50x2030
DATA-SMART AGRICULTURE

TECHNICAL NOTE ON CROP CUTTING

WITH A FOCUS ON MAIZE

NOVEMBER 2025
50x2030 TECHNICAL NOTES FOR COUNTRY TEAMS

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This document is a product of the 50x2030 Initiative to Close the Agricultural Data Gap and was developed by Giulia Ponzini, Ismael Yacoubou Djima, Sydney Gourlay, and Alemayehu Ambel of the World Bank's Living Standards Measurement Study (LSMS) team. Valuable comments and inputs were received from FAO colleagues working on 50x2030 Data Production activities, particularly Dramane Bako who provided extensive inputs related to sampling. This document draws heavily from previous methodological work conducted by the LSMS team, the experience of crop-cutting in national surveys, and other existing guidance.

The 50x2030 Initiative to Close the Agricultural Data Gap is a multi-agency effort aimed at supporting 50 low- and lower-middle-income countries to produce fundamental agricultural and rural data through the use of integrated agricultural and rural surveys. For more on the Initiative, please visit www.50x2030.org.

This publication is part of a series of 50x2030 Technical Notes for Country Teams that will provide digestible, implementation-focused guidance for data producers and survey practitioners. Each note offers a brief summary of the motivation for specific survey design decisions followed by detailed, practical guidance that can be directly translated into survey design or training efforts. These notes are part of the existing 50x2030 Technical Note series.

CONTENTS

1. INTRODUCTION & MOTIVATION

Total crop production and crop yields are fundamental indicators in agricultural statistics, as well as for policy-relevant research aimed at improving food production and the well-being of agricultural households. Many household and agricultural surveys rely on estimates of crop production for a given season provided by survey respondents, which then also inform estimates of crop yields. This approach, though relatively cost-effective and quick to implement, comes with challenges. These challenges, which include the use of non-standard production units, the tendency of respondents to round off production estimates, and other sources of intentional and unintentional bias, can negatively impact the accuracy of the data and ultimately provide misleading information on production and productivity.

What are the risks of relying on farmer estimates of crop production? There is robust empirical evidence of data quality concerns and, often systematic, measurement errors in farmer-reported harvest estimates. These errors can influence not only estimates of production but also estimates of crop yields (Desiere and Jolliffe, 2018; Gourlay et al., 2019; Abay et al., 2019; Yacoubou Djima and Kilic, 2024), where crop yields are generally overestimated by farmers on average. The scatterplot in Figure 1 depicts the differences observed in wheat yields in Ethiopia, as estimated by farmer reporting and via crop-cutting (Abay et al., 2019), while Figure 2 illustrates the difference in maize yields observed across methods by plot size, also in Ethiopia, as reported by Desiere and Jolliffe (2018). Similarly, work by Gourlay, Kilic, and Lobell (2019), leveraging data from a two-round methodological study in Uganda, find that self-reported maize yields are more than 85 percent higher than crop-cut yields on average in each wave. Other evidence also suggests that error in the reporting of production is also related to error in the estimates of plot area, which can result in biased understandings of the relationship between land and productivity either in terms of over estimation or underestimation (Abay et al., 2019). Measurement error in farmer-reported production estimates limits their suitability for use in the development and calibration of crop yield maps (Paliwal & Jain, 2020; 50x2030 Initiative, *forthcoming*).

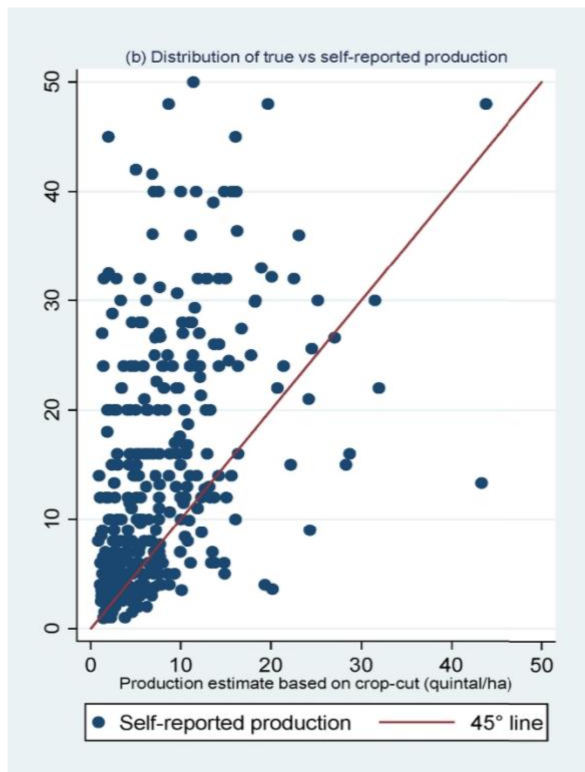

Figure 1. Scatterplot of self-reported vs crop-cut yield estimates for wheat in Ethiopia. This figure is extracted from Abay et al. (2019, Figure 2, panel (b)). The horizontal axis is wheat production (quintal/ha) as measured by crop-cutting while the vertical axis is the self-reported wheat production on the same plots. The red line indicates the 45-degree line of equality.

Though farmer estimates of crop production provide useful insights, especially when used as inputs into imputation models aimed at producing improved estimates of crop production and yields (see Box 3), the measurement error observed with this approach may result in misinformed policy. Crop-cutting offers a complementary method to significantly improve the accuracy of data on crop production and yield.

