
a) A tabulation plan proved ineffective at driving a constructive policy discussion: each produced statistical table, in fact, while in itself useful, led to unplanned questions that resulted in the generation of an endless cascade of tables. For example, once a table was produced on milk yield per cow; stakeholders started demanding tables by type of breed; by herd size; by household's access to veterinary services; by household's membership in livestock association; by availability of a processing plant in the community; and other. In other words, decision-makers were not able, but for a key set of statistical tables, to clearly define the information content of all the tables they would have liked NSOs to generate out of the available livestock dataset; and
b) Training in using statistical software was also considered as a poor investment to facilitate the use of official livestock data. Most stakeholders use NSOs data and statistics occasionally, and training makes sense only if the trainees make regular use of the acquired skills. In addition, data users concurred that an explorative analysis of NSOs data was largely sufficient for policy purposes and, therefore, that there was no need to use statistical packages to generate summary statistics.

NBS and UBOS agreed therefore, in close consultation with the Ministries responsible for livestock, to experiment with disseminating NSOs' livestock data in a simple spreadsheet with embedded statistical commands. The dissemination of microdata was possible in both countries as the data had been already disseminated in both STATA and SPSS, i.e. NBS in Tanzania and UBOS in Uganda had already succesfully addressed all the legal and ethical issues associated with micro-data dissemination (Dupriez and Boyko, 2010). Eventually, NBS and UBOS disseminated the livestock microdata in *MS Excel*, and for two major reasons: first, it was found that the majority of stakeholders have *MS Excel* installed on their computer (fig. 7); second, with respect to other possible forms of micro-data dissemination (e.g. CVS, text), *MS Excel* has embedded statistical commands that allow users to generate summary statistics straightforwardly, including weighted statistics. Of course, any other popular data spreadsheet with embedded statistical commands would be as good as *MS Excel* to disseminate microdata to users and provide them with some statistical power. The following is the procedure taken on board by NBS and UBOS Team to come up with datasets in *MS Excel* for the stakeholders.

a) First, the Ministries responsible for livestock, identified a set of livestock-related variables out of the Tanzania and Uganda National Panel Surveys of particular relevance for policy making, from animal ownership through animal vaccination to the utilization of livestock-related services;

b) Second, NBS and UBOS generated targeted datasets around those variables, including one dataset on key socio-economic characteristics of livestock-keeping and non-livestock-keeping households; one dataset on animal ownership and basic production practices for all livestock-keeping households in the country; and detailed datasets on livestock ownership and production practices for indigenous cattle-, indigenous goat-, indigenous sheep-, local chicken-, and pig-keeping households. NBS and UBOS generated also livestock sub-datasets by rural and urban households, and included in all datasets a dummy poverty variable and an annual income variable; and
c) Third, NBS and UBOS provided the Ministries responsible for livestock with the developed livestock datasets in *MS Excel* spreadsheets: this was doable given the sample size of the National Panel Surveys: it comprised about 1,800 livestock-keeping households in Uganda and about 2,100 in Tanzania. The distributed *MS Excel* spreadsheets included *ad hoc* commands to calculate representative statistics at different levels of aggregation, notably the weighted average, the median and the standard deviation.[1]

Fig.7. *'Statistical-related' software installed on respondents' computers*



With livestock data available in *MS Excel* spreadsheets, the Ministries responsible for livestock could:

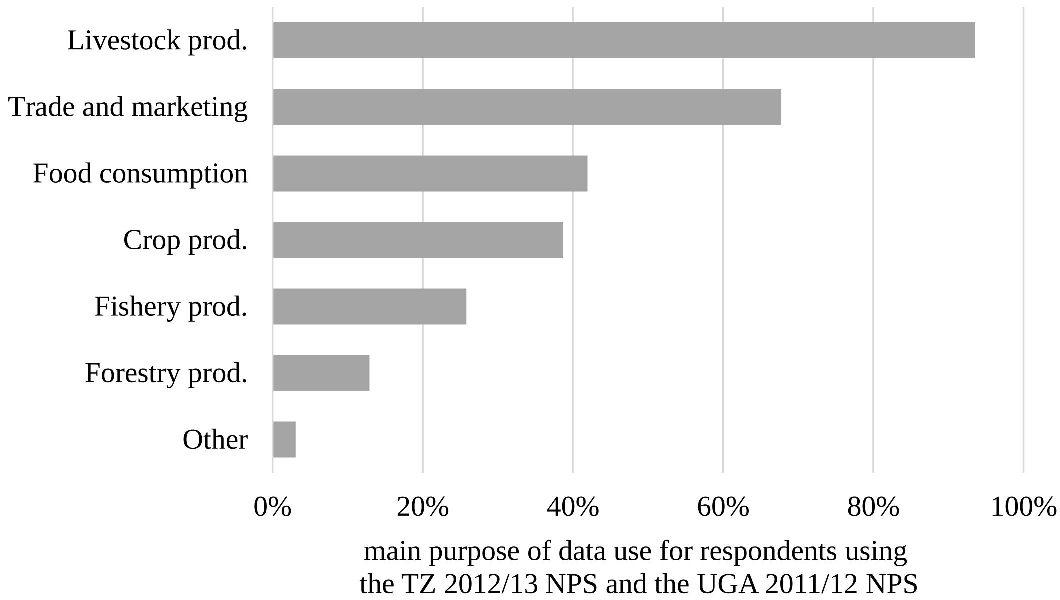
a) Correct few unambiguous data-entry errors, which could not be detected through standard statistical procedures (e.g. adjusting the weight of a live chicken from 13 to 1.3 kilos);
b) Generate additional variables to respond to specific policy questions (e.g. a dummy on household consumption of any type of animal protein); and
c) Perform an explorative analysis of the household-level livestock data, which is summarised in two reports on the Smallholder Livestock Sector in Tanzania and Uganda (MALF, 2016; MAAIF, 2016). It was one of the first times ever in which staff in the Ministries responsible for livestock generated representative statistics out of a NSO' dataset with no need of technical assistance or investments in capacity building.

Results from the 2016 survey implemented by NBS and UBOS on the utilization of agricultural data and statistics indicate that, disseminating datasets in spreadsheets with embedded

[1] The main challenges in exporting the NPS livestock data in a statistically usable *MS Excel* spreadsheet were to give codes 0 and 1 to all dichotomous questions and to split multiple response questions into different columns with codes 0 and 1. See UBOS (2016) *NPS 2011/12: Section and Datasets on Livestock – Basic Information Document* or NBS (2016) *NPS 2012/13: Section and Datasets on Livestock – Basic Information Document* for codes and commands to calculate the representative average, median and standard deviation in *MS Excel*.

statistical commands (*MS Excel* in this case) widely facilitates and motivates the use of data for various purposes. Among the respondents that utilized the Tanzania 2012/13 National Panel Survey and the 2011/12 Uganda National Panel Survey, 98 percent developed some statistical tables on livestock, with statistics on marketing and food consumption ranking second and third (68% and 42% of respondents respectively) (Fig.8). The analysis of the NPS livestock datasets undertook by the national governments suggested that, in both countries, limited access to livestock services is a binding constraint to livestock development: both MAAIF and MALF are currently gathering and analyzing additional data and information for designing an effective policy to improve the systems of animal health services in Uganda and Tanzania respectively.

Fig. 8. *Utilization of the Tanzania 2012/13 National Panel Survey and the Uganda 2011/12 National Panel Survey by purpose*



4. Conclusions

This paper analysed the extent to which public and private sector stakeholders in Tanzania and Uganda use official agricultural statistics as produced by the Tanzania National Bureau of Statistics and the Uganda Bureau of Statistics (respectively. It builds on data from an online survey implemented by NBS and UBOS in the first quarter of 2016. Results showed that stakeholders use only a minor share of the agricultural data collected by the NSOs, which promoted NBS and UBOS to innovate .

The paper presents two innovations to enhance the utilization of agricultural data and statistics, which have been tested and implemented using household level livestock data in Tanzania and Uganda. The first is to complement investments that improve the quantity and quality of official statistics with investments to collect the information needed for decision-makers to design and implement policies and investments on the ground. Collecting data to depict the situation on the ground, which is what official statistics largely do, is in fact not sufficient on its own to generate evidence to find effective ways to improve it. The second innovation is on data utilization: data can be disseminated not only in NSOs' reports and - when ethical and legal issues related to microdata dissemination are successfully addressed - as statistical software files, but also in simple spreadsheets with embedded statistical commands, which suit the need of stakeholders. This approach empowers stakeholders and is implementable with a more efficient allocation of NSOs' available resources. As the largest share of NSOs collected data currently remain unused, National

Statistics Offices could consider reducing the quantity of the data collected and allocate the saved resources to generate and disseminate targeted datasets, as demanded by stakeholders, in simple spreadsheets.

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Assessing the Impact of Agricultural Research: Data Requirements and Quality of Current Statistics in Europe

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ABSTRACT[1]

Assessing the impact of agricultural research on sustainability targetsoften implies to face two main issues: the complexity of the causal path, and the lack of appropriate data. In this paper, we discuss which data would be necessary to measure short- and long-term impacts in Europe,and suggest a set of indicators to evaluate their quality, considering both metadata and collected data form the Eurostat database. An application isshown for a selection of 20 variables.In our results, qualitative and quantitative indicatorsoften provide conflicting information.We believe that such contrast is due to the fact that metadata can describe data quality only partially, while collected data can emphasize further quality features like the pattern of missing values and the presence of outliers.

Keywords: Data quality indicators;Data quality dimensions;Impact of agricultural research.

1. Introduction

Agriculture is an important target of EU and national policies. In particular, there is an increasing demand of knowledge on the effects of agricultural research on the EU sustainability targets. The achievement of suchknowledgedepends on two main factors: the complexity of the causal path, and the lack of appropriate data. Agricultural activities produce effects through a large number of pathways, from short-term impacts on agriculture production tolong-term impacts on people's sustainable well-being. Ideally, a unified analytical approach would jointly consider impacts across all the relevant sustainability dimensions at a local, national and over-national level.Methodologies in the literature range from disaggregate to aggregate analysis, from the assessment of economic rate of return to the assessment ofmulti-dimensional impacts.However, the extent of available statistical methods often contrasts with a general lack of appropriate data.This paper provides an insight into the quality of availablestatistics (Eurostat data) when analysing the effect of agricultural research on multiple targets in Europe.The paper is organized as follows. In Section 2, we concisely focus on the themes of interest of datarequired to investigate the short- and long-term effects of agricultural research in Europe. In Section 3, we suggest somesynthetic indicators for the quality of data.In Section 4,we compute suchindicators for a selection of variables representative of the themes of interest above. Conclusions are provided in Section 5.

2. Data: themes of interest

Following Bartolini et al. (2014), wedelineate the impact pathway from agricultural research expenditure to multiple sustainability dimensions through five interconnected levels: context/external drivers, investment, research activity, outcome andimpact.

The context/external driverslevel accounts for countries' specific characteristics, which may act as a confounder of the relationships among the other levels. Contextvariables includemacroeconomic variables (e.g. gross domestic product) as well as the disposal of agricultural resources (e.g. land and labour). External drivers take into account policies, regulations and laws, as

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well as technology innovations from economic sectors other than agriculture (for instance, chemical and mechanic patent applications as pointed out by Thirtle et al., 2008).

The investment level includes the variables describinghow agricultural research is fundedwithin each country (e.g.,general government and business enterprise expenditure).

Outputs of research activity represent the first and most immediate results of research investments.Campbell et al. (2013) consider human resources (e.g., number of high qualified researchers), quality of research (e.g., number of EU funded projects), innovation (e.g., number of patent applications), research infrastructures, industrial specialization and publications.

The outcome level includes the immediate impact of research activity on farm production.Productivity of the agricultural sectoris the representative variable of this level.

The impact level contains variables non-immediately affected by research investment and encompasses multiple dimensions. This level includesfor instance, changes in farmers' economic conditions and wellbeing, changes in environmental conditions (pollution emissions; biodiversity; soil and water quality) and changes in social conditions (health, education, food security, poverty, migration, etc.).

Output, outcome and impact variables identifythe possible targets of European agricultural research. Applying textual mining techniques on the abstracts of EU funded research projectsin agriculture[2], Bartolini*et al.* (2016) analyse changes in the share of budget among different research targets from 1994 to 2009, and found that,during late 90s, economic competitiveness and reduction of environmental pressure were the highest priorities of research projects, while, since 2000, the larger share of budget was finalized to support projects having an expected impact on the health of European consumers and citizens.

Assessing the impact of agricultural research requires recovering adequate data for each theme of interest (level) above. Eurostat, FAO, OECD, ILO, the World bank and other international institutions disseminate data on most of them. However, due to the heterogeneity of the issues covered, availabilityand quality of data vary significantly across countries and time. Along with well- established and harmonized statistics (e.g., labour or national accounts statistics), we find poor quality data. Statistics seem adequate at first glance butsometimes concealmissing values, short time series or breaks in the series. In our view, it would be helpful if statistics were disseminated along with synthetic quality scores, in order to make immediately clear their actual usability. In the next sections, we suggest some quality indicators and present results for a selection of 20 variables representative of the impact pathway from agricultural research expenditure to multiple sustainability dimensions.

3. Quality indicators

Assessing the impact of agricultural research in European countries requires managing both time series and cross-section data sets. On the one hand, long time series for investment and research variables are required since their effects on target variables occur at different time lags. On the otherhand, complete and comparable cross section statistics are needed to allow international comparisons. Thus, comparability over time and among countries represent the most importantquality requirements.

Several institutions disseminate time series and cross-section data sets on the themes of interest detailed in Section 2, so that the identification of the best data source for each variable isanecessaryfirst step. In this paper, we focus on Eurostat statistics only,as Eurostat is the primary data source for European countries, anddisseminatesthe best metadata on data quality through single reports for each statistic (Euro-SDMX Metadata Structure files; ESMS files henceforth).

