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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:

$$GM_{jT} = TR_{jT} - TVC_{jT} \quad (1)$$

$$TR_{jT} = P_j Q_{jT} \quad (2)$$

$$TVC_{jT} = \sum_{i=1}^{n} P_{xi} X_i \quad (3)$$

$$GM_{jT} = P_j Q_{jT} - \sum_{i=1}^{n} P_{xi} X_{iT} \quad (4)$$

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:

$$lnQ = lnB_o + \beta_1 lnX_1 + \beta_2 lnX_2 + \beta_3 lnX_3 + \cdots + \varepsilon^{\mu_i} \quad (5)$$

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.

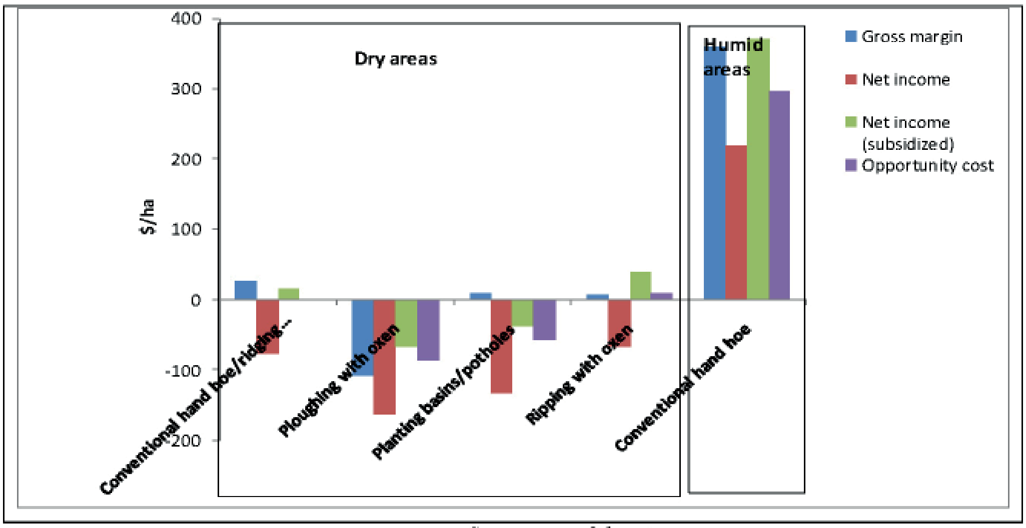
[3] This fertilizer category includes: Compound D, Compound X, Compound R, Compound S, Triple Super Phosphate (TSP), Single Super Phosphate SSP).

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

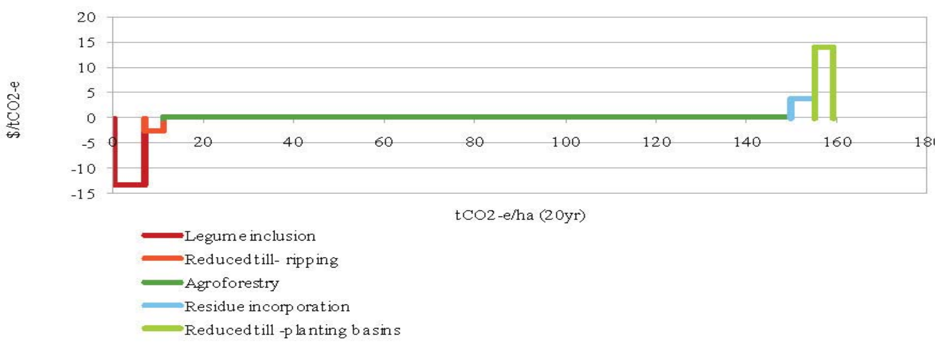
	Log of maize yields (kg/ha) AER IIa	
	(1)	(2)
SLM practices		
MSD (1=yes, 0=no)	0.172**	0.178*
Residue retention (1=yes, 0=no)	0.096	0.096
Crop rotation with legumes (1=yes, 0=no)	0.260	0.260
Weather variables		
Total rainfall during cropping season (mm)	0.001	0.001
Average of dekadal max temperatures 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.

References

Ajayi, O.C., F.K. Akinnifesi, J. Mullila-Mitti, J.J. DeWolf and P.W. Matakala. 2006. Adoption of agroforestry technologies in Zambia: synthesis of key findings and implications for policy

Baldwin, K.R. 2009. "Crop rotations on Organic Farms". North Carolina Cooperative Extension Service

Branca G, McCarthy N, Lipper L, Jolejole MC. Food security, climate change and sustainable land management. A review (2013). Agronomy for sustainable development, 33:635–650, doi: 10.1007/s13593-013-0133-1 Branca G., Lipper L., Sorrentino A. (2015). Cost-effectiveness of climate-related agricultural investments in developing countries: a case study. New Medit, n.2/2015.