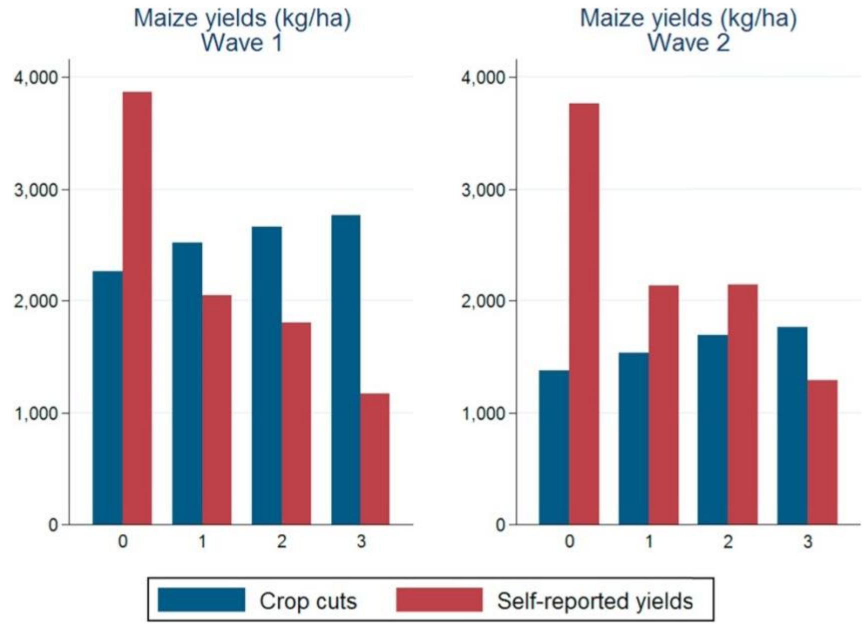

Figure 2. Maize yields as measured by crop cutting and farmer self-reports. This figure is replicated from Desiere and Jolliffe (2018, Figure 1). Maize yields, estimated through self-reports and crop-cuts on the same plots, are presented for two waves of data from the Ethiopia Socioeconomic Survey. Vertical axes are estimated yields in kilograms per hectare, and horizontal axes are plot-size quartiles. The quartiles have average plot sizes of 132 m^2, 421 m^2, 1127 m^2, and 3660 m^2.

What is crop cutting? Crop cutting is a more objective method of measuring crop production and has long been considered the recommended approach by the Food and Agriculture Organization of the United Nations (FAO, 1982). Crop cutting entails the identification of a portion of an agricultural plot of a predetermined size, referred to henceforth as a *subplot*, and subsequently harvesting and weighing every crop of interest that is cultivated within that subplot. See Box 1 for examples of subplot sizes in different surveys. There are various approaches to determining the location of the subplot, such as following a randomization protocol (as is recommended in this document) or systematic placement. Examples of these variations can be found in Fermont and Benson (2011) and Kosmowski et al. (2021), while Ayalew et al. (2023) highlight the important implications of the choice of protocol. The size and number of the crop-cutting subplot(s) may also vary. In addition to achieving estimates of crop yield from the subplot (total harvested quantity divided by the area of that subplot), that yield can also be multiplied by the total area of the plot to estimate total production on that plot.

Crop-cutting requires households/farms to be visited at least twice. Field teams visit the farm once at the post-planting stage and once when the crop is mature, but before the plot is harvested (i.e. before the post-harvest visit). During the first visit, the enumerator will proceed with the demarcation of the area of the crop cutting subplot. During the second visit, the enumerator will guide the harvest of the crop. The crop harvested from the subplot will be weighed at the time of harvest. Depending on the crop, it may also be necessary to record the moisture of the harvested crop and/or dry the crop further and re-weigh after thoroughly dried. The harvesting time may vary by crop; therefore, if the crop cutting is done on

Box 1. Subplot sizes

The size of the crop-cutting subplot – for example, an 4m x 4m subplot or an 8m x 8m subplot – can have implications on both the quality of the resulting data and fieldwork costs. Generally, the larger the size of the crop cutting subplot, the more representative the subplot will be of production on the entire plot. However, larger subplots take more time to harvest, and they can also lead to lower levels of compliance from households if households need to harvest a portion of their plots early. Larger subplots can also lead to more frequent challenges in fitting the subplot in the area of a plot, especially when plots are typically small or irregularly shaped. In some cases, survey practitioners opt to collect more than one subplot within a given plot, to increase the representativeness of the crop cutting area.

The table below summarizes key crop cutting design elements, including the size of crop cutting subplot, for select surveys:

Country	Type of Survey	Crop type	At what level were plots selected for crop-cutting?	Subplot size
Ethiopia	National survey (ERSS 3)	Varied (23 total)	Enumeration area	4m x 4m
Mali	National survey	Varied (38 total)	Enumeration area	Varied: - Millet, Sorghum. Maize, cowpea: 3mx3m - Rice: 1mx1m - Peanut, Soja: 2mx2m
Mali	Subnational methodological study (ERIVaS 2017)	Sorghum	Household	8m x 8m, divided into 4 quadrants
Uganda	Subnational methodological study (MAPS 2016)	Maize	Household	8m x 8m, divided into 4 quadrants

many plots and on many crops of the household/holding, the enumerator will have to visit during the harvest period of each plot/crop.

Despite being considered the gold standard, crop cutting has its own pitfalls and can lead to estimates with measurement error (Desiere and Jolliffe, 2018; Gourlay et al., 2019). To be successful, crop cutting needs to be well implemented and carefully supervised.

This document aims to provide data producers with guidance to effectively implement crop cutting in the context of 50x2030-supported surveys, including considerations for fieldwork planning, equipment and personnel needs, and protocols for the identification of crop cutting subplots and subsequent harvest. Though not conducted in all 50x2030-supported surveys, particularly given the resource needs and survey design requirements (discussed below), crop cutting is proposed as an optional method to obtain a more accurate measure of the production of a country's main crops where feasible. This document builds largely on the literature and the experience amassed as part of previous methodological research implemented by the World Bank's Living Standards Measurement Study (LSMS) team and in crop cutting efforts undertaken as part of national surveys. While the guidance provided in this document is generally relevant to the crop cutting of seasonal crops, the document gives particular attention to the crop cutting of maize, as it is one of the most common crops subject to crop cutting.[1]

1.1 Contextual considerations for crop cutting of maize

Though this document aims to support crop-cutting for various seasonal crops, given the emphasis placed on maize throughout this document and its importance in many 50x2030 countries, it is useful to highlight certain characteristics of maize cultivation that are relevant for planning and implementing maize crop cutting efforts. The primary considerations are cropping patterns and harvest periods.

First, maize can be cultivated in a pure stand (monocropped) fashion, in which maize is the only crop on a given plot, or in a mixed cropped or intercropped fashion, in which at least one other crop is cultivated on the plot along with maize. This has an important implication on both crop-cutting arrangement and yield measurement through crop cutting. Some crops will take more space and hence reduce the area covered by maize substantially. Others grow without considerable effect on the total area covered by maize. A decision is to be taken on whether both pure stand and intercropped plots are subject to crop cutting. The incidence of cultivating maize alone versus with other crops varies across countries. **Error! Reference source not found.** illustrates the frequency of intercropping on maize plots across countries included in the LSMS-Integrated Surveys on Agriculture (LSMS-ISA) program. In some countries, like Nigeria, nearly all maize plots are intercropped while in others, like Mali, nearly all maize plots are pure stand.