[2] 4th FP (1994-1998), 5th FP (1999-2002) and 6th FP (2002-2006) projects. Only projects with main topic 'Agriculture and food' or subtopic 'Agriculture'within the 'Biotechnology' topic were selected.

However, basing on Eurostat available metadata it is not immediateto detect the overall quality level of each variable, nor to understand for which analysis each variable could be fruitfully used (time series or cross sectional analysis, or both). In this section, we propose some quality indicatorsto beprovided along with data in order tomake users immediately aware of their actual usability.We consider both metadata and collected data.

3.1 Qualitative indicators based on Eurostat metadata

A detailed report on data quality (ESMS file) is available for all the statistics in the Eurostat database. ESMS reports contain very useful information but their length (no less than 5 pages) andtheirlevel of detail may discourage the user.

We summarize ESMS reports into four variables. The first variableconsiders the typology of data sources used to collect/produce data, assuming that the level of comparability and accuracy decrease going from Censuses to National Accounts, Surveys,Administrative data sources and Mixed data sources (such as inventories derived from various data sources). The second variabletakes into account the 'Institutional mandate'section of ESMS files, which specifies if statistics are produced/collected on behalf of EU regulations and if they are disseminates on a mandatory, gentlemen's agreement or voluntary basis. In this case, we assume that data quality improves if the collection, production and transmission of data are regulated. The third and fourth variables assign a quality level(low, medium, good and high) on the temporal and the geographical comparability, respectively. The quality level is derived directly from the assessments given in the 'coherence and comparability' section of ESMS documents.

3.2 Quantitative indicators based on data evidence

We develop several quality indicators on the basis of the evidence stemming from collected statistics. We considered two features of quality: missing data and outlier data. First, we focus on missing values, providing measures of their incidence both in time and space (i.e. across countries). Then, we consider the incidence of contiguous values in each time series. Finally, we focus on the detection of outliers, once all the time series are made stationary. The value of each indicator varies from 0 (minimum quality) to 1 (maximum quality).

Notation is the following. The set of countries is denoted as $j = 1, \dots, J$, and $X_{i,j,t}$ denotes the i-th variable ($i = 1, \dots, I$)in the j-th country at time slice t ($t = 1, 2, \dots, T$).

Missing data incidence

Let $o_{i,j,t}$ be a dummy variable such that $o_{i,j,t} = 1$ if the value of $X_{i,j,t}$ is available (not missing), otherwse $o_{i,j,t} = 0$. We define three indicators measuring the incidence of missing data.

- **Spatial Availability Index**. Proportion of available data for a certain variable in a certain country:

$$SAI_{ij} = \frac{1}{T} \sum_{t=1}^{T} o_{i,j,t}$$

- **Temporal Availability Index**. Proportion of available data for a certain variable at a certain time slice:

$$TAI_{it} = \frac{1}{J}\sum_{j=1}^{J} o_{i,j,t}$$

- **Contiguity Index**. Contiguity of available data for a certain variable in a certain country, computed as the proportion of available data adjacent to an available datum:

$$CI_{ij} = \frac{1}{T-1}\sum_{t=1}^{T-1} o_{i,j,t}\, o_{i,j,t+1}$$

Outlier data incidence

The distribution of a time series may change through time, that is it may contain an unit root or may not be stationary. If this is the case, the detection of outlier data does not make sense. For each variable$i$ and for each country j, denote the order of integration as d_{ij}, that is the minimum number of differences required to obtain a significant result of the Dickey-Fuller test (rejection of the unit root hypothesis). Consider the *Skewness-adjusted Outlyingness* (Brys et al., 2005), a robust measure of outlyingness for skewned distributions:

$$\zeta_{ijt} = \begin{cases} \dfrac{\tilde{X}_{i,j,t} - M_{ij}}{R_{ij} - M_{ij}} & \tilde{X}_{i,j,t} \geq M_{ij} \\[2ex] \dfrac{M_{ij} - \tilde{X}_{i,j,t}}{M_{ij} - L_{ij}} & otherwise \end{cases}$$

with:

$$L_{ij} = \begin{cases} Q_{ij} - 1.5e^{-4MC_{ij}}(QQ_{ij} - Q_{ij}) & MC_{ij} \geq 0 \\ Q_{ij} - 1.5e^{-3MC_{ij}}(QQ_{ij} - Q_{ij}) & otherwise \end{cases}$$

$$R_{ij} = \begin{cases} QQ_{ij} + 1.5e^{-3MC_{ij}}(QQ_{ij} - Q_{ij}) & MC_{ij} \geq 0 \\ QQ_{ij} + 1.5e^{-4MC_{ij}}(QQ_{ij} - Q_{ij}) & otherwise \end{cases}$$

where $\tilde{X}_{i,j,t}$ represents $X_{i,j,t}$ after applying d_{ij} differences, whereas M_{ij}, Q_{ij}, QQ_{ij} and MC_{ij} are the median, the first quartile, the third quartile and the medcouple (an adjusted measure of skewness: Brys et al., 2004) of the i-th variable in the j-th country after applying d_{ij} differences, respectively. According to such outlyingness measure, $\tilde{X}_{i,j,t}$ is an outlier if $\zeta_{ijt} < L_{ij}$ or $L_{ij} > R_{ij}$. If this is the case, let $u_{i,j,t} = 0$, otherwise $u_{i,j,t} = 1$. We define the **Outlyingness Index** as the proportion of non-outlier data for a certain variable in a certain country:

$$OI_{ij} = \frac{1}{T}\sum_{t=1}^{T} u_{i,j,t}$$

4. Results

We selected a total of 20variables representative of each level of the research impact pathway from agricultural research expenditure to multiple sustainability dimension,excepting the Output level, aswe were not able to find Eurostat statistics on total factor productivity for Agriculture. Actually, according to Schreyer (OECD, 2015), in Europe only Statistics Denmark, Statistics

Finland, Statistics Sweden and ONS deliver estimates of total factor productivity for the A and B sectors of NACE classification.

We downloaded data and metadata from Eurostatwebsite (http://ec.europa.eu/eurostat/data/database) in May 2016. We considered15 EU countries (AT, BE, DE, DK, EL, ES, FI, FR, IE, IT, LU, NL, PT, SE and UK) in the period 1980-2015. For each of the selected variables, we computed quantitative (columns 4, 5 and 6) and qualitative (columns 8, 9, 10 and 11) indicators as defined in Section 3.2. Also, we derived anoverall quantitative indicator I1 (column 7) and an overall qualitative indicator I2 (column 12). Indicator I1 is obtained as follows: quartiles of each quantitative indicator are computed, then values from 1 to 4 are assigned to each quantitative indicator for each variabledepending on the nearest quartile (1 for the first quartile, 2 for the second, and so on), andfinallysuch valuesare averaged for each variable.Indicator I2is subjectively derived from the values taken by qualitative indicators. Results are shown in Table 1.

Figure 1 compares the I1 and I2 values after the variables under analysis are clustered into four groups:blue dots correspond to Economic variables, grey dots to Research variables, yellow dots to Social variables and orange dots to Environmental variables.We see that indicators I1 and I2 do not provide unanimous indication on data quality (Pearson correlation coefficient equal to -0.09): Research variables are characterized by low values of I2 and high values ofI1, Economic and Social variables show a balance between the values taken by the two overall indicators, Environmental variables exhibit a heterogeneous combination.

Figure 1. Comparison of overall qualitative and quantitative indicators for a selection of variables.

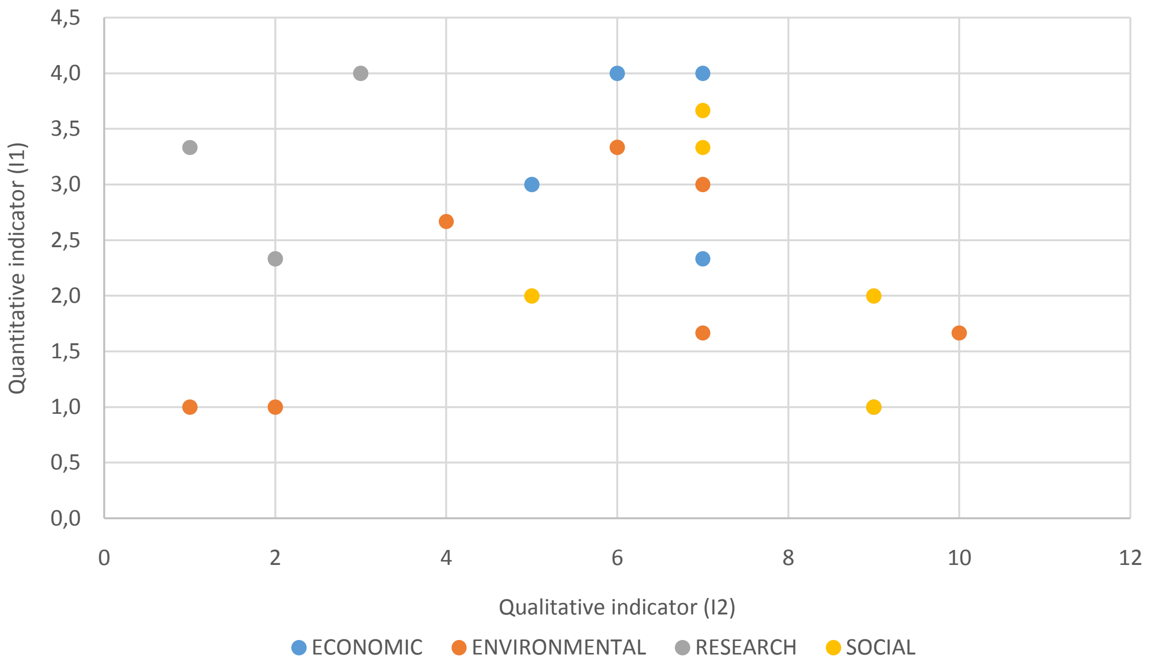

Table 1.Quality indicators based on collected data and quality reports from the Eurostat database on the 20 selected variables.

Description	Level of the impact pathway	Indicators computed on collected data				Indicators based on Eurostat ESMS files				
		Non-missing values	Contiguous over time	Non-outliers	I1: Overall quantitative	Primary data source	Institutional mandate	Comparability over time	Comparability across countries	I2: Overall qualitative
HA of arable land	ECONOMIC	0.86	0.83	0.99	4.0	Mixed sources (Economic Accounts for Agriculture)	EU Regulations (2004) sets harmonized methodology. Provision is on gentlemen's agreement	good	high	7
Business enterprise research expenditure for Agriculture	RESEARCH	0.31	0.29	0.98	2.3	Survey/Administrative	From 2004, collection is mandatory and regulated	Medium	Low	2
Greenhouse gas emissions from agriculture	ENVIRONMENTAL	0.64	0.63	0.98	3.0	Mixed sources (data produced by EEA)	Regulation in 2013. It is not clear if provision of data is mandatory	good	good	7
Energy for primary production	ENVIRONMENTAL	0.67	0.66	0.99	3.3	Censuses/Surveys (agricultural structure surveys)	Several EU Regulations. Provision is mandatory	medium	good	6
Share of energy from renewable sources in gross final energy consumption	ENVIRONMENTAL	0.28	0.26	0.98	1.7	Survey/Administrative	EC Regulations on methodologies. Data collection is voluntary	Good	good	7
Net entrepreneurial income of Agriculture – 2005=100	ECONOMIC	0.85	0.84	0.99	3.0	Mixed (Economic Accounts for Agriculture)	EU Regulations (2004) sets harmonized methodology. Provision is on gentlemen's agreement	Good	Medium	5
consumption estimate of Nitrogene	ENVIRONMENTAL	0.38	0.37	0.98	2.7	Survey/Administrative	Eurostat has no legal act in place requiring these data. The data are requested by gentlemen's agreement.	good	low	4
Government research expenditure for Agriculture	RESEARCH	0.9	0.89	0.99	4.0	Administrative	From 2004, collection is mandatory and regulated	Medium	Medium	3
Green house gas emission per capita	ENVIRONMENTAL	0.36	0.34	0.95	1.7	Mixed sources	Regulated and mandatory since 2004	high	high	10
Gross value added of Agriculture	ECONOMIC	0.88	0.88	0.99	4.0	Mixed (Economic Accounts for Agriculture)	EU Regulations (2004) sets the legal basis for a harmonized methodology. Provision is on gentlemen's agreement	Good	Good	6
Quota of persons with a good health status in rural areas	SOCIAL	0.27	0.25	0.93	1.0	Surveys/Administrative	Up to 2004(ECHP survey), data collaction was based on a gentleman's agreement. From2005 (Eusilc instrument) collection becomes mandatory.	High	High	9
Mean familiar income in rural areas	ECONOMIC	0.29	0.26	0.94	1.0	Surveys/Administrative	Up to 2004(ECHP survey), data collaction was based on a gentleman's agreement. From2005 (Eusilc instrument) collection becomes mandatory.	High	High	9
Annual work units salaried	SOCIAL	0.88	0.88	0.97	3.3	Mixed (Economic Accounts for Agriculture)	EU Regulations (2004) sets harmonized methodology. Provision is on gentlemen's agreement	good	high	7
Annual work units	SOCIAL	0.91	0.9	0.98	3.7	Mixed (Economic Accounts for Agriculture)	EU Regulations (2004) sets harmonized methodology. Provision is on gentlemen's agreement	good	high	7
Fully converted crop area (ha)	ENVIRONMENTAL	0.3	0.26	0.96	1.0	Administrative data	Gentlemen's agreement up to 2007. Then, transmission based on EU regulations	low	low	2
Number of agricultural patent applications: Agriculture, foresty, fishing	RESEARCH	0.84	0.81	0.99	3.3	Administrative	No official legal acts. Provision is voluntary	Low	Low	1
People at risk of poverty or social exclusion in thinly-populated area	SOCIAL	0.31	0.29	0.97	2.0	Surveys/Administrative	Up to 2004(ECHP survey), data collaction was based on a gentleman's agreement.	High	High	9
Utilised agricoltural area (1000 ha)	ECONOMIC	0.84	0.81	0.97	2.3	Mixed (Economic Accounts for Agriculture)	EU Regulations (2004) sets harmonized methodology. Provision is on gentlemen's agreement	good	high	7
Unemployment rate in rural areas	SOCIAL	0.61	0.6	0.97	2.0	Survey (EU-LFS)	Regulated and mandatory collection since 1998	medium	medium	5
Water used in Agriculture, forestry and fishing	ENVIRONMENTAL	0.01	0.01	-	1.0	Survey/Administrative	Data collection is voluntary	low	low	1

5. Concluding remarks

The evaluation of the short- and long-term impacts of agricultural research in Europe is an important theme for EU decision-making. To investigate thisphenomenon, it is necessary to dispose of high quality time and cross section data for a large numbers of variables. At a first sight, official statistics supply a plenty of information on the themes of interests (levels of the impact pathway from agricultural research expenditure to multiple sustainability dimensions). However, quality deficiencies due to missing values, outliers, short time series and break in the series may considerably affect the reliability of statistical analysis.