Brown, M. L. (1980). Farm budgets: from farm income analysis to agricultural project analysis. World Bank Staff Occasional Papers, International Bank for Reconstruction and Development 1980. ISBN 0-8018-2387-0

Burke, B., Jayne, T. M. Hichaambwa and D. Banda. 2011. The Cost of Producing Maize in Zambia, IAPRI working paper number 50, Food Security Research Project

Chidumayo, E.N. 1987. A shifting cultivation land use system under population pressure in Zambia, Agro-forestry systems 5: 15-25

Delgado, J. A., P.M. Groffman, M.A. Nearing, T. Goddard, D. Reicosky, R. Lal, N. R. Kitchen, C. W. Rice, D. Towery, and P. Salon. 2011. Conservation practices to mitigate and adapt to climate change, Journal of Soil and Water Conservation July/August 2011, vol. 66, no. 4, 118A-129A.

Dinkins, C.P., C. Jones and K. McVay. 2008. Nutrient Management in No till and Minimum Till systems, Montana State University Extension Service.

Dixon J., Gulliver A., Gibbon D. (2011) Farming systems and poverty: improving farmers' livelihoods in a changing world. FAO and World Bank, Rome and Washington D.C.

FAO and IIASA (2012), GAEZ - Global Agro-Ecological Zones, http://www.fao.org/nr/gaez/en/

FAO (2010) "Climate-smart" agriculture. Policies, practices and financing for food security, adaptation and mitigation. Food and Agriculture Organization of the United Nations, Rome

Haggblade, S. S. Kabwe,and C. Plerhoples. 2011. Productivity impact of Conservation Farming on Smallholder Cotton Farmers in Zambia, Working paper number 47, Food Security Research Project

IPCC (2006). Guidelines for National Greenhouse Gas Inventories, Intergovernmental Panel on Climate Change.

Kaczan D., Arslan A., Lipper L. 2013. Climate-Smart Agriculture? A review of current practice of agroforestry and conservation agriculture in Malawi and Zambia. ESA Working Paper No. 13-07. FAO. Rome, October. http://www.fao.org/3/a-ar715e.pdf

Lal R (1997a) Degradation and resilience of soils. Phil Trans R Soc London B 352:869–889. doi:10.1098/rstb.1997.0078

Malcolm L.R. (1990), Fifty years of farm management in Australia: survey and review. Review of marketing and agricultural economics, vol.58, n.1, April.

MAL and CSO. 2013. 2012/2013 Crop Forecast Survey Report. Government of the Republic of Zambia

MAL and CSO. 2012. 2011/2012 Crop Forecast Survey Report. Government of the Republic of Zambia

MAL. 2013. Agriculture Statistical Bulletin, Government of the Republic of Zambia

MAL. 2007. Investment Opportunities in Agriculture, Government of the Republic of Zambia

MAL and WB, 2012. Livestock toolkit implementation: mid-term report. Ministry of Agriculture and Livestock and The World Bank. Lusaka.

Mupangwa, W., S. Twomlow and S. Walker. 2008. Minimum tillage and mulching effect on cowpea yield and soil water content, ICRISAT-Bulawayo, Matopos Research Station

Nkatiko, C. 2013. Conservation Farming Unit, Director Operations. Personal Communication.

Paarlberg R. (2010). Food politics: what everyone needs to know. Oxford University Press.

Pearce D. (1998). Cost-benefit analysis and environmental policy. Oxford review of economic policy, vol.14, no.4,

Pretty JN (2008) Agricultural sustainability: concepts, principles and evidence. Phil Trans R Soc London B 363(1491):447–466. doi:10.1098/rstb.2007.2163

Pretty JN (2011) Editorial: sustainable intensification in Africa. Int J Agric Sustain 9(1):3–4. doi:10.3763/ijas.2010.0583

Sebastian, K. (2014) "Agroecological Zones," Atlas of African Agriculture Research & Development: Revealing Agriculture's Place in Africa, International Food Policy Research Institute (IFPRI).

Stehfest E., Bouwman L., (2006). N2O and NO emission from agricultural fields and soils under natural vegetation: summarizing available measurement data and modeling of global annual emissions. Nutrient Cycling in Agroecosystems 74(3), 207-228.

Swinton S.M., Lowenberg-DeBoer J. (2013). Evaluating the Profitability of Site-Specific Farming. Journal of Production Agriculture Vol. 11 No. 4, p. 439-446. doi:10.2134/jpa1998.0439

Thierfelder, C. and P.C.Wall. 2010. Rotation In Conservation Agriculture Systems Of Zambia: Effects On Soil Quality And Water Relations, Exploring Agriculture, volume 46 (3), pp. 309–325

Vetter S., Hillier J, Albanito F. (2014), Climate Change mitigation from agriculture activities in Malawi, Viet Nam and Zambia, Final Report, University of Aberdeen, Aberdeen, UK

Whiteside, M. 2011. Evidence Base for Climate Resilient and Productive Agriculture in Southern Africa, DFID Southern Africa.

Whittaker, G.L., Biing-Hwan L., Utpal V. (1995). Restricting pesticide use. The impact on profitability by farm size. J. Agri. Appl. Econ., 27(2): 352-362

Woodfine A (2009) The potential of sustainable land management practices for climate change mitigation and adaptation in sub- Saharan Africa. Food and Agriculture Organization of the United Nations, Rome

World Bank (2006) Sustainable land management: challenges, opportunities, and trade-offs. The World Bank, Washington, DC.

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