Secondly, the timing of maize harvest is essential when planning for crop cutting. Field teams will need to be available for harvesting, and longer or more varied harvest periods can translate into the need to keep field teams deployed for longer periods of time or with greater flexibility. Nationally representative surveys cover extensive areas with diverse agro-ecological zones, with each potentially having different agricultural seasons and maize harvest times. Figure 4 shows the peak harvest months of maize across seven countries, based on farmers' responses in LSMS-ISA surveys (2010-2022). The pooled data illustrate the timing of maize harvests and its implications for crop-cutting data collection. In some countries, harvest periods are clustered within certain months. For example, Ethiopia's harvest peaks in September/October and ends by February, with October to December being particularly important. In other countries, harvest may extend over a larger period of time. Mali's harvest lasts a few months, while Tanzania's spans many months, likely due to agro-ecological diversity across regions.

[1] For more information on implementing crop-cutting for extended harvest crops, and cassava in particular, refer to Kilic et al. (2021).

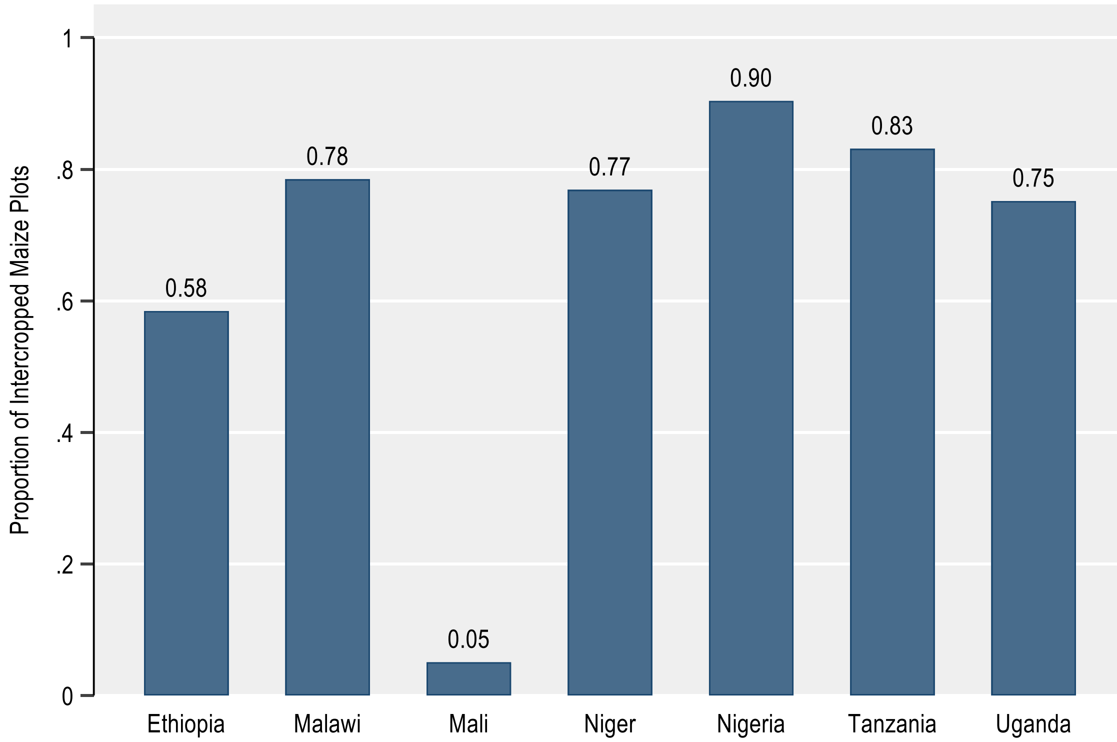

Figure 3. Incidence of intercropping on maize plots. Source: Authors' compilation from several waves of LSMS-ISA surveys.

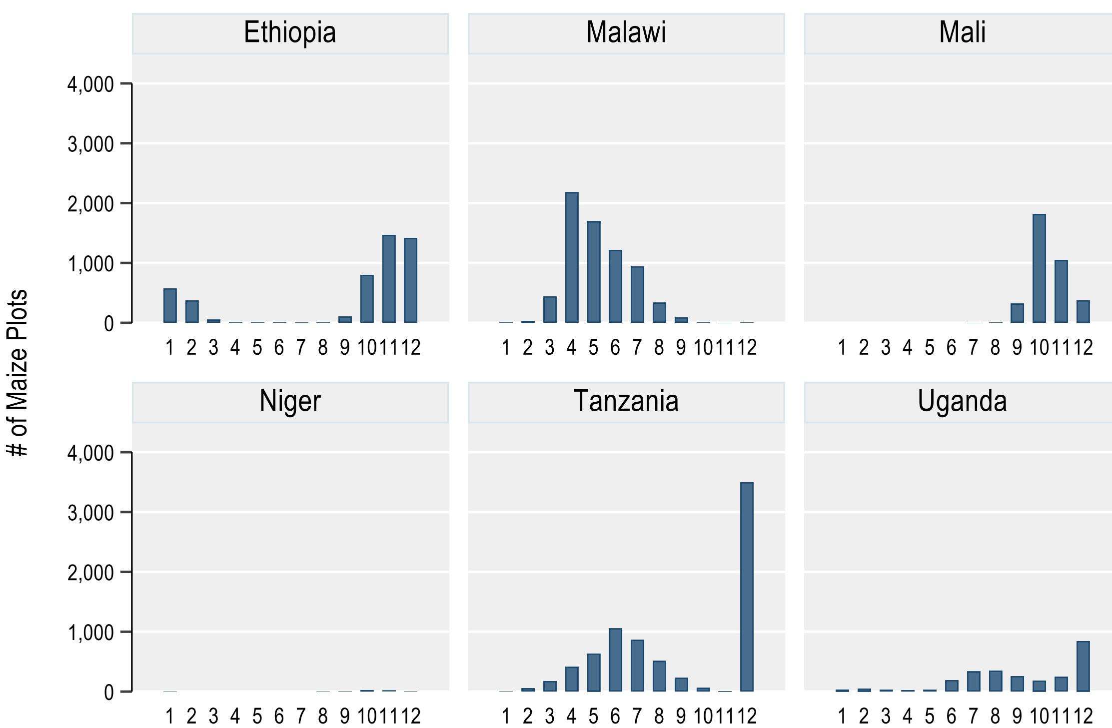

Figure 4. Month of maize harvest completion. Source: Authors' compilation from several waves of LSMS-ISA surveys

2. SURVEY REQUIREMENTS: ENABLING CONDITIONS FOR CROP-CUTTING IMPLEMENTATION

Integrating crop-cutting into nationally representative surveys requires a specific survey design and a careful implementation plan, as well as some questionnaire design-related considerations. Key factors for consideration include: the number and timing of field visits, the level of data collection, the questionnaire content needed to make the most use out of crop-cutting data, and general requirements of the survey sample. These points, as well as discussion of where and how crop-cutting can be integrated into 50x2030 questionnaires, are discussed below.