In this paper, we propose some quality indicators to be provided along with data in order to make users immediately aware of their actual usability.We compute such indicators on a subset of variables representative of each levels of the researchimpact pathway from agricultural research expenditure to multiple sustainability dimensions. These measures combine qualitative information on data quality published by Eurostat with quantitative evidence stemming from data. By comparing the values of overall quality indicators I1 and I2, we find contrasting indication: quality level stemming from metadata does not to match the one stemming from collected data.We believe that such contrast is due to the fact that metadata can describe data quality only partially, while collected data can emphasize further quality features like the pattern of missing values and the presence of outliers.

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Measuring the results of FAO's statistics work

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ABSTRACT

The growing awareness of the importance of evidence-based decision making in governments and organizations at all levels emphasises the role of statistics in monitoring and achieving national and international development targets. The Food and Agriculture Organization (FAO) of the United Nations plays an essential role in monitoring global food and agriculture statistics by developing methods and standards, providing capacity building support to member countries, and disseminating global databases.

This paper aims to propose a methodology to assess, monitor and report on FAO's statistics work, by evaluating the quality of agricultural data at country level and of their use in evidence based decision- making. FAO's statistics work was last assessed as part of the Corporate Outcome Assessment in 2014 and 2015. Changes in the international policy environment and lessons learned from the previous assessment, led to a revised FAO Results Framework. The 2017 Corporate Outcome Assessment will leverage the last assessment while incorporating some significant improvements. The methodological revisions include the harmonization of the results chain and outcome formulation for FAO's statistics work across Strategic Objectives, alignment with the Sustainable Development Goals (SDGs), and changes to the survey design and sampling methodology.

Keywords: agricultural statistics, evidence-based decision making, policy monitoring, results framework, strategic planning, corporate assessment, Sustainable Development Goals, balanced sampling method.

1. Introduction

In September 2015, the United Nations General Assembly formally adopted the universal, integrated and transformative 2030 Agenda for Sustainable Development, along with its 17 Sustainable Development Goals (SDGs) and 169 associated targets. Agriculture plays a central role in achieving these goals, which include eradicating hunger and poverty, ensuring sustainable management of natural resources, and combatting climate change.

At the same time, evidence-based decision making (EBDM) is becoming increasingly recognized as an important tool for change on the national and international levels. Within the context of EBDM, policy decisions are informed by rigorous analysis using relevant and accurate data. High quality statistics play an important role, not only in designing new policies, but also in monitoring progress towards national and international development goals and targets, and in evaluating policy impact. FAO is positioned to play a crucial role in achieving the SDG targets and influencing positive change, as it sits at the intersection of statistics, policy, and agriculture. , FAO has been identified as the *custodian agency* for 21 indicators and as a *contributing agency* for an additional 4.

This paper presents the methodology developed and used by FAO to assess, monitor and report on both the quality of agricultural statistics at country level, as well as the level of their use in evidence-based decision making. The paper is organized as follows: Section 2 provides an overview of FAO's role in food and agriculture statistics; Section 3 describes the new FAO Results Framework to support monitoring; Section 4 presents FAO's methodology, experience, and lessons learned in monitoring Outcome level progress in the *Medium Term Plan 2014-2017*; and Section 5 illustrates some of the methodological improvements defined so far for assessing the results of FAO's statistics work as part of the next *Medium Term Plan 2018-21*.

2. FAO's Role in the Production of Food and Agriculture Statistics

High-quality statistics are essential for designing and targeting policies to reduce hunger, malnutrition and rural poverty, promoting sustainable use of natural resources, and increasing resilience to threats and crises. They provide the foundation for evidence-based decision making for governments, the private sector and the international community and play a critical role in monitoring progress towards national and international development goals and targets.

FAO's statistics work is comprised of three main functions: (a) to assemble, analyse, and provide access to data for national, regional and global monitoring, including for the SDGs; (b) to develop the required statistical methods/tools for food and agriculture statistics; and (c) to provide technical assistance and capacity building to member countries for the implementation of international standards in agricultural statistics. In the new FAO Strategic Framework, statistics plays a dual role by directly contributing to specific outputs of the five Strategic Objectives (SOs) and by creating the internal and external enabling environments to facilitate delivery of corporate results under Objective 6 (O6), the FAO internal objective to ensure technical quality, knowledge and services. The FAO Medium Term Plan 2014-17 (MTP 2014-17) results framework identified a specific Outcome within Objective 6 to ensure the quality and integrity of FAO's Statistical work.

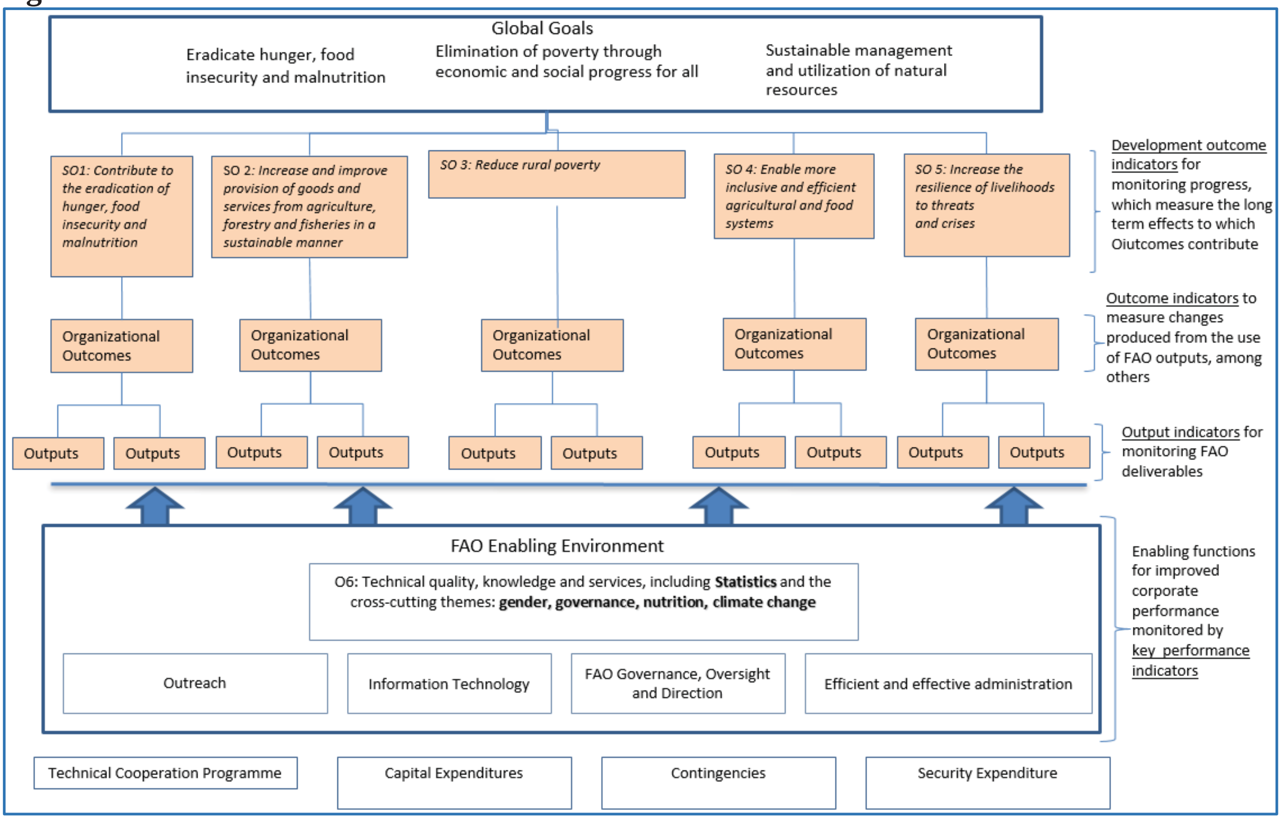
In a decentralized statistical system, such as that of the FAO, this can only be guaranteed through a strong governance system and corporate accountability framework that defines the responsibilities of the different units involved in statistical work. To this end, FAO has recently adopted a comprehensive Quality Assurance Framework, providing guidelines on best practices to be applied to all statistical processes and products in order to ensure corporate consistency, to avoid duplication and fragmentation of statistical activities, and to guarantee the quality of FAO data, whilst making the most effective use of resources. The Chief Statistician at FAO oversees FAO's statistical work across all SOs, and is responsible for delivering results under O6. The

Interdepartmental Working Group on Statistics (IDWG), along with representatives from all technical divisions involved in statistical work, support the Chief Statistician in these efforts.

The FAO Statistical Work Programme is developed by the FAO Chief Statistician with the support of FAO technical divisions and the IDWG on Statistics and it mainly focuses on:

a. Supporting the production and dissemination the 21 SDG indicators under FAO custodianship, in addition to the established compilation/dissemination of food and agricultural statistics;
b. Strengthening the statistical capacity of member countries, including on SDG monitoring, through the provision of training, technical assistance and support in the adoption of new and cost-effective survey methods.
c. Improving communication with countries and development partners on the importance of high quality data, and advocating for the increased use of statistics in decision making and for its proper inclusion in country programmes;
d. Ensuring that the FAO Statistical System is able to respond promptly and effectively to new data demands.

Figure 1: *The FAO results chain model*



3. FAO Results Framework

The Director General's Medium Term Plan for 2014-2017 and the Programme of Work and Budget for 2014-2015 outline FAO's new result-based model and monitoring framework (FAO, 2013). In the FAO results-chain model, each of the five SOs links to a set of Organizational Outcomes (OOs), which are underpinned by Organizational Outputs.

Outcomes reflect the changes in the country-level enabling environment needed to achieve each specific SO. For each SO, the Outcome indicators measure the main determinants of success. These indicators include factors such as relevance of policy and programming frameworks, level of committed resources and investments, level of coordination/partnerships, and availability/use of information and data for decision making. The indicators measure countries' progress in making reforms and developing capacity in order to achieve the SO. A set of indicators is defined for each Outcome within each SO.

Outputs are a set of deliverables that result from FAO's intervention (tangible products and services) and for which FAO is directly accountable. In this case, indicators are selected to reflect the key outputs of the Organization, those which have the most important influence on the outcomes at country level.

3.1 Statistics in FAO Results Framework

Statistics contributes in two ways to the implementation of the MTP 2014-17. Under each SO, statistics produce outputs and services at the country level to help inform EBDM. Under Objective 6, statistics serve as a global public good, ensuring technical quality for the analytical and policy work of FAO and other external stakeholders. The second outcome of Objective 6, Outcome 6.2 is therefore entirely devoted to statistics with the aim to ensure quality of FAO Statistics to support evidence-based decision making at all levels. This outcome covers the quality and integrity of FAO's statistical work, and is measured using two indicators:

Outcome	Indicator
6.2.A: Use of statistics for evidence-based policy making in the fields of food security and nutrition, sustainable agriculture, rural poverty and resilience to threats and crises	Number of countries in which statistics is available, accessible and used for evidence-based decision making
6.2.B: Level of statistical capacity development in member countries	Number of countries having shown significant progress in statistical capacity

Outcome 6.2 in Objective 6 is supported by the following four distinct ***Outputs*** and indicators:

Output	Indicator
6.2.1: Methods for the collection, compilation, dissemination, analysis and use of data under different data domains are developed and shared	Number of new guidelines and technical standards published
6.2.2: Support provided to strengthen national statistical institutions and to improve the competencies of national statisticians in collecting, analysing and disseminating data.	Number of new statistics capacity building projects in countries
6.2.3: High quality and internationally comparable data are produced and accessed by all countries	Number of FAOSTAT visits
6.2.4: Strengthened governance and coordination of FAO statistics and improved internal capacity to evaluate the results of FAO's work.	Number of new datasets included in the corporate Statistical Working System

Finally, most of the SOs incorporate an OO-level indicator to monitor country capacity to generate and use statistics for analysis and decision making within the specific SO.

