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Methodological experiment on measuring cassava production, productivity, and variety identification in Malawi

T. Kilic | The World Bank, Living Standards Measurement Study Team (LSMS), Development Data Group | Rome | Italy

H. Moylan | The World Bank, LSMS, DECDG | Rome | Italy

J. Ilukor | The World Bank, LSMS, DECDG | Kampala, | Uganda

I. Pangapanga Phiri | Lilongwe University of Agriculture and Natural Resources | Lilongwe | 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

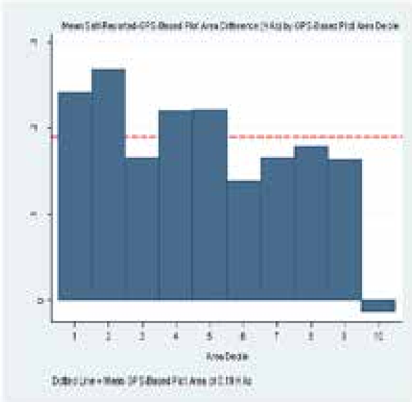

Table 2 - 6 months of Cassava Production in KGs

	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

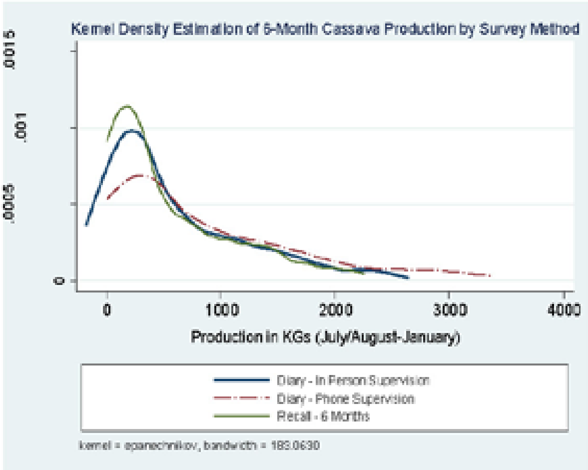

Table 4 - Estimated Cassava Production (KG) Comparisons by Land Tercile

		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	-	-