2.1 Number and timing of field visits

Crop-cutting consists of two main activities, the details of which will be explained in section 3: (i) the demarcation of the crop-cutting area (the sub-plots), within which the crop-cutting exercise is done; and, (ii) actual harvest and weight of the crop from the crop-cutting area. To appropriately and reliably conduct crop-cutting, the demarcation of the crop-cutting area is conducted in a post-planting visit, while the harvest of the crop-cutting area is conducted in a separate visit, when the crop is ready for harvest, which is typically before the traditional post-harvest survey is administered. Complementary information is collected during a post-harvest visit, as well as data on the harvest of crops that were not included in the crop-cutting exercise.

To implement crop-cutting, therefore, an agricultural plot must be visited in the period after planting but before harvest. Given this, **a survey that is designed for implementation in a single visit is not a good candidate for crop-cutting implementation**.[2] As a starting point, a survey must be designed in a two-visit approach, to which a third, interim visit will be added for the harvesting of the crop-cutting area.

Crop-cutting activities are highly time sensitive. Survey planners, managers, and field teams need to keep in mind the planting and harvesting dates of the crop of interest, and adjust implementation schedules accordingly, noting that the implementation timing may differ across regions or agroecological zones. The post-planting visit ought to take place after the crop of interest has been planted so that the boundaries of the plot determined, but not too late such that any of the crop has been harvested. From a practical perspective, it is also easiest to implement this visit while the crop is still young, for example with knee-

[2] Although there are a few known cases in which crop-cutting has been conducted in the context of a single visit survey, where both the crop-cutting subplot demarcation and harvesting are done at the time of the survey (in the harvest or post-harvest period), this is not the recommended approach. This approach may result in some improvement in data quality over respondent estimation alone, though there are many potential sources of error and further research is needed to understand the overall gains in data quality. In this case, a primary source of error is related to the timing of the harvest vis-à-vis the survey visit. If the survey visit is after the harvest has been completed, it will not be possible to conduct physical harvest of the crop-cutting subplot and the best case scenario would be to estimate the harvest based on the number of plants in the crop-cutting area (which may be feasible for some crops, depending on the timing of the visit, but even then you are unable to reasonably estimate crop damage). Alternatively, if the survey visit is before harvest is completed, it is likely that self-reported estimates would suffer as respondents have not yet harvested, and while this may not be an important issue for plots on which crop-cutting is conducted it would be a significant issue on plots that do not receive crop-cutting. Similarly, a two-visit survey operation may be tempted to forgo the interim crop-cut harvest visit due to resource constraints and conduct the harvest at the same time as the post-harvest survey, but the abovementioned risks remain. For these reasons, this technical note is focused exclusively on crop-cutting in the context of a two-visit survey.

high maize, to prevent the need to operate in more difficult conditions, such as with chest-high maize, which could make use of the measuring tape and other equipment more challenging. For the harvesting of the crop-cutting areas, additional flexibility is likely to be needed as the harvest dates may vary more across the country. The harvest visit ought to take place when the farmer, or the majority of the farmers in the community, have indicated that the crop is ready for harvest. As seen in Figure 4, the timing of maize harvest can vary within a country. In the case of maize, the crop should be harvested when dry on the cob, as fresh maize cannot be readily shelled.

2.2 Level & granularity of data collection

Surveys that collect data on crop production at aggregate levels, such as at the farm level, are not candidates for crop cutting. For crop cutting to be implemented, a survey must collect agricultural data at the plot level. Typically, agricultural surveys, including those conducted under the 50x2030 Initiative, follow a nested parcel-plot structure, where some information is collected at the parcel level (such as tenure status of the parcel of land) and some information is collected at the plot level (including crop production and cultivated area, among others).[3] Plot level data collection is critical for a number of reasons. First, a plot roster will be necessary in order to select the land that is subject to crop-cutting (more on this below). Additionally, it is essential to have measures of plot area in order to estimate total production on that plot. As mentioned above, the yields estimated through the crop cutting exercise are applied to the total area of the plot to produce estimates of total production on that plot.

Additionally, data should also be collected at the plot-crop level, such that there is information reported on which crops are cultivated on each plot. This is critical for understanding which plots are intercropped and which are pure stand, and, in the case of intercropped plots, the combination of crops cultivated and the area under each crop as these are necessary inputs for estimating and reporting yields.

2.3 Complementary data points

In addition to data on plot area and crop cultivation patterns, as noted above, there are additional data points that are required and others that are useful. Some of these are used to support the yield estimation itself by providing quality control and complementary data to validate the yield estimates. These can include collection of data on the number of maize plants planted on the plot, number of maize plants *planted* in crop cutting subplot, number of maize plants *harvested* from the subplot during the crop cutting exercise, number of maize cobs harvested from the subplot during the crop cutting exercise, and moisture content of the maize at the time of weighing. Additionally, recording the number of plants damaged in the subplot and number of plants pre-harvested by households (i.e., plants that were harvested from the subplot prior to the arrival of the field teams despite instruction not to harvest) is also useful. Beyond supporting quality control in crop-cutting estimates, the combination of these data points can allow for an understanding of non-compliance in the crop-cutting exercise, enable the adjustment of crop-cutting

[3] A parcel is defined as any piece of land of one land tenure type entirely surrounded by other land, water, road, forest or other features not forming part of the holding, or forming part of the holding under a different land tenure type (FAO, 2017). A plot is defined as a continuous piece of land on which a specific crop or a mixture of crops is grown or which is fallow is waiting to be planted, under a uniform, consistent crop management system. A parcel consists of one or more plots.

weights for plants that were pre-harvested, and explain any reports of "0" crop cutting harvest (as a function of crop damage and/or non-compliance).

Relatedly, GPS-based area measurement is strongly recommended when conducting crop-cutting. Implementation of this approach will allow for significantly improved estimates of plot level production, as there is vast evidence on systematic measurement error in plot areas estimated by farmers. Georeferencing of plots subject to crop cutting also increases the analytical value of crop cutting data while also facilitating supervision by ensuring enumerators where present in the appropriate areas. See Box 2 for more details.

Finally, some topics should be considered for inclusion as they are very useful inputs into understanding agricultural productivity and informing productivity-focused policies. These include, for example, date of planting (date of crop cutting harvest also to be captured), plot slope, type of seed used, used of organic and inorganic inputs applied on the plot, and other relevant farming practices. These topics are included in most 50x2030 reference questionnaires.