OO level indicators measuring the existence and use of information systems, data and statistics	
SO1	Countries with high quality analytical products generated through functional information systems in support of food security and nutrition policy and programming processes
SO2	Countries that use statistics extensively in policy making processes pertaining to agriculture and natural resources management.
SO3	Capacities to monitor and analyse social protection policies and programmes
SO5	Countries with capacity to deliver regular information and trigger timely actions against potential, known and emerging threats to agriculture, food and nutrition

4. Monitoring Progress in the Medium Term Plan 2014-2017

Monitoring and reporting for the Medium Term Plan is conducted every two years at the Outcome level, and every year at the Output level. Given the nature of the Outcomes, very few data are currently available in the public domain on the selected indicators. Moreover, no information is currently produced on FAO's direct contribution to the achievement of the Organizational Outcomes (OO). Consequently, the data to inform the Outcome indicators are only partially obtained through secondary data, while the main source of information is the Corporate Outcome Assessment. This includes a review of key national policy documents, and a perception survey on the quality, availability, and accessibility of data that are needed to inform the FAO SOs.

The first assessment was conducted in 2014, and was used to establish baselines for the indicators. A second assessment was conducted at the end of 2015 to measure progress made on the indicators since baseline, and to assess FAO's direct contribution to these results. The next assessment will be conducted at the end of 2017, as part of the Medium Term Plan 2014-17 monitoring and reporting cycle.

4.1 The Design of the Corporate Baseline Assessment (CBA 2014)

The Corporate Baseline Assessment (CBA) was conducted in 2014, and assessed those countries where FAO delivered a meaningful programme of work during the 2011-2012 biennium. In total, 148 FAO member countries satisfied this criterion, and were included in the target population. In order to limit the length of time, costs, and human resources needed to conduct the assessment, the CBA analysed a sample of 80 countries, rather than the entire target population.

Countries were selected for inclusion in the CBA in order to obtain a representative sample of the population, taking into consideration factors such as geographical region, performance within each of the five SOs, and importance to FAO delivery. The key indicators reflecting the country's performance within the SOs are:

Indicators reflecting country performance within each of the five SOs	
SO1	Prevalence of stunting among children under 5
SO2	Average arable land per person
SO3	Poverty headcount ratio at $1.25 a day in PPPs
SO4	Proportion of agriculture value added over the GDP
SO5	Vulnerability Index and Crisis Index Final Index Rank

The main criterion used to select countries for the sample was the level of delivery (in USD). This ensured that countries with larger FAO programmes had a higher chance of being included in the sample. In addition to level of delivery, sample countries were also selected based on a set of six stratification variables, based on geographical region and the five SO indicator groups[1]. In this context, some countries were included in the sample with certainty, as they were assigned an inclusion probability equal to1[2]. The amount of delivery was used to allocate the sample among the strata and to define the selection probabilities.

In order to ensure the representativeness of the sample at global level for the entire work programme of the Organization, the sampling design was based on a random selection procedure that accounted for all the SOs simultaneously. Due to the small size of the population (and consequently of the sample), the sample was selected using the balanced sampling method (Deville and Tille, 2004). This method is the most efficient methodology designed for the selection of a

[1] For each of the five indicators, the countries have been classified into two groups on the basis of the median value of the distribution of the indicator. A third group for each indicator was defined reflecting the countries with missing values.
[2] The list of self-representative countries includes: Somalia, Afghanistan, Pakistan, Sudan, DR Congo, Zimbabwe and Bangladesh.

random sample in terms of marginal allocations (Falorsi and Righi, 2008). Therefore, the randomly selected sample ensures all the marginal allocations as well as the total sample size.

In the first phase of the fully-fledged survey, the sample size was fixed at 39 countries. Subsequently, in order to satisfy the need of the SO Teams to obtain data for all FAO focus countries, the final sample size was increased to a total of 80 countries. Given that the list of focus countries changed SO by SO, the total number of countries surveyed was different for each SO[3] (55 countries for SO1, 50 countries for SO2, 58 countries for SO3 and 55 countries for SO5).

Data were collected through a structured questionnaire with sections dedicated to each SO. The specific questions in each section were defined based on the data requirements of each SO Team. When possible, data were obtained from existing data sources (secondary data) and were therefore not included in the survey questionnaire.

The respondents in each country were identified, with the support of the FAO country offices, as senior representatives of six stakeholder groups: government, UN agencies, international donors and International Financial Institutions, research institutions/academia, civil society and the private sector. This diverse group of perspectives ensured a comprehensive assessment of each country's capacity for and commitment to achieving the Strategic Objectives. Given the broad range of respondents involved, the survey was conducted through a facilitated data collection event. At this event, facilitators explained the assessment's objectives and questionnaires, and then respondents individually completed their relevant sections. A total of 1474 questionnaires (334 for SO1, 346 for SO2, 490 for SO3 and 304 for SO5) were collected.

The estimates of the Outcome-level indicators and sub-indicators for the whole population were obtained using adjusted sampling weights. The initial sampling weights, calculated as the inverse of the inclusion probability of the 39 sample countries of the initial CBA, were adjusted to take into account non respondent countries (2 for SO1, SO2 and SO5, 3 for SO3). These weights allowed the indicators' values to be expanded from the sample countries to the target population.

After broadening the sample to include all SO focus countries, different weighting systems were defined to provide representative estimates for each SO. Two domains, unplanned for in the original sampling design, were also considered for each SO: the set of the focus countries and the set of non-focus countries. The weight adjustment was performed taking into account regional differences.

Finally, each Outcome-level indicator was derived by combining the values of sub-indicators derived from the CBA and those taken from secondary sources. Survey data for a specific country were firstly aggregated by group of respondents (through a simple mean), and then aggregated at country level (also through a simple mean). A score was calculated for each indicator, ranging from zero to one, as a result of an average of the values of the sub-indicators.

4.2 The Design of the Corporate Outcome Assessment (COA 2015)

At the end of 2015, another assessment was conducted to assess changes at the country and global levels at the end of the 2014-2015 biennium. COA 2015 was very similar to the CBA and surveyed the same set of countries to obtain estimates of the changes that occurred in the national enabling environment during the two year period. The COA planned to collect data on the same set of respondents, to obtain an evaluation of the change during the two year period not affected by the variability due to a change in the respondent.

The questionnaires were expanded to include two additional sections: a) FAO's perceived role in *contributing to change*; and b) a more articulated *assessment of the use of statistics for evidence-based decision making*.

In parallel to the primary data collection, secondary data were updated whenever possible. The COA obtained reliable estimates of the following three variables at aggregate level:

[3] The CBA did not cover SO4. Therefore the OO indicators for SO4 were obtained only through secondary data.

a. Values of the Outcome-level indicators in 2015;
b. Changes in the values of the Outcome-level indicators between 2014 and 2015;
c. Percentage of FAO contribution to this change, based on responses to specific questions inserted in the questionnaires

Data collection took place from December 2015- January 2016, and differed somewhat from the CBA. While the CBA collected all data at data collection events, the COA data collection differed by country: some countries still collected data through organized data collection events; for others the respondents received the questionnaires and national consultants followed-up to ensure coverage and timely response.

In the COA, two different sets of weights were used to develop global indicator estimates. The first was used to obtain the 2015 estimates of the Outcome indicators and FAO's contribution to the change, while the second was used to estimate the differences between the Outcome indicators at the two points in time.

The first set of cross-sectional weights were used for expanding the sample of the respondent countries to the target population. The second set of longitudinal weights were used for estimating the differences of Outcome indicators by expanding, to the whole population, the countries responded both to the CBA and COA (co-present countries). Thus, four weighting systems were obtained (one for each SO) following the same procedure used for the weights of CBA and a weight adjustment was carried out, taking into account regional differences in the rate of non-responses.

4.3 Challenges and Lessons Learned

The biggest challenge that emerged during the COA was attrition of respondents. Many of the CBA respondents could not be found for the COA, or, to a lesser extent, declined to be interviewed. These respondents had to be replaced by other stakeholders at short notice, which caused reduced comparability between the two assessments and a decline in the quality of results. Since many of the survey questions were based on respondents' *perceptions*, the change in respondents introduced variability into the survey results, thus reducing their overall reliability and accuracy.

Moreover, a set of sample countries were excluded from the final estimates[4] because the number of respondents by stakeholder groups was not sufficient to ensure unbiased results. Table 2 compares the number of countries included in the theoretical sample by SO, and the number of those that actually participated in both the CBA and the COA. A significant decline was registered, especially for SO1.

Number of countries in the sample of the CBA and the COA by SO

	Theoretical sample	Actual sample		
		CBA	COA	Co-present in CBA and COA
SO1	*55*	53	41	40
SO2	*50*	48	43	42
SO3	*58*	55	51	49
SO5	*55*	53	46	45

The challenges faced in the data collection phase were primarily caused by a few issues in the survey implementation:

a. *Short interval between the two assessments:* Due to organizational issues, especially the countries added in the enlargement stage completed the CBA questionnaires with almost one

[4] The criteria used for including countries' data for the estimation of the final results were to have valid questionnaires for at least 2 stakeholders' groups and a minimum of 3 questionnaires in total.

year delay (September 2014). The COA questionnaires for all 80 countries were completed in November-December 2015. This meant that many respondents were requested to complete almost identical questionnaires after just one year, which led to a lower response rate in some countries. Furthermore, some OO indicators did not show any significant change in such a short time period.

b. *Timing of the COA*: Data collection began in November 2015 and the deadline to return the questionnaires fell during the holiday season (December 2015 - January 2016), which affected the actual time dedicated to complete the exercise, and the possibility of subsequent follow-ups to try expand the number and diversity of respondents.
c. *Length and complexity of the questionnaires:* Due to the large number of sub-indicators, the CBA questionnaires were lengthy and complex. The COA questionnaires were even longer, as they incorporated additional questions on stakeholders' perceptions about the FAO contribution to change, as well as an additional section on the use of statistics. Moreover, the heterogeneity of the topics covered made it difficult for a single respondent to have the knowledge and experience to answer all sections with the accuracy required.
d. *Time lag of secondary data.* Secondary data are normally published with a time lag (for e.g. 2014 data is available only after 2015) with variable delays among different sources. Due to the short period of time between implementation of the CBA and COA, few indicators could be updated.

These issues affected the quality of the COA results, and increased the difficulties in conducting meaningful data analysis across the assessments at country level. In the comparison between the CBA and COA, some of the changes detected over time were likely due to measurement errors, especially considering the limited time elapsed between the two surveys.

5. Looking Ahead: The New COA Design for Medium Term Plan 2018-21

5.1. Review of the FAO Results Framework

FAO's programme of work is constantly evolving to respond to changes in the international policy environment. The new trends and challenges emerging at global level, as well as the new international policy frameworks recently adopted (2030 Agenda for Sustainable Development, the Paris Agreement on climate change, the COP 21 and 22, the follow-ups to the ICN2 and to the World Humanitarian Summit), provide the opportunity to adjust FAO's focus and work programme in order to integrate new priorities and the resulting demands from member countries.

There is also clear recognition of the need to refine the FAO results framework on the basis of lessons learned during the implementation of the MTP 2014-17. The technical adjustments identified for the next MTP include improvements in the theory of change, the clarity and consistency of outcome and output formulations, and the measurability and relevance of the indicators. This review of the FAO Strategic Framework and Results Framework is currently being carried out as part of the Medium Term Plan 2018-21 planning phases.

Finally, regarding Statistics, the results framework is being revised to avoid overlap between outcomes in Objective 6 and the SOs and the information compiled under various SOs will be used to feed the assessment of Objective 6. Moreover, the use of statistics in decision making is not directly linked to the current statistical capacity development work of FAO, which focuses mainly on helping countries to produce new and better quality data, not on helping them to transform data in key messages and communicate them well to the media and the decision-makers. Data access itself is only one component of EBDM. Therefore, capturing the impact of FAO's statistics work on decision making requires the consideration of different layers and different actors in those processes related to decision making. This helps explain the multi-stakeholder approach to monitoring and reporting on level of availability and capacities in the use of statistics.

5.2 Methodological improvements in the design of the COA

The lessons learned from the implementation of the COA 2015 coupled with the opportunity provided by the mid-term review of the FAO Strategic Framework and Results Framework, have led to following changes:

1) Increased harmonization in the Outcomes formulation and Results Framework across SOs;
2) Alignment to relevant global SDG indicators, to work towards a unique monitoring system;
3) Simplification of the overall structure of the Outcome indicators to facilitate the assessment;
4) Improvements in the methodological design of the COA 2017 survey. In particular:
    a. Improve the identification of relevant stakeholders groups by SO, and increase the number of respondents per stakeholder group to better measure variance within groups;
    b. Improve the data collection process by revising and simplifying the questionnaires and using an online form;
    c. Replace the current manual approach for policy reviews, which is subjective and very resource intensive, with a web-scraping tool to assess whether national policy documents utilize FAO's recommendations/frameworks;
    d. Reduce the proportion of secondary data;
    e. Use retrospective questions to allow for comparison of results over time and address attrition in respondents between surveys;
    f. Change the sampling design of the COA 2017 to address the need to produce estimates of the indicators by SO and by Region, in addition to national estimates for the focus countries.

5.3 Improving the Measurement of Results of FAO's Statistics Work

In developing the COA 2017 questionnaire, special attention is being dedicated to the harmonization of the indicators measuring the availability and use of high quality data, information and statistics at country level for improving evidence-based decision making with regard to every SO. A set of standardized questions is being added to each SO's questionnaire. More precisely, questions that clearly address data *availability*, *quality*, *accessibility* and *utilization* (at the policy/program design stage and monitoring stage) will be included.

A new stakeholder group in the pool of key respondents will also be introduced to obtain the views of those more closely associated to data generation, availability, use and assessment of quality of statistical information at country level. Senior officers in government agencies which produce official agricultural statistics (typically the National Statistics Office and some line ministries, including the Ministry of Agriculture) will be asked to fill in only relevant parts of the questionnaire, i.e. those related to the quality of agricultural statistical data at country level.