2.4 Integrating crop-cutting into 50x2030 questionnaires and surveys

Crop cutting does not need to be paired with any specific rotating module in the Initiative's survey structure, assuming the requirements above around visitation structure and level of data collection are met. However, the objectives of the exercise and the burden of the survey should be taken into considerations. If the objectives are only to obtain improved estimates of production, integration of crop cutting with the CORE alone or with the Machine, Equipment, and Assets (MEA) instruments would be sufficient, and since those are the shortest instruments the burden would be minimized. Integration with the Farm Income, Labor, and Productivity (ILP) or Production Methods and Environment (PME) instruments would allow for more in-depth analysis of agricultural productivity, in addition to obtaining improved estimates of production, given the wealth of information that would be collected alongside the crop cutting exercise. These instruments, however, are more lengthy and therefore come with more burden for the respondent, enumerator, and fieldwork budget.

For all of the 50x2030 reference questionnaires, including the reference questionnaire for crop-cutting, visit: https://www.50x2030.org/resources/survey-instruments.

Box 2. Critical Complements to Crop-Cutting Activities: Georeferencing and Land Area Measurement

In surveys employing crop-cutting to measure yields, two complementary activities—georeferencing of the selected agricultural plots and objective measurement of the plot areas using GPS—are essential for maximizing data accuracy, usability, and value. Without precise location and land area data, the value of crop-cutting exercises can be significantly diminished, introducing risks of bias for estimates of total agricultural production and limiting the uses of the data.

The Importance of Land Area Measurement for Crop Production Estimation

Crop-cutting provides direct yield measurements, as the production from the crop-cutting subplot is measured and the area of the subplot known, but translating these into total production estimates for the plot as a whole, and for extrapolating to the total cultivated area in a given administrative area, for example, requires accurate plot area data. If plot area is misreported or imprecisely measured, even the most carefully executed crop-cutting exercise will produce flawed estimates of total production.

Farmer-reported plot areas are known to be prone to systematic biases, with evidence suggesting that farmers can underestimate the smallest plots by more than 300% (Carletto et al., 2017). Relying on self-reported values can therefore introduce production statistics when yields measured through crop-cutting are applied to the full plot area to estimate total production for the plot, ultimately affecting agricultural decision-making. To mitigate these risks, the 50x2030 Initiative strongly recommends the use of GPS devices for land area measurement, not only for plots that are subject to crop-cutting, but all cultivated plots (see the 50x2030 Technical Note on Land Area Measurement).

The Added Value of Georeferencing in Crop Cutting Surveys

Georeferencing survey data, which entails the collection of GPS coordinates from the agricultural plot in which the crop-cutting is conducted, strengthens the implementation and value of crop cutting in several ways:

- **Quality Control and Fieldwork Management** – Collecting GPS coordinates allows survey supervisors and managers to ensure field teams visit the correct locations and facilitates follow-up visits by pinpointing exact plot locations.
- **Integration with Remote Sensing for Yield Estimation** – Georeferenced crop-cutting data is critical for calibrating satellite-based models of crop yields, such as those employed to produce crop-yield maps. Lobell et al. (2020) illustrate that crop yield models that are not calibrated on crop-cutting data can significantly overestimate yields.
- **Enhanced Analytical Value through Integration with Geospatial Data** – With location data, survey data can be enriched with external geospatial datasets, such as climate and weather information. Having GPS coordinates for the plots on which crop-cutting is conducted, for example, can allow users to extract information on climate and weather factors for that specific location which can provide deeper insights into how environmental factors influence crop yields and production.

Given the many advantages of georeferencing survey data, especially in the case where crop-cutting is conducted, the 50x2030 Initiative recommends the collection of GPS coordinates at the plot level, in addition to georeferencing the location of the dwelling or farm. For more details on georeferencing, see the see the 50x2030 Technical Note on the Collection of GPS Coordinates.

3. SAMPLING: OPTIONS FOR IDENTIFYING THE SAMPLE OF PLOTS SUBJECT TO CROP CUTTING

Identification of the sample size and design for a crop cutting exercise is a critical step in preparation. While Section 4 discusses the selection of crop-cutting subplots within a plot, this section describes the options for determining which plots (and how many) should be subject to crop-cutting. Although the most reliable estimates would be obtained by performing crop cutting on all plots of all farms of the survey sample this may not be feasible at scale given the high costs of crop cutting implementation and supervision. Rather, the crop cutting may be administered to a subsample of farms and/or plots. A subsample of holdings and/or plots may be used especially when only national-level estimates of crop yields are expected from the survey or if the results of crop cutting are intended to be used for correcting yield estimates based on farmers' declarations using imputation approaches such as those described in Box 3.

When opting to conduct crop-cutting on a sub-sample of farms and/or plots, there are two primary options. First, plots subject crop-cutting can be selected directly from a list of plots (bypassing the household/farm level). This is an efficient option in terms of quality of estimation, particularly when the main objective is for national statistics, but has some operational constraints. To utilize this approach, is necessary to have a complete listing of all cultivated plots (with the crop of interest) within the enumeration area of other level from which the sample would be drawn. Therefore, this listing should be completed in a timely manner to allow the processing of the data and selection of the subsample of plots, ensuring enough time is allowed to conduct the survey and crop-cutting activities following the listing and selection of plots. In addition, large plots or plots very far from the dwelling may appear in the sample, increasing operational costs.

Alternatively, plots can be selected from within households/farms selected for the survey (or a selected subset of those households/farms). In this case, a full listing of plots is not required in advance of the survey. A subsample of households/farms and either all or a subsample of plots cultivated by those households/farms can be selected for crop cutting. This may allow inclusion of more plots than the previous option and at a lower cost, since the household/farm is a cluster of plots. However, it is less efficient than the previous option as cluster sampling leads to larger variance. When following this approach, plots meeting predetermined criteria can be randomly selected through the CAPI application to streamline the randomization and prevent selection bias introduced by respondents or enumerators.

The choice between the two approaches is surely going to be guided by logistical and budget considerations, but it will be important to ensure that the survey will collect the minimum number of plots per crop[4] for estimating yield at the required domain. Annex 1 provides details of how to compute the sample size needed following different approaches. A precision-based approach can be adopted, where the minimum number of plots per crop per domain is derived from ratio-estimation formulas that incorporate variability in production and harvested area, their correlation, design effects, and expected response rates—ideally informed by prior surveys (Annex 1, Section 1.1). Alternatively, in settings with low yield variability, average plot's yield and the domain's ratio yield have close value, and so a mean-based sample size formulas may be used (Annex 1, Section 1.3). Section 2.1 of the annex provides an

[4] Intercrop combinations can be considered to be one crop (e.g., maize-bean intercropped plots).

approach to determine the number of clusters (EA, households) needed for each crop if a subsample of plots within clusters are to be selected (i.e., plots are selected from a full list of plots either at the enumeration area or household level), while Section 2.2 provides an approach to estimate the number of clusters needed if all plots within the selected clusters are subject to crop cutting.