The data collected for different SOs through the new questionnaires will allow FAO to develop a composite indicator on the availability and quality of national statistical data in the statistics fields covered by FAO.

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THEMATIC SET

H48

THE NEW PROFESSIONAL PROFILE OF AGRICULTURAL STATISTICIANS

Session Organizer
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J.L. Parsons | USDA National Agricultural Statistics Service | Washington, DC | USA
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The role of the subject matter and the methodological skill in the profile of modern agricultural Statistician

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ABSTRACT

Agricultural statistician as others statisticians use statistical methods to collect and analyze data and solve real-world problems in the fields of agriculture. The World is changing, agriculture also. There are many mutations even in subject matter and methodological skill. The role of statistician is changing, through both the availability of large volumes of data and the recognition that informed decisions are sometimes best made by those who understand how such data might be used. There is so a need of a profile of modern agricultural statistician to come up with challenges.

This paper discusses the role of the subject matter and the methodological skill in the profile of modern agricultural statistician. We argue that facing new methodological developments, changes induced by ICT and current issues (economic, social or environmental), adaptation and retraining of researchers or practitioners or revision of training curricula remains a must. The interest of the issues discussed in this paper lies in the desire to meet the needs of the professional world and research to meet the thematic analysis requirements not only to current issues but also in the conceptual aspects related to the agricultural sector. Indeed, gender issues, sustainable resource management, poverty ... are specific analytical aspect that must be addressed and adapted to the agricultural sector. There then arises the question of the methodological approach, appropriate to identify the said aspects in conducting research and agricultural surveys.

Keywords: Statistician, methodological skill, curricula

"We need to build National Statistical Systems, in fact National Information Systems, consisting of official statistics, geospatial information and other non-traditional data, that are relevant for a multitude of purposes, and yet organised in a solid, coherent and integrated manner."

Stefan Schweinfest, Director, UN Statistics Division
Keynote address World Statistics Day 2015.

Introduction

Statistical science has undergone various changes over the years. Its development went hand in hand with the needs of society. Responding firstly to the provision of administrative data, statistical methods was developed with the methods of descriptive statistics (Sir Ronald Fischer 1890-1962) which has extended its application in various fields including econometric modeling, sampling techniques, etc. Its use is further enhanced with the development of computer technology, the increase in calculations power.

Today, more than ever, there is a new revolution in the use of statistics with information technology, the development of large masses of data, the growing need for evidence based decision on statistical data.

In the modern world of computers and information technology, the importance of statistics is very well recognized by all the disciplines. Statistics has originated as a science of statehood and found applications slowly and steadily in Agriculture, Economics, Commerce, Biology, Medicine, Industry, planning, education and so on. As on date, there is no other human walk of life where statistics cannot be applied.

The role of statisticians is changing, through both the availability of large volumes of data and the recognition that informed decisions are sometimes best made by those who understand how such data might be used.

This poses challenges both in terms of quality and topics covered in the training of statistician. This is particularly true for the agricultural sector. Indeed the importance of the agricultural sector is well established especially for developing economies. For example, in Africa the agricultural sector occupied at least half of the population and plays a key role in economic growth in reducing poverty. Also, it is crucial to have reliable and updated statistics for appropriate economic policies. This requires therefore well trained and qualified statisticians to address these issues. So there is a need of a profile of a modern agricultural statistician in line with technological and methodological developments.

This paper shows that the profile of modern agricultural statistician is shaped by new methodological skills related to technological developments, new subjects matter and business needs in this sector. Therefore, there should be a revision of training curricula and an adaptation and retraining of researchers and practitioners.

The argumentation is organized into sections. The first section recalls the challenges in the agricultural sector and in agricultural statistics. The second section presents the main methodological and technological developments affecting the profile of modern agricultural statistician. Before conclusion the final section discusses the implications for training and capacity building of researchers and practitioners.

1. Agriculture and it's challenges

The place of agriculture in the economies is well established. Representing between 30 to 50% of developing country GDP, the agricultural sector is an important source of income for the population and a factor in reducing poverty. The expectations for this sector are important in terms of reliable and timely available statistics, both for the population and for policymakers. These expectations are reinforced by recent technological developments: social networks, high flow velocities of information, new technology development, etc.

Particular attention is thus paid to issues of agricultural policy which poses various challenges including that of the availability of reliable data itself connected to data collection problems in agriculture, methodological issues and research in the area of agricultural statistics.

Challenges of data collection in agriculture

Diverse challenges, consequence of the mode and the type of agriculture practised in developing countries, arise in term of quality and personal characteristics of the farmers, the diversity of the cultures and the agricultural practices between regions, the type of practised agriculture and the methodological questions relating thereto.

In developing countries, agriculture is mainly a family type of agriculture practiced on small surface. Farmers are generally of a low level of education and use a combination of farming practices and techniques.

The diversity of regions, the agricultural calendar and types of culture according to these regions requires appropriate estimation methodologies of the main aggregates.

The sub sectors of agriculture pose specific challenges in evaluation of livestock, small animals, for fishing and aquaculture.

The sub-sector of the fishing poses the challenge of measuring production both inland fisheries and non-continental, traditional fishing and non-traditional. At the forest level, the same challenges exist in terms of estimation of wood production, deforestation surface, etc.

Also, the agricultural sector is highly dependent on weather conditions. These climatic conditions represent external factors to consider for the treatment and estimates of agricultural statistics.

In many developing countries, most producers are also consumers and collecting relevant data for understanding the decision making of smallholder producers where they are making both production and consumption decisions simultaneously are another challenge. Other problems that affect statistical activities are the extent to which agricultural activities are determined by the environment in which they take place and the impact of external events, especially weather conditions. There is a requirement, therefore, for detailed time series data that are disaggregated by agro-ecological zone, which is a major challenge for data collection.

Meeting these challenges of agricultural statistics entails having technical and adequate instruments for measurement. This is very important especially for statisticians because with the recent technological development, decision makers and more generally populations demand accurate statistics that is available in time.

Statistical methods in the agricultural sector have evolved over time and have taken to supporting new technologies and social networking.

2. New methodological developments and subject matter

The development of information and communication technologies have revolutionized the collection, storage, processing and dissemination of data. For example the development of mobile telephony and popularization of smartphones enable the collection and transmission of data. The tasks with paper and pen are increasingly abandoned as well as data entry steps after collecting paper. The information and communications technology (ICT), especially mobile phones and tablets, applications for creating digital investigations and software that allow users to upload data to real-time storage, reduced conventional problems facing the activities of data collection and analysis.

The technology itself is not sufficient to meet the project objectives. Even a platform to collect data for free does not guarantee that the right data be collected efficiently. A team that can design the collection, implement and evaluate the data is as important as technology. Training is an important element in the data collection operations through ICT tools.

We are in a dynamic and rapidly changing era in the field of production and processing of information, especially statistics. The change agents can be grouped into four classes. There is first the data revolution that operates through the digital transformation, new data sources and competition between data providers. Then there are the new metrics that should consider globalization, reality growing complexity, geodata. Then there is still the values imparted to statistics that led to arbitration between quality and resources, simplification of procedures accompanied by reduced budget. Finally, the need to propose policies based on the facts in the requirements of quality and cooperation.

These drivers of changes can be broken in the thematic domain of agricultural statistics as noted by the global strategy of agricultural statistics. Defining a framework should help integrate agricultural statistics into the national statistical system to meet the needs of users and stakeholders in a coherent framework.

A master sample frame for agriculture which will be the foundation for all data collections based on sample surveys or censuses is required for the integration of agriculture into the national statistical systems. The master sample frame must provide the basis for the selection of probability based samples of farms and households with the capability to link the farm characteristics with the household and then connect both to the land cover and use dimensions.

Update data collection methods should include complete survey framework that also takes into consideration the data sources in addition to sample surveys that provide input into the survey framework. Improved methods are required for producing food security data, market information that affect agricultural activities and farmers' decisions.

Table 2 shows the thematic domains and of the corresponding training and research topics.

3. The implications for training

The challenges in agricultural statistics, technological development and thematic of interest for the agricultural statistics influence the profile of the modern agricultural statistician.

The combination of technological development, agricultural statistical challenges and topics of interest question the profile of the new agricultural statistician. The profile of the classical statistician does not seem now quite appropriate.

The profile of these statisticians is modified according to the skills they should acquire in connection with the thematic as noted in Table 1.

The modern statistician should dominate the challenges posed in conducting the work of the statistician.
In the scope of the specification of requirements, skills should cover the demand for data on small area and disaggregated data, real-time data request and in connection with a multi-sector programming.

In terms of design, the modern agricultural statistician should be able to mobilize the satellite data and technology related in term of methodological and technical practice.

For data collection, he should mobilize modern technologies for data collection and electronic technologies including applications for collection and transmission of data.

More generally, the technological skills will be adapted in all areas of processing, analysis, dissemination and evaluation of data.

Table 1 : Challenges in statistical process model

Key business process	New challenge in business process
Specify needs	Streamlining and Joint Programming of Multisector Needs; Demand for Small-Area and Disaggregated Data; Demand for More Current Data, Real-Time Demands
Design	Integration of Remote-Sensed Data; Leveraging Other Authoritative Data Sources; Changing Paradigm of Data Gathering Pilot-testing of census and/or survey instrument
Collect	Use of State-of-the-Art Technology for Data Collection; Georeferenced data collection Electronic data collection and transmission
Process	Integration of Scanning and Machine Intelligent Data Capture Technologies; Innovative Transfer of Mobile Electronic Data into Master Data Files Automated Preemptive Data Quality Checks and Data Cleaning Applications
Analyse	Multisector Thematic Analysis of Census and/or Survey Data Linked to National and Sustainable Development Goals; Needs of Citizen and Private Sector; User-Friendly Data, Easier to Understand Generate Reports and Maps
Disseminate	Electronics dissemination Web services, APIs, Cloud based Electronic storage and retrieval
Evaluate	Real-Time Census and/or Survey Monitoring Demand for real time analysis Historic comparison and measure

Source: author

Also, other more transversal skills should be mobilized for modern agricultural statistician. These complementary skills relate analytical and IT Capacities, process management capabilities, communication skills and the development of analytical expertise.

4. Issues to be addressed

Training programs

Training and capacity building programs will be adapted to these topics and technologies. There will be a combination of different modes that are

- Shorter duration training leading to certificate programmes
- Longer duration training leading to degree programmes
- Customized training programmes
- Training for corporate sector
- Ad hoc training programmes

These types of training will thus integrate a heavy dose of technology and technique. That is the use of GPS data in statistical production, the use of satellite data, changing data collection methods incorporating electronic technologies for collecting and transmitting data. A prominent place should be given to the mastery of statistical software in agriculture.

Table 2: Thematic domain for agricultural statistics

Thematic domain	Training and research topic
Reference framework	• Framework for development of an integrated agricultural statistics programme • Mainstreaming agriculture into NSDS • Implementation of an Integrated Survey Framework
Master frame for integrated survey	• Use of GPS in the production of agricultural statistics • Linking area frames with list Frames • Use of remote sensing
Data collection methods	• Improvement of estimation of crop area, yield and production • Methods for estimating crop area, yield and production (mixed crops, repeated cropping, continuous cropping) • Methods for estimating yield of root crops • Cost of production • Methodology for enumerating nomadic livestock, estimating livestock products • Adoption of new technologies • Forestry and deforestation • Crop forecasting and early warning • Inland fishery, aquaculture • Interaction between climate, environment, global warming and agriculture • Land cover monitoring
Food security	• Methodology for the estimation of supply utilization account, food balance sheets, food stocks, edible forest products • Nutrition indicators • Use of households surveys / LSMS for food security indicators
Market information	• Estimation of farm gate prices • Collecting data on agriculture rural and border market prices • Collecting data on factors and product markets affecting agricultural

	activities
Data analysis	• Reconciliation of census data with survey data • Determination of user's information needs for decision making • Use of small area estimation methods for improving agricultural statistics
Improvement and use of administrative data	• Improvement of administrative data • Use of administrative data for improving agricultural statistics • Estimation of informal cross border trade data

Source: author

Indeed, gender issues, sustainable resource management, poverty ... are specific analytical aspect that must be addressed and adapted to the agricultural sector.
The new agricultural statistician will be a sort of combination of classical statistician and information influenced by challenges in agriculture and in technologies.

Conclusion

The world changes, technologies are evolving in line with the needs for statistical information and policy management. There is an exponential increase in the volume and types of data available, creating unprecedented possibilities for informing and transforming society and protecting the environment. The agricultural statistician like the others statisticians is at the heart of the process and use the techniques and methods of collecting and analyzing data to provide solutions to problems in the agricultural fields. The statistician should adapt itself to changes in both specific thematic and in the methodological skills.

We have shown that the profile of the modern agricultural statistician built with these technological and thematic changes and that the training and capacity building should be adapted accordingly.
New technological developments and topics as well economic, social than environmental are drivers for curricula and capacity bulding of researchers and practitioners.

The necessity to profile definition of modern agricultural statistician lies in the need to meet the needs of the professional world of agriculture. It should also consider cross-cutting issues such as gender, sustainable development, poverty reduction and other related agricultural thematic. However, it should consider the methodological issues raised by these dimensions and aspects for research and the production of agricultural statistics.

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The role of Communication skills in the profile of modern Agricultural Statisticians

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ABSTRACT

In the last few years the process of data statistical production in agricultural statistics in Poland was modernized. Data are collected exclusively with the use of electronic equipment - paper questionnaires are no longer in use, both for the obligatory reporting system, and for the sample surveys in private farms. The new techniques effected of diminishing the number of personal interviews (CAPI) and increasing the number of telephone interviews.