Box 3. Survey design requirements for imputation of crop production estimates

Collecting crop production data at scale in surveys through crop-cutting can be resource-intensive and logistically challenging, often leading to this measure of crop yields being unavailable in a subsample of surveys or the entire survey altogether. When working with the resulting datasets, instead of relying on self-reported measures, which have been shown to be biased, analysts can apply imputation methods. There is growing evidence that these methods can provide reliable estimates for a wide range of economic applications. In the case of yield measurements, recent validation studies have shown that machine learning tools can also be leveraged effectively in this effort (Yacoubou Djima and Kilic, 2024; Yacoubou Djima et al, 2024). These empirical exercises offer several lessons for the implementation of crop-cutting in surveys.

1. **Farmer-reported crop yield emerges as a key predictor, despite its shortcomings:** While farmer-reports based crop yield may be subject to biases, it still plays a significant role in predicting crop cut yields. Moreover, the models performed better for crops with low intercropping rates and high commercialization rates, i.e., the crops that farmers may be better positioned to report more accurate production information on.

2. **Geospatial data boost prediction accuracy:** Including geospatial predictors, such as rainfall, elevation and distance to markets, significantly improves the accuracy of imputed crop cut yields. These variables provide objective data that capture environmental and location-specific factors influencing crop productivity.

3. **Imputation works best within the same survey round:** The imputed crop cut yields are more accurate when we predict the missing data within the same survey round. When applying the models to predict yields across different survey rounds (i.e., using data from the 2017 survey to predict 2018 yields), the results were less accurate. This suggests that the year-to-year variability in crop production—driven by factors such as weather and farming practices—makes it difficult to generalize predictions across different seasons.

4. **Limiting crop cutting to a modest subsample of plots can be sufficient for model training:** For most crops, machine learning models generated yield estimates that closely matched those from crop cutting, even when using a small subsample of the crop cut data. Conducting crop cutting at a minimum for 1/3 of the sample, and more optimally for 50 percent of the sample, can offer a cost-effective approach while achieving reliable machine learning predictions of crop cut yields. This has significant implications for reducing costs in future surveys by limiting the need for extensive crop cutting.

5. **Sampling of a share of the plots within all primary sampling units for crop-cut appears to be necessary:** Since machine learning algorithms can perform well out of sample, the logistics and supervision of crop-cutting can potentially be simplified by limiting the survey footprint

to fewer areas in a given country. However, findings so far imply that using crop-cutting data confined to a particular stratum as a training set may only result in reliable predictions if the chosen region is sufficiently heterogeneous in terms of crop yields. Deciding which stratum has this characteristic is difficult to do ex-ante, and as such, subsampling within all primary sampling units appears to be necessary.

4. IMPLEMENTATION

This section provides an overview of the crop-cutting process as well as key considerations for implementation, including team composition, fieldwork organization with mobile, resident, or semi-resident enumerators, equipment needs, and training and supervision.

4.1. Crop-Cutting Fieldwork

Crop cutting fieldwork entails the identification of a portion of a *subplot* and subsequently harvesting and weighing every crop of interest that is cultivated within that subplot. As such, the fieldwork for crop cutting is organized around two main activities: the demarcation of a subplot of a pre-determined size, and the harvest and weighing of the crop harvested. To ensure objective and accurate measurements of plot areas and weights during these steps, these activities must be conducted according to the crops' calendar: shortly after the planting and at the harvesting time. This timing is crucial for at least two reasons. First, only at the end of the planting period will it be possible for the field teams to identify with certainty the households growing specific crops, identify the plots in the household farm which are planted with these crops, and then randomly select the plots and demarcate the subplot area for the exercise. Second, the crop-cut harvest must be carried out when the crops have reached their full maturity. In what follows, we describe the fieldwork process for the two main activities of crop cutting. An example protocol for the implementation of crop-cutting is included in Annex 2.

4.1.1. Post-planting fieldwork: area measurement and subplot demarcation.

The post planting visit occurs after the crops have been planted. During this visit, each enumerator conducts the area measurement on the plots selected for crop cutting, sets up the crop cutting subplot, and administers the post-planting questionnaire.

Land area measurement

The measurement of the entire plot's area is crucial for accurately scaling the total production from the subplot area to the entire plot area. As highlighted in Box 2, it is recommended to use GPS for objective measurement of the selected plot area. Without precise land area data, estimates of total production on the plot can be biased.[5] GPS-based land area measurement requires the enumerator to pace around the perimeter of the plot at an even pace, pausing briefly at each corner, while the device regularly captures

[5] For more discussion on area measurement using handheld GPS devices and comparison of area measurement with alternative methods, consult Carletto et al. (2017).

GPS coordinates, and then calculating the enclosed area based on these recorded coordinates. Most GPS devices allow for saving plot outlines, which can be converted into shape file in geospatial software. Linking these plots outlines with survey data significantly increases the analytical value of the data at minimal cost. For instance, as high-resolution satellite imagery becomes increasingly available, capturing plot outlines will enable the survey data to be complemented with detailed spatial data which are necessary for remote sense applications (see for example Lobell et al, 2020a; 2020b). Readers can refer to the 50x2030 Technical Note on Land Area Measurement for an example protocol for in-field area measurement. These steps ensure that the area measurement is accurate, and the GPS data is properly saved and recorded for future review.

Demarcation of the crop-cutting subplot

In a crop cutting exercise, the selection of a crop-cutting subplot within a given plot should be random. The protocol described below, and in Annex 2, guarantees that the crop cutting subplot is demarcated on a randomized section of the plot, facilitating an unbiased evaluation of productivity in the area under study. Figure 5 illustrates the subplots for three plots from a sorghum yield measurement experiment in Mali, where crop cut subplots were randomly selected. In the figure, the left panel shows a crop-cut subplot positioned in the center of the plot, while the middle panel depicts a subplot located near the edge of the plot. The last panel gives a perspective of an 8x8m crop cut in an average sized field (1.5 ha) in Mali. Although alternative approaches to subplot selection exist, emerging evidence supports the use of a randomized approach. For instance, Kosmowski et al. (2021) found that randomly positioned quadrants outperform systematic sampling schemes, indicating that random subplot selection offers the highest accuracy and is the most cost-effective method for estimating the sample mean of yields.

The protocol detailed in Annex 2 describes a randomized approach. The method ensures objectivity and consistency by using random numbers (see example in Annex 3) for determining starting points and distances walked during the process, and utilizes a defined set of supporting equipment to locate and demarcate the 8mx8m subplot (see Table 1).