The new system of statistical production and data collection requires additional communication skills for the interviewers, such as:

- excellent knowledge of the subject matter i.e. the goal of the survey, basic information on agriculture in the surveyed area, basic information on a farm (if the farm was selected for other surveys)
- ability to establish contact with the farmer
- patience
- resistance to stress.

To improve the communication skills of the interviewers, several undertakings were initiated including professional trainings at the central and regional level, both for trainers and interviewers. E-learning has also been developed in order to enable improving the knowledge in the time preferred by employee.

As it was mentioned, the new techniques required both the professional knowledge and the use of modern technology. To increase quality and effectiveness of the interview, so called hints are commonly used in the IT application. In case of uncertainty the interviewer may click on the word and the definition appears. It helps the interviewer to go smoothly through the questionnaire.

There are also some other tools to help to communicate and collect the data:

- the announcing letter from the President of the Central Statistical Office sent to every holding, which was selected to the survey,
- the info line providing information and help for respondents,
- the organizational and methodological survey descriptions,
- promotion activities concerning statistics in general and statistical surveys in particular,
- improvement of IT tools.

Apparently, agricultural statisticians need to improve their communications skills in due to progressive specialization of employees, whose participate in - various trainings at the central and regional level. The trainings concern communication with media, finding the best way to sell the product, namely, agricultural statistics, and how to communicate with methodologists, IT specialists, survey coordinators and interviewers. The most important goal of these activities is to get the best result – high completeness and the best quality. To achieve this goal, except the skills the support of the technology is essential, hence the development of systems handling with metadata or new communication tools is essential. The other issue is presence of statistical institutions in social media, which requires engagement of statistician with entirely new competences.

Keywords: communication, data collection, modern methods

INTRODUCTION

Each country, each economic group or political party, implementing its program functions through its inherent structure of the authorities. and management must have the appropriate resource information that provides greater rationality and effectiveness of its policies.

Fundamental importance of statistics in democratic societies is to provide all categories of users appropriate range of information. Democratic processes may be implemented by the public in an appropriate manner only if there are the conditions for monitoring the development of the society on the basis of reliable and objective information that reflects the realities and consequences of political decisions.

These two statements are fundamental to the statistics and show in fact that in order to implement posed and ambitious goals, should seek to ensure good communication between the general public and the statistics realizing its statutory tasks.

Both the definition of statistics and the scope of surveys have evolved over the centuries. While in the XVIII century statistics have been defined as "a word recently introduced to express an image or a brief description of some of the kingdom, county or municipality" (Encyclopedia Britannica third edition of 1797), in XIX century statistics was considered as science and incorporated as a section of the British Association for the Advancement of Science. The Royal Statistical Society was founded in 1834. Statistics was defined then as follows: "the facts relevant to humans, possible to present in the form of numbers, multiplied in sufficient quantity indicating the general laws".

Statistical data usually are collected during statistical surveys – either full (comprehensive) or sample, where the primary source of information is the man.

In the last years the idea of acquiring the data from administrative sources is widely promoted, which on the one hand aims to reduce the respondents burden in the times of rapid growth of different surveys, inquiries, Gallup polls – conducted by telephone by institutions other than official statistics.

Official statistics is also updating the methods of data collection, using the CATI method more frequently in order to reduce the costs of statistical surveys. This enforces having adequate communication skills by statisticians to find a common language with various bodies, without which implementation of statistical surveys is impossible.

In the last years in Poland in agricultural statistics the breakthrough was noticed associated with the method of data collection. Due to the decision concerning resignation from the paper questionnaires the system of data collection on media information (internet, phone) was developed.
Paper questionnaires have been replaced by electronic application and hand-helds and tablets were introduced. This solutions forced the Polish statisticians other type of communication, primarily with IT people, but also with respondents who were accustomed to regular visits by interviewers.

COMMUNICATION

Speaking about communication one have to think what are so called target groups to which we want to reach with statistical information.

The main target groups, which Polish statistics communicates have been defined taking into consideration strategic goals of the European Union in the scope of dissemination and communication expressed in the Regulation of the European Parliament and the Council (EU) 99/2013 of 15 January 2013 on the European statistical program 2013-2017 with further amendments (Goal 4.1) directions of communication improvement of statistics with environment indicated in „The ESS VISION 2020" prepared in the framework of the ESSC as well as based on the strategic communication goals of the Polish official statistics.
According to the above, in the Polish statistics following communication target groups have been distinguish among the external environment:

Public sphere (public administration, self-government administration, National Bank of Poland and other banks, finance and insurance institutions, justice and law enforcement, associations, organizations, foundations),

Business sphere **(enterprises, analysts in companies, economic self-government)**
Scientific-educational sphere **(research institutions, universities, schools)**

Media (press, radio, television, internet media, journalists)

Foreign recipients (institutional recipients, international organizations, social organizations, statistical institutions, individual persons, students)

Individuals – persons looking for statistical information (neither connected with research activity nor with professional work)

Entities connected with statistical services (program partners of the CSO, engaged in the preparation and realization of the statistical program of official statistics, data providers from the information systems of public administration, respondents, candidates for the job)

From the point of view of agricultural statistics, especially having in mind the use of modern methods of data collection, specialization of farms, specific and ever-increasing needs of international organizations (FAO, OECD), the European Commission and national users of statistical data, the presented above breakdown of target groups is not entirely justified.

Modern agricultural statistician responsible for statistical surveys has to have broad skills depending the level (long list of diversified skills):

- inside the office – (interdisciplinary) with people from other departments and especially with the census people - if different from current statistical surveys and with the IT people, who play bigger and bigger role in statistical surveys,
- outside the office - with the field staff – interviewers, experts, employees from local governments supporting statisticians,
- respondents = farmers (thanks to them we are engaged in such fascinating area as agriculture) and farmers' organizations – to persuade them to provide the data because they are important also for them,
- stakeholders in the Ministry of Agriculture – to have an influence on the final shape of the legal acts significant for statistics (decreasing the respondents and statisticians' burden), here sociological skills are very important to avoid situation, they push us to do, what we do not want to do,
- owners of administrative data – to be allowed to get administrative data comparable and on time to be useful for statistics, with definitions compatible to those used in statistics and ensured good quality,
- media - how to interpret statistical data and phenomena, how to analyze them,
- among statisticians – exchange of experience in professional statistical journals,
- scientific environment – more and more frequently demanding anonymized individual data for in depth analyses.

What kind of activities from the statistical office should be undertaken to meet this objectives?

Effective communication is based on the principle of "I know who I'm talking to - I'm talking the language attractive and understandable to the recipient". Knowledge of the target groups is the basis of effective communication. Well-described group determine not only the type of message that should be addressed to them, the type of channel through which the message should reach them, the level of complexity of the language in which the message should be formulated, as well as the level of interest led to their message.

The overall message addressed to all recipients should contain the same idea, however the message addressed to each of the groups should be formulated taking into account its specific expectations, the level of interest and the possibilities of perception. At the same time for the addressees of communication relevant tools should be used to efficiently deliver the desired information. When planning communication activities for specific target groups, their expectations in terms of messages and proper, most effective tools of communication should be redefined.

In general we should know the background of the recipients of our information. Different communication skills are required to talk with scientific environment or with the stakeholders and different with farmers or farmers organizations as our respondents.

The skills inside the office.

Communication with the IT people is very important. More and more of statistical surveys is conducted using the electronic tools, like the internet (CAWI), tablets for interviewers (CAPI) or computer connected with the telephone (CATI). For this methods of data collection special applications must be developed, friendly both for respondents and interviewers. Ideal situation is if IT specialists know a little agriculture and agriculture statisticians know a little programming. This enables communication between both parties and ensure good results – good quality of the survey thanks to the simple and clear definitions and questions, rules of navigation through the application according to the specified paths, instructions how to handle errors. Apart from the questionnaire itself, the system of managing the survey is very important – among others tracking the progress of survey, completeness and quality of questions in the operational database.

All the needs of agriculture statisticians must be forwarded to the IT specialists in a concrete way, having in mind the expected results. When planning such statistical survey like farm structure survey, during the planning phase detailed analyses should be made concerning:

- EU legal acts from the point of view of characteristics required in the agricultural surveys,
- the needs of domestic users,
- EU and national definitions and their comparability,
- National and Eurostat validation rules,
- accessibility and quality of administrative sources,
- links between the questionnaire sections,
- experience from previous surveys (sequence of particular sections, sequence of questions, the form and the content of questions, mistakes that occurred most often),
- range values for quantitative characteristics,
- data collection methods.

This is only the example, that modern technology actually makes it easier to work, but requires additional knowledge.

A very important is communication with the people responsible for the census in case they are different units or organizations. All measures must be ensured to keep the comparability of results obtained in the census and other statistical surveys.

<u>Communication with the field staff – regional statistical offices</u>.

This is very important for agriculture statisticians, because the success – good quality with a high response rate survey results depend from the field services. Regular meetings with them builds the team, allows for exchange of experience in different regions, discuss problems, and to build good relationship, which help later in daily work. In the case of Poland regular trainings are organized for statisticians from regional statistical offices responsible for field work. They are trained both in the merit subject of the survey (refreshing existing rules and definitions, discussing in depth the new elements of the survey) and the technical elements – the electronic questionnaire – how to go through the application, how to treat the hard or discretionary errors, how to track and analyze the survey progress and results in a special module. In addition for communication among interviewers, supervisors, specialists from the headquarter and other involved in statistical survey a special tool was developed called JIRA, to put questions, announce problems and get the same answers at the same time.

Every year interviewers from the regional statistical offices in Poland are trained to extend and consolidate the knowledge of the legal basis of the functioning of public statistics, sampling methods and construction of the questionnaire. They also improve their interpersonal skills and how to cope with difficult situations. Statisticians can also use the e-learning program.

<u>Communication with the field staff – experts.</u>

Agriculture is a very broad area of statistics, depending on meteorological and economic conditions. It is good to have first-hand information. Having this in mind in Poland special contracts are signed with field experts recruiting from agriculture advisory extensions. They provide monthly information on different issues during the year and in the vegetation season – adequate information on the area and expected yields of individual crops.

The main objective of the communication activities is to convince potential experts about the nature of their participation in the project as well as that they constitute the important source of information on agriculture. They usually know the neighborhood, farmers and general condition of the area under their responsibility, so talking to farmers they also represent agricultural statistics – in a way.

Important part of activity of agriculture statisticians is participation in a different local conferences and fests organized for farmers, when statistical information are distributed. In some of such occasions farmers have had opportunity to provide data on a special computer for the currently conducted survey.

Respondents

Respondents are very important target group, from the communication point of view. Due to the need to maximize the percentage of completed reports and obtain the best quality data, official statistics should make every effort to ensure the proper way to communicate with respondents. The main objective of the communication is to convince the respondents about the importance of their participation in the survey and to convince them that they are the only source of information. It is also important to emphasize the fact that the information gathered by the survey will be used only to develop aggregate information and analysis, and individual data will not be available anywhere. Agriculture respondents in Poland can be divided into 2 specific groups, which are the subject of various communication activities: natural persons' farms as well as legal persons and organizational units without legal personality, which carry out the reporting obligation.

Towards physical persons – individual farmers, such activities like sending an invitation letter, explaining the goal of the survey, the ways and technics of data collection, information concerning statistical interviewers and possibilities of confirming their identity, statistical confidentiality and access to the survey results. If the e-mail address is known, respondent receives a message concerning participation in statistical survey.
On the website the questionnaires are placed informing on the frequency of data collection, allowing for earlier acquainted with the scope of the collected data, with the possibility of print. For all farmers there is also possibility for self-filling the questionnaire. In addition a special hotline (info) runs during the survey. All must be sure that statistical confidentiality will be kept.

In case of farm structure survey or agricultural census, posters are placed in the municipal offices, branch offices of the paying agencies and other visible places in the rural areas, as well as broadcast at local TV or radio are held to promote the survey and attract farmers to provide information.
They are a very important communication channels with farmers building the trust between both interested parties.

Towards legal persons and organizational units without legal personality, which carry out the reporting obligation similar activities are undertaken like placing on the CSO web site information concerning all surveys during the year as well as the questionnaires, to allow prior acquainted with the scope of the study. Electronic tool to provide the data, together with the information concerning login, account activation, contact person in case of unforeseen problems is also provided as well as discussion forum where comments can be submitted.

Stakeholders. Central administration and local government is a very important partner in the process of communication of Polish official statistics, including agriculture statistics. Communication actions that are taken to this group can be divided into activities addressed to the data users, data providers (including their role of owners of administrative registers) as well as the partners having an influence on the content and realization of the statistical survey program.

Policy makers' need reliable information to support decisions, so they have to be ensured, they can use statistics as reliable, evidence-based and an unbiased picture. This message must go from statistics, and in my opinion, the process of building of the statistical survey program, involvement in the consultation process of elaboration of European regulations concerning statistics allows for further understanding and cooperation. On the other hand statisticians, for good and effective communication, should have the knowledge on the Common Agriculture Policy (goals, priorities, mechanisms, implementation and evaluation) to collect and provide comparable data on agriculture and its structure in the country and at the European level.

In case of media and journalists statisticians should pay a special attention. This group of data users is crucial for the image of statistics, because they have the direct influence on other recipients of statistical information. Media are both the recipient of the message, as well as generate the same messages in the mass media – newspapers, radio, TV and in the internet (including social media). Message must be concrete, clear and on time. Quality of statement is very important – writing articles is perhaps less stressful, but personal participation in the radio or television broadcast reinforces the message. The form of communication is conducted in different ways – like press conferences, briefings, short messages in a paper form, interviews etc.
On the other hand statisticians should not only provide information to journalists, but also undertake an effort to improve the statistical literacy among them for better interpretation of statistical data and phenomena.

Scientific environment. Publications with in-depth analyses are elaborated together with and for researchers. In the process of bilateral consultation on the scope of statistical program, they have a contribution to the surveys conducted by official statistics. They also use the results generated by statistics. The new, modern forms of data presentation, vizualization and dissemination makes it possible that researchers can make their own calculations. Close contacts with researchers are important – we invite them to provide lectures at statistical conferences and statisticians are invited on scientific conferences to explain methodology, the process of data production, present the data and express professional skills. Among statisticians we usually share our experience in professional journals.

SUMMING-UP - CHALLENGES

To meet all requirements of contemporary statistics, statisticians are the subject to a constant process of training, improving their knowledge. In today's complex production process of statistics and their dissemination, agriculture statisticians need to improve ways to "reach out" to farmers (respondents) who are specific and increasingly demanding social group, as well as effectively communicate with owners of administrative registers, providers and recipients of statistical data.

Communication skills, as it was mentioned earlier are crucial for identification of information needs of data users and ability to respond flexibly to their needs in terms of survey topics, to attract the forms of data presentation with the use of modern communication channels as well as building partnership with data users.

Elaborated and published by Eurostat document “Digital Communication, User analytics and Innovative products” (ESS.VIP DIGICOM) provides information and show the new challenges. Underlines, that users’ needs are crucial and the European Statistical System should be flexible and responsive to them. The project will have a parallel approach – on one hand it will improve the methods for gaining insight into unmet needs of current and future users and on the other hand actually developing the innovative solutions meeting those needs.

Indicated priorities – tasks to perform in the near future will require new or improved communication skills from statisticians, including agriculture statisticians, who in many cases are pioneers in applying and implementing new solutions.

In the modern world, the comprehensive knowledge and interpersonal skills are as important as professional knowledge. In our work as agriculture statisticians, we communicate daily on different levels and in different ranges, using not only face to face talks but also phone calls, e-mails etc. We undertake decisions, we forward information and we perform commands. One should not forget, that some forms of communication arise from performed functions, therefore profiling contacts and improvement of communication skills is formed in a natural way.

SEVENTH INTERNATIONAL CONFERENCE ON AGRICULTURAL STATISTICS

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

Modernization of Agricultural Statistics in Support of the Sustainable Development Agenda
(Rome, Italy 26-28 October 2016)

Parallel Session – Cross Thematic set H:
Data dissemination & communication / Use of statistics for policy making & research
[48] The new professional profile of Agricultural Statisticians

Information Technology Skills in the Profile of Modern Agricultural Statisticians

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Abstract

Information technology skills are needed at each stage of official agricultural statistics production; including frame development, data collection, survey cleaning, analysis, summarization and disclosure, and publication. This topic will address the skills required tocomplete each phase of the statistical data collectionprocess and how statisticians can effectively partner with information technology specialists within the Ministries of Agriculture and National Statistical Organizations.

This paper will provide background on the evolution of information technology (IT) at NASS as it relates to the production of official agricultural statistics. It will also discuss the skills statisticians need and ways in which those skills can be developed.

Keywords: Skills, Information Technology, Data Collection, United States Department of Agriculture, USDA, National Agricultural Statistics Service, NASS

1. Introduction

The National Agricultural Statistics Service (NASS) is the principle agricultural statistics data collection organization within the United States Department of Agriculture. The agency conducts hundreds of surveys every year and prepares reports covering virtually every aspect of agriculture in the United States. NASS's mission is to provide timely, accurate, and useful statistics in service to U.S. agriculture.

Beginning in 2009, NASS started a journey to pursue three transformations, primarily to provide savings in staff resource costs and improve the quality of our statistical products by enabling the centralization or regionalization of survey operations. The transformational initiatives involved: (1) centralizing and consolidating network services from 48 locations (Parsons and Gleaton, 2011); (2) standardizing survey metadata and integrating survey data into easily accessible databases across all surveys; and (3) consolidating and generalizing survey applications for the agency's diverse survey program (Nealon, 2013). During this same time period, NASS reorganized its headquarters operations, opened a national operating center and consolidated the vast majority of its field staff into twelve regional offices. About one-half of agency statisticians and technology professionals are located in the field with the remainder located at a national operations center or a headquarter location. These changes all aspects of agency operations including the technology skills required of much of our workforce.

Most NASS hires are agricultural statisticians, mathematical statisticians or are in the information technology job series. The agricultural/survey statisticians tend to have a background in agriculture and economics with the requirement of having completed several math and statistics classes. Many of theagricultural/survey statisticians we hire today have a masters degree and a few have doctoral degrees. Our mathematical statisticians have at least a bachelors degree, typically in mathematics or statistics.Most have a masters degree and we hire several with doctoral degrees. Those with specialized degrees are concentrated in our research and methodology teams. Our information technology specialists are often hired mid-career and have varied backgrounds depending upon their specialization (e.g. database administrator, software developer).

In this paper we will discuss the need for technical skills and the development of those skills for statisticians collecting and disseminating official statistics on items related to agriculture. We will share the experiences at the National Agricultural Statistics Service and relate how those experiences might inform others with similar opportunities and challenges. We will focus on agricultural/survey statisticians in the first years of their professional career, but will offer some limited observations on the development of other key groups of employees.

2. Developing Technical Skills of Statisticians

NASS and other similar statistical organizations are 'data factories'. The 'tools' in our factories are for the most part, information technology applications and staff need theskills to leverage, develop and enhance those tools. The layout of the factory floor of those generating official statistics will be pretty familiar across different organizations. The Generic Statistical Business Process Model (GSBPM) components describe and define the set of business processes needed to produce official statistics (Appendix A). The major business processes include: specifying needs, design, build, collect, process, analyze, disseminate, archive and evaluate.

Each of these major business functions have information technology tools that underpin the statistical processing activity that must be completed to produce relevant official statistics. For example, NASS uses Blaise software for data collection in its call centers and for interactive editing of some of the surveys conducted. Statisticians located in regional field offices work in Blaise frequently editing data and reviewing records. A smaller group of statisticians, working with survey methodologists, design Blaise data collection and editing instruments. These statistician/designers interact with those information technology professionals that support the application, the infrastructure, centralized database and metadata on which the application depends. Those statisticians providing this backend support must interact and collaborate with others that support the other enterprise tools so that the entire 'factory' runs effectively.

Over time NASS has created protocols to develop and train newer agricultural statisticians. For the cohort of newer agricultural statisticians involved primarily in data collection and estimation working in our regional offices, the training efforts are relatively standardized. Additionally, every employee in NASS is required to have an individual development plan (IDP). An IDP is a tool to assist employees in career and personal development. Its primary purpose is to help employees reach short and long-term career goals, as well as improve current job performance (US Office of Personnel Management). For newer agricultural statisticians several training events and career experiences are included in their plan along with specialized items that address their particular career interests or job responsibilities. NASS has also developed career guides to assist employees in managing their career development (NASS, 2016).

Each year our training and career development group conducts a training needs assessment. Typically, the assessment is sent to first and second level supervisors to prioritize training needs that are widely recognized. Managers are informed by the gaps they observe in the staff they supervise and in the IDP consultations they conduct with their staff. In addition, statisticians receive a version of the assessment so they can take a personal assessment of their skills in these essential areas.

The assessment helps to prioritize the areas on which to train and further focus how the training is specifically delivered. The following is a snippet of a recent assessment to help drive the annual formal training agenda. As shown, many of the areas are a blend of concepts and use of the actual tools.

Figure 1: Skills Assessment Grid

	What percent of your unit's ag and math stats:				
	Do not regularly use this skill in their current position	Are NOT AT ALL Proficient and need significant additional training or experience	Are SOMEWHAT Proficient but need some additional training or experience	Are COMPLETELY Proficient and do not need any additional training or experience	Total
cSMS Functions--Set DCMS codes and identify survey modes (Paper, CAPI, CAWI, CATI)					100%
cSMS Functions--Use Events tool to set data collection flags based on DCMS codes					100%
Blaise Processes--Identify records of concern					100%
Blaise Processes--Conduct forms editing - identify and interpret warnings, and resolve data inconsistency					100%

Most of our newer statisticians work in team settings and are paired with one or more experienced statisticians. A great deal of informal on-the-job training takes place in this setting. Our newer statisticians generally bring good generalized technical skills such that they are very comfortable with typical information technology office tools. However, our 'factory' has many specialized business processes and information technology tools to support those processes. Our experienced team leads are a key resource in developing the skills of our newer staff and helping them understand the survey concepts and the specific applications and tools used within the agency.

We blend this on-the-job training with more formal training sessions developed from input received on the training assessment and constrained by budgetary resources. Formal training sessions are usually a business week in length and are typically held at our training facility located within our national operations center. These sessions typically include thirty to fifty participants. Most of our training is focused on a particular survey or survey program or task.We also have a series of courses that focus on survey and estimation concepts. In every training case, staff bring their laptops, connect wirelessly to our network and virtual desktop environment to work with applications and tools that are integral to the training.

Our distributed operating environment is enhanced by being able to conduct hybrid learning environments. For example, we frequently are able to include additional instructors and technical expertsvia video teleconference (VTC). This allows us to tap a larger set of skilled trainers for interactive training sessions. In addition to the week-long sessions, we conduct frequent VTC sessions of one or two hours. Some focus on survey management issues, but others – through screen sharing – help to educate a distributed workforce on new or updated information technology tools.

NASS has made strong effective efforts to move toward enterprise level applications for case management, editing, summarization, analysis and other key functions (Drennen and Parsons, 2014; Parsons and Duxbury, 2013). These enterprise tools can accommodate highly varied survey efforts. They rely on centralized relational databases and curated metadata (Nealon, 2013). NASS also moves data from the transactional databases that support these applications to analytical databases. We train newer statisticians to leverage standardized queries and predefined analytical tools to support the generation of accurate official statistics.

However, not all answers to relevant data issues will be found in these standardized queries and predefined analytical tools. We train more experienced agricultural statisticians to leverage business intelligence tools to explore and resolve data issues not easily addressed directly from within the tools. Our data services team that includes database administrators and metadata specialists often assist in hosting sessions on effective data exploration.

Some of the applications and technology that our agricultural statisticians use are not developed from within NASS. For example, statisticians in our regional offices frequently use applications from another USDA agency to mine farm program administrative data to verify operating status and estimate for nonresponse.

Most of our regional agricultural statisticians are generalists and work across the ‘factory floor’. However, we have some niche tasks in which our regional agricultural statisticians develop expertise. For example, our field data collection staff use Apple iPads for data collection, data transmission, and survey training. A corps of our regional statisticians help keep this fleet of several thousand devices operating and their users trained. We hold periodic training to support this corps of employees as tools and procedures are updated.

Many of our headquarters agricultural statisticians are former regional statisticians. Frequently, the headquarter roles have a specific focus such as frame development, gathering survey requirements, or estimation and dissemination. Their general background and experience is invaluable to be able to connect their specialization to the broader work of the organization.

Conversely, many of our mathematical statisticians are hired with skills in sampling or statistical programming and placed in specialized roles. We use temporary assignments and other experiences to expose these more specialized statisticians to other roles and tools used within the organization. Most recently our methodology team hired nearly twenty new mathematical statisticians into a variety of jobs. We have taken advantage of having an entire cohort of new specialized statisticians to hold a series of training sessions on the tools and concepts unique to the organization.

While tools and technology are imperative to the success of the modern agricultural statistician, the most important attribute is critical thinking. In fact, we must ensure that training on the “how” does not crowd out the “why”.

The profile of the modern agricultural statistician and the agricultural statistical agencycontinues to evolve. The tools we use and the focus on relational databases and the ability to manipulate data continues to grow. As we move forward, new skills will become more important. For example, we are using web scraping techniques to develop specialized lists of farm operations and explore the use of the technique to measure list sampling frame coverage. Specialized statisticians and geographers at NASS leverage big data to develop geospatial data products and inform other work of the organization. Almost certainly in the future, sensor, drone and other big data sources will inform our work and drive the technology skill set of our statisticians.

3. Conclusion

Another description of the nexus of the computer scientist, quantitative social scientist and statistician is the ‘data scientist’. Undoubtedly, NASS and other organizations that produce official government statistics will increasingly need employees that are comfortable in the space that blends computing and computer science skills and statistics. As has always been the case, it is challenging to produce accurate and relevant official statistics for agriculture, but there has never been a more demanding, exciting, or interesting time to work in the field of agricultural statistics.