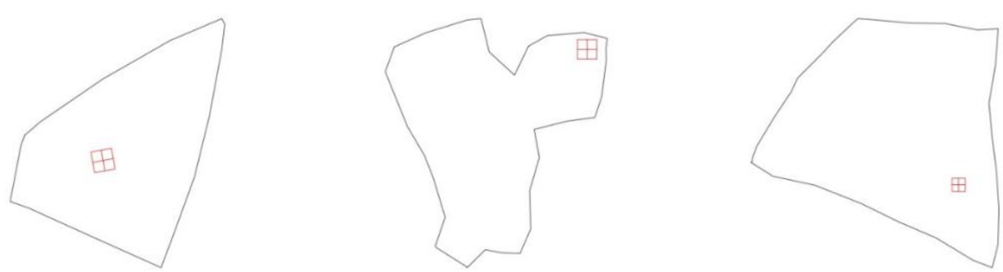

Figure 5: Illustration of crop cut subplots in fields. In the figure, the left panel shows a crop-cut subplot positioned in the center of the plot, while the middle panel depicts a subplot located near the edge of the plot. The last panel gives a perspective of an 8x8m crop cut in an average sized field (1.5 ha) in Mali. Source: ERIVaS Experiment.

The procedure begins by selecting a random starting corner of the plot (when measuring the area, the enumerator counts the number of corners of the plot). Using a random number table, the first number chosen – i.e., the first number in the table that is less than or equal to the number of corners on the given plot when reading the table from left to right – indicates the corner from which the measurement will start. The lengths of the sides of the plot stemming from the selected corner are then measured, and the longer and shorter sides of the plot are identified.

The next step consists of walking along the longer side of the plot for a randomly determined distance (using the random number table for a given plot) and then turning into the plot and walking parallel with the shorter side for another randomly selected distance (again based on the random number table). The use of a compass ensures the walk is done parallel to the short side, which will limit the occurrences of the initial subplot attempt falling outside of the plot boundaries. The endpoint of the procedure is marked when the last step is taken, at which point the first corner of the crop cutting subplot is identified.

Starting from this first corner, the remaining three points of the subplot are identified by measuring 8 meters directly to the east (second corner), from there to the north (third corner), then to the west (fourth corner), and finally to the south to arrive back at the first corner. Four sticks, one placed at each corner, and a rope connecting them will demarcate the subplot.

Administration of the crop-cut module of the post-planting questionnaire

Throughout the exercise, the enumerator should refer to and complete the crop-cutting module in the post-planting questionnaire.[6] This module includes demarcation of the crop cut subplot, collection of the GPS location of that subplot, and information on crop coverage within that subplot.[7] The module is at the parcel-plot-crop level and focuses only on the crops relevant for crop-cutting in a given survey. More specifically, the module asks about the number of plants of each crop found on the plot and in the subplot (though plant counts may only be feasible for certain crops, like maize, where plants are easily distinguished). Note that this module should be preceded by complete plot and crop rosters, which also include GPS-based plot area measurement.

4.1.2. Harvest (crop cutting) fieldwork: harvest and weight of the produce.

The post-harvest visit occurs when the crop cutting crop is ready for harvest. During this visit, each enumerator harvests the crops of interest from the crop-cutting subplot and administers the post-planting questionnaire.

Harvest of the crop-cutting subplot

In this section, we discuss the protocol in the context of maize specifically, though general guidance applies across crops. The harvest visit should be carefully scheduled with households, such that the field teams conduct the harvest visit when the respondents deem the crop to be ready for harvest and when, in the case of maize, the crop is dry enough to shell (as weights must be taken with the maize in grain form). A crop-cut monitor, hired prior to the completion of the post-planting fieldwork, will periodically visit the sampled plots to ensure the subplots are not tampered with and to facilitate appropriate scheduling of the crop-cut harvest.

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[6] Refer to the 50x2030 reference questionnaire for crop-cutting, available at: https://www.50x2030.org/resources/survey-instruments

[7] Note that many plot level questions that are essential for the overall crop cutting exercise – namely GPS-based plot area measurement – are included as part of the plot roster module, which is completed prior to the crop-cutting questionnaire module. Plot area measurement is an *essential* component of crop-cutting. If GPS-based plot area measurement is not included as part of the general plot roster, it must be conducted for plots with crop-cutting.

The main activities during the harvest visit include harvesting, counting plants and cobs, shelling, and weighing the produce, as detailed in Annex 2. The procedure begins with counting the plants harvested during the crop-cut, which can be compared to the post-planting count to assess any potential preharvest loss. In each subplot, cobs are then counted before shelling. This step can be valuable at the analytical stage. Analysts can use the cob count and the total shelled weight to estimate a grain-per-cob conversion factor, which can then be used to refine self-reported yields when the harvest is reported in cobs rather than in grain form. Once harvested and shelled, the grain should be weighed precisely using digital scales, and the data should be recorded in the crop-cutting questionnaire.

When maize is first harvested, it often contains a higher moisture content, which could affect the weight measurements. Some crop-cutting protocols may recommend further drying and re-weighing of the dry grains as well. By drying the harvested crop further the moisture content stabilizes, ensuring that the weight recorded reflects the true yield, without excess moisture that could artificially inflate the weight. Proper drying also prevents spoilage and allows for more reliable data when assessing crop yields. This procedure, however, requires supervision and for the enumerators to come back to the household for this second measurement. An alternative procedure consists of obtaining the moisture level of the grain and using this measure at the analysis stage to standardize the weights of grains weighed at different moisture levels.

Completion of the crop-cut harvest module

The purpose of crop-cut harvest module is to record all relevant information regarding the harvest procedure and includes other necessary details for an accurate estimate of the harvest. This includes the date of crop-cut harvest, questions on the cultivation pattern on the given plot, how the density of the crop of interest on the subplot compares to that on the rest of the plot, and critical information about any pre-harvesting of the subplot (i.e., non-compliance by households) and damage on the subplot. The module is filled by the enumerator based on what he/she observes during the subplot harvest, as well as objective measurements including: number of plants harvested from the subplot, number of cobs harvested from the subplot, and weight and moisture of the shelled grains harvested from the subplot.

4.2. Team composition, staff duties and fieldwork organization

4.2.1. Team composition and staff duties

Crop-cutting teams are typically composed of enumerators and a team leader. It is recommended that these teams be supplemented by crop-cut monitors and crop-cut assistants, who are locally hired individuals, especially if the enumerators are not residents of the area. Each member of the team has distinct responsibilities and is expected to work in a coordinated manner. The primary role of the enumerator is to collect data accurately, which includes both administering questionnaires and conducting objective measurements, such as land area measurement and maize crop cutting.