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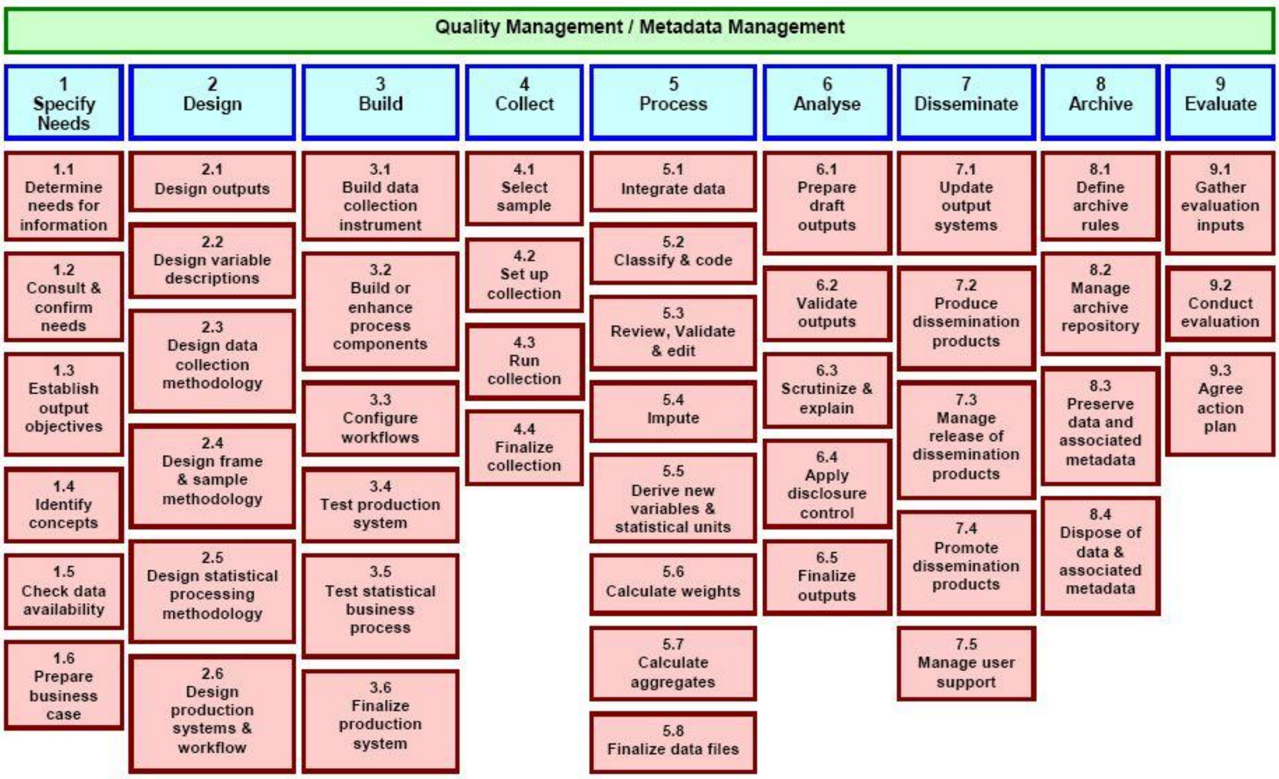
APPENDIX A: Generic Statistical Business Process Model (UNECE); The General Business Architecture for a Statistical Agency



http://www1.unece.org/stat/platform/display/GSBPM/GSBPM+v5.0

The GSBPM describes and defines the set of business processes needed to produce official statistics. It provides a standard framework and harmonized terminology to help statistical organizations to modernize their statistical production processes, as well as to share methods and components.

PRE-CONFERENCE & CONFERENCE SIDE EVENTS

YOUNG STATISTICIANS

A two-day Training Seminar on Methodology for Agricultural Censuses and Surveys has been held on October 24 and 25, 2016. The seminar was intended for young statisticians working in the field of agricultural statistics, or statisticians new to the field of agricultural statistics to encourage an active interest.

GS TRAINING AND OUTREACH WORKSHOP ON AGRICULTURAL SURVEYS

A two-day workshop has been held at FAO headquarters in Rome, on 24-25 October 2016, back to back to the ICAS VII Conference. The Training and Outreach Workshop on Agricultural Surveys was opened for representatives of National Statistical Offices and Ministries of Agriculture and researchers, technicians and statisticians specialized in agricultural statistics methodology.

SEMINAR ON STRENGTHENING COLLABORATION BETWEEN AGRICULTURAL ECONOMISTS AND AGRICULTURAL STATISTICIANS

The seminar was held at FAO headquarters in Rome on 25 October 2016 and it was aimed at connecting producers and users of agricultural statistics with emphasis on the use of Agricultural Statistics in economic analysis.

COMMITTEES

ICAS VII SCIENTIFIC PROGRAMME COMMITTEE

The technical content of this Seventh International Conference on Agricultural Statistics was set by the ICAS VII Scientific Programme Committee, co-chaired by the Chair of ISI CAS and the President of the Italian National Institute of Statistics (Istat).

CO-CHAIRS

Giorgio Alleva | Istat President
Pietro Gennari | Chief Statistician | Food and Agriculture Organization of the United Nations (FAO) | Rome | Italy

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Michael Steiner | National Agricultural Statistical Service, US Department of Agriculture (USDA-NASS) – USA

COMMITTEES

ICAS VII NATIONAL SCIENTIFIC COORDINATION COMMITTEE

The National Scientific Coordination Committee was set to promote the wide participation of Italy in the various fields of interest of the Conference. It also contributed to identifying the topics to be included in the different sessions; singling out the speakers; providing assistance to the evaluation activities of the national and international contributions deriving from the call for papers; offering a scientific support to Istat in carrying out the works.

CHAIR

Giorgio Alleva | Istat President

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Luca Cesaro | National Institute of Agricultural Economics | Italy
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COMMITTEES

ICAS VII LOCAL ORGANIZING COMMITTEE

The group was tasked with the definition of the integrated communication project and the PR strategy in support of the event; the management of the process of acquiring, sharing and monitoring of scientific documentation; the definition of editorial standards and the issue of proceedings; the implementation of the dedicated website.

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Nizalov D. | Cap. Dev. for Evidence-Based Land & Agricultural Policy Making Project in Ukraine | Kiev | Ukraine | C.18
Nkunzimana T. | JRC/European Commission | C.16
Nocentini S. | Dipartimento di Gestione dei Sistemi Agrari, Alimentari e Forestali | University of Florence | Florence | Italy | D.25
Nord M. | FAO | Rome | Italy | B.10
Nsiima L. | Ministry of Livestock and Fisheries Development | Dar es Salaam | United Republic of Tanzania | A.04 – H.47

Nwosu C. | FAO | Rome | Italy | B.10
Nyamsi U. E. | FAO | Accra | Ghana | F.35 – G.44
O'Neill L. | Statistics Canada | Ottawa | Canada PL2
Obayelu A.E. | Federal University of Agriculture Abeokuta | Abeokuta | Nigeria | B.08
Obayelu O. A. | University of Ibadan | Ibadan | Nigeria | C.16
Obersteiner M. | IIASA | Laxenburg | Austria | G.45
Obst C. | FAO | Rome | Italy | C.19
Oduniyi O. S. | University of South Africa | Johannesburg | South Africa | E.28
Ohiomoba S. I. | Federal Ministry of Agriculture | Abuja | Nigeria | A.06
Okello P. | Uganda Bureau of Statistics | Kampala | Uganda | H.47
Okotie V. O. | Federal Ministry of Agriculture | Abuja | Nigeria | A.06
Olva H. | Servicio de Información Agroalimentaria y Pesquera (SIAP-SAGARPA) | Ciudad de México | México | G.42
Ornelas P. | Servicio de Información Agroalimentaria y Pesquera (SIAP-SAGARPA) | Ciudad de México | México | G.42
Otchere F. | UNICEF | Florence | Italy | A.04
Ottaviani D. | FAO | Rome | Italy | C.19
Ottaviano M. | Università degli Studi del Molise | Pesche | Italy | G.42
Otterskog L. | Statistics Sweden | Örebro | Sweden | B.13
Ouedraogo E. | FAO | Accra | Ghana | F.35 – G.44
Owino A. Y. | School of Statistics and Planning | Makerere University | Kampala | Uganda | B.10
Oya C. | SOAS - University of London | London | United Kingdom | A.05
Ozbek F. S. | Turkish Statistical Institute | Ankara | Turkey | F.33
Pace E. | ISPRA - Institute for Environmental Protection and Research | Rome | Italy | B.13
Pacifico R. | ISPRA - Institute for Environmental Protection and Research | Rome | Italy | B.13
Pacini B. | University of Pisa | Pisa | Italy | H.47
Pagliacci F. | Università di Modena e Reggio Emilia | Modena | Italy | A.01
Pagliarella M. C. | Università degli Studi del Molise | Pesche | Italy | G.42
Pagliuca D. | Istat | Rome | Italy | C.22
Palmegiani G. | LUISS University of Rome | Rome | Italy | D.24
Palmieri A. | Eurostat | Luxembourg | Luxembourg | D.25
Pangapanga I.P. | Lilongwe University of Agriculture and Natural Resources | Lilongwe | Malawi | B.07 – F.34 – H.46
Pangapanga L. T. | Research for Development | Lilongwe | Malawi | F.34 – H.46
Paolantonio A. | IFAD | Rome | Italy | C.22
Pareto A. | Istat | Rome | Italy | C.20
Paris P. | ISPRA - Institute for Environmental Protection and Research | Rome | Italy | B.13
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Parsons J.L. | USDA National Agricultural Statistics Service | Washington, DC | USA | H.48
Pasqui M. | Istituto di Biometeorologia del Consiglio Nazionale delle Ricerche | Rome | Italy | E.28
Pazvakawambwa L | University of Namibia | Windhoek | Namibia | B.11
Pennec A. | SIRS | Villeneuve d'Ascq | France | G.42
Percic M. | FAO | Rome | Italy | A.05
Pérez S. | INEGI | Aguascalientes | Mexico | F.32 – F.34
Perger C. | IIASA | Laxenburg | Austria | G.45
Persson D. | Swedish Board of Agriculture | Jönköping | Sweden | F.32
Pesola L. | Dipartimento di Scienze Agro-Ambientali e Territoriali | University of Bari | Bari | Italy | D.25
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Piersante A. | FAO | Rome | Italy | F.35
Poppe K. | LEI Wageningen UR | Wageningen | The Netherlands | PL3

Porciani L. | Istat | Rome | Italy | H.47
Portoghesi L. | University of Tuscia | Viterbo | Italy | F.31
Povellato A | CREA-INEA | Legnaro | Italy | B.13
Pramanik C. | Tata Consultancy Services | Hyderabad | India | C.21
Pramanik C. | e-Rural Services | Hafeezpet | Hyderabad | India | G.43
Praneet P. V. | Tata Consultancy Services | Kochi | India | C.21
Prasil S. | Statistics Canada | Ottawa | Canada | F.32 – G.45
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Quaresima S. | Istituto di Biometeorologia del Consiglio Nazionale delle Ricerche | Rome | Italy | E.28
Rabaute T. | CS, Systèmes d'information | Le Plessis Robinson | France | F.30
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Ramasamy S. | FAO | Rome | Italy | F.38
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Righi P. | Istat | Rome | Italy | PL2 – F.29
Rodriguez Figueroa S. Y. | DANE | Bogotá | Colombia | F.29
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Rossi A. | FAO | Rome | Italy | E.26
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Russo V. | University of Bologna | Bologna | Italy | B.12
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Sahi N. | BuildFusion, Inc. | Kolkata | India | G.43
Sallustio L. | Università degli Studi del Molise | Pesche | Italy | D.25 – G.42
Salvati N. | University of Pisa | Pisa | Italy | F.35
Sannier C. | SIRS | Villeneuve d'Ascq | France | G.42
Sarangi S. | Tata Consultancy Services | Mumbai | India | C.21
Saravia-Matus S. | Consultant FAO | Rome | Italy | C.21
Savastano S. | University of Rome Tor Vergata | Rome | Italy | C.23
Savignaud M. | CS, Systèmes d'information | Le Plessis Robinson | France | F.30
Scandizzo P. L. | University of Rome Tor Vergata | Rome | Italy | C.23
Scarnò M. | CINECA | Rome | Italy | D.25 – F.29
Scarpinella M. S. | Sapienza University of Rome | Rome | Italy | E.26
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Selenius J. | Eurostat | Luxembourg | Luxembourg | F.37
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Serafini M. | CREA | Rome | Italy | G.43
Seri G. | Istat | Rome | Italy | G.45
Sermoneta C. | Istat | Rome | Italy | B.12 – B.13
Shelestov A. | Space Research Institute, NAS | Kyiv | Ukraine | F.30
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Solari F. | Istat | Rome | Italy | F.35
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Surinov A. | Federal State Statistics Service (Rosstat) | Moscow | Russian Federation | F.39
Svensson U. | Swedish Board of Agriculture | Jönköping | Sweden | F.32
Tagliacozzo G. | Istat | Rome | Italy | D.24 – E.28
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Tankari M. | IFPRI | Dakar | Senegal | G.40
Tayyib S. | FAO | Rome | Italy | B.15
Temoso O. | University of New England | Armidale | Australia | B.07
Tersigni S. | Istat | Rome | Italy | D.24 – E.28 – F.30
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Tsuji S. | FAO | Rome | Italy | C.19
Tubiello F. | FAO | Rome | Italy | C.19
Tuoto T. | Istat | Rome | Italy | F.32
Turchetti S. | IRPET | Florence | Italy | A.02
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Vassallo M. | CREA | Rome | Italy | G.43
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Vidoli F. | University of Roma Tre | Rome | Italy | B.08
Vignani D. | Istat | Rome | Italy | D.24 – E.28
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Vitale V. | Istat | Rome | Italy | F.30
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Viviani S. | FAO | Rome | Italy | B.10
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Vrolijk H. | LEI Wageningen UR | Wageningen | The Netherlands | PL3
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Waine T. W. | Cranfield University | Cranfield | United Kingdom | B.09
Waleed M. | Central Agency for public Mobilization and statistics (CAPMAS) | Cairo | Egypt | H.46
Wallgren A. | BA Statistiksystem AB | Vintrosa | Sweden | F.33
Wallgren B. | BA Statistiksystem AB | Vintrosa | Sweden | F.33
Weichselbaum J. | GeoVille Information Systems GmbH | Innsbruck | Austria | G.45
Welch M. | The World Bank | Washington, DC | USA | H.46
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Young L. | USDA National Agricultural Statistics Service | Washington, DC | USA | F.29
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Zezza Alberto | The World Bank, Development Data Group | Rome | Italy | B.10 – C.18
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Zhang Y. | Agriculture and Agri-Food Canada | Ottawa | Canada | G.43
Zheng Y. | Chinese Academy of Sciences | Beijing | China | G.42
Zhou T. | USDA National Agricultural Statistics Service | Washington, DC | USA | F.39
Zhou W. | National Bureau of Statistics of China | Beijing | China | G.44