Enumerators may receive support from crop-cut monitors and crop-cut assistants. The monitor's role involves periodically visiting the plots of the households to ensure that the crop-cut subplot is not tampered with and, at the time of the harvest visit, assisting in the shelling of harvested maize. This role is particularly crucial when enumerators are "mobile" and required to travel across the country for other survey activities. Crop-cut assistants help with the shelling of harvested maize during the harvest visit.

Each team of enumerators is led by a team leader who always travels with the team. The team leader acts as the overall coordinator and supervisor for the team, ensuring that the team completes all duties in a timely and high-quality manner. If enumerators encounter any issues or require assistance, they report to the team leader. The team leader may also conduct household interviews, when necessary and feasible, to maintain the fieldwork schedule. The team leader is responsible for a variety of activities, including:

- Assigning interviews to enumerators, reviewing questionnaires, and transmitting data to the head office.
- Coordinating fieldwork activities.
- Communicating with local crop-cut monitors regarding the timing of maize crop-cutting.
- Transmitting data to the head office.
- Maintaining communication with the head office.

It is important for the survey team responsible for implementation to think critically about team organization, adapting it to the context and emphasizing the duties of team members. Crop cutting, being a complex operation to integrate into a survey, demands seamless collaboration among team members with clearly defined roles. The success of the operation hinges on the technical skills of dedicated high-quality enumerators, rigorous training, and effective supervision, ensuring that each member fulfills their responsibilities accurately and efficiently.

4.2.2. Fieldwork organization with resident/semi -resident enumerators

When crop cutting fieldwork is conducted with resident or semi-resident enumerators, the enumerators are set in a specific location and are responsible for one or several EAs that are very close to each other and in general they schedule their visits for interviews directly with the household. This modus operandi works both for survey interviews and the crop cutting operation. The protocol of the Ethiopia Socioeconomic Survey (ESS), for instance, requires that once the household is selected, the enumerator reaches out to make an appointment for the field team to visit the plot and demarcate the crop-cutting subplot. Similarly, the household will decide the appropriate harvest time and will communicate it with the field team and arrange the moment for the crop-cut itself. There are several advantages to having resident enumerators:

- It is much easier for the enumerators to be there at the proper harvest time and thus there is lower risk that the subplots are harvested by the household prior to the harvest visit
- Fieldwork operations are more flexible and can therefore accommodate several crop calendars

Nevertheless, managing the presence of resident/semi-resident enumerators across the EAs that they oversee can be challenging as the enumerators must move efficiently between households or enumeration areas. If the set of enumeration areas assigned to enumerators is sufficiently homogeneous concerning the agro-climatic characteristics of the crop, the additional difficulties compared to having resident enumerators might be limited. If semi-resident enumerators are deployed over a particularly large geographic area, the assistance of crop-cut monitors may become necessary. In any case, it will be important for the enumerators to establish a schedule based on the info on anticipated harvest time for the households and this schedule should also be available to supervisors so that they can monitor the progress and reallocate resources if necessary.

4.2.3. Fieldwork organization with mobile enumerators

Often, nationally representative household surveys are organized in such a way that the logistical management of enumerators is centralized, and field teams move across the country to conduct interviews. Coordinating crop-cutting activities becomes more complicated, since it may become more difficult to be present in the relevant enumeration areas at the appropriate time for harvest. This makes the adoption of certain protocol elements essential, such as measuring the moisture level of the crop to standardize the weight of harvests taken at different maturity times, or hiring local crop-cut monitors to support the teams in anticipating the correct harvest periods and oversee the harvest itself. While it is possible to have the same mobile teams conducting both the survey data collection and crop-cutting activities, the competing demands and timelines of the activities can introduce risk (for example, if the teams are expected to conduct a post-harvest survey in one part of the country but it is also time for crop-cutting harvest in another part of the country). Mobile teams might necessitate the use of additional enumerator teams dedicated to crop-cutting activities, resulting in higher costs associated with both the increased number of field teams and the number of vehicles and drivers. While survey enumerators could easily mark subplots during the administration of the post-planting questionnaire, the harvesting activity could be entirely entrusted to a dedicated set of enumerators or crop-cut monitors.

4.3 Equipment

Table 1 provides an overview of the essential equipment required for the implementation of crop-cutting operations in agricultural surveys. The equipment is organized according to the two main phases of the crop-cutting process: subplot selection and demarcation, and crop-cut harvest.

<u>Subplot Selection and Demarcation</u>

- *Compass*: This device is crucial for capturing geographic bearings in degrees, ensuring that the orientation of the subplot within the larger plot is both accurate and unbiased. By setting precise directions, the compass maximizes the possibility that the subplot will fall entirely within the plot boundaries.
- *Measuring Tape*: Marked in metric units, the measuring tape is indispensable for determining the exact dimensions and placement of the subplot.
- *Sticks:* These serve as physical markers for the corners of the selected area, providing clear visual boundaries that guide both demarcation and subsequent harvesting activities. The use of sticks ensures that the subplot is easily identifiable and that its boundaries are maintained throughout the survey process.
- *Rope:* Stretched between the sticks, the rope further delineates the subplot, ensuring that the area to be harvested is well-defined. This helps maintain the integrity of the subplot's boundaries.

<u>Crop-Cut Harvest</u>

- *Digital Weighing Scale:* This tool is used to obtain accurate measurements of the harvested crop, specifically in grain form. In case the subplot is sub-divided in quadrants, each of the quadrants within the entire subplot must be weighed separately
- *Moisture Meter:* A critical tool for assessing the moisture content of the grain at harvest, the moisture meter is essential for standardizing yield estimates. By providing accurate moisture readings, it ensures comparability across different plots and survey rounds, contributing to the reliability of the data collected.

Together, these tools form the backbone of a robust crop-cutting protocol, enabling survey teams to collect reliable and precise data on crop yields. By ensuring that each phase of the crop-cutting process is supported by the appropriate equipment, survey planners can enhance the accuracy and consistency of their yield estimates.

Table 1. Equipment Needed for Crop-Cutting

Stage of Data Collection	Equipment needed
Subplot selection and demarcation	**Compass:** This is a device used for capturing geographic bearings in degrees. It is used to set directions within the plot, maximizing the possibility that the subplot will fall inside of the plot. **Measuring Tape:** This is a distance-measuring instrument marked in metric-units, which will be used to determine the location of the crop-cutting subplot. **Sticks:** These will be used to mark the four corners of the subplot(s) selected for crop cutting. **Rope:** A rope connecting the sticks placed at the corners and along each side will be used to demarcate the selected subplot.
Crop-cut harvest	**Digital Weighing Scale:** This will be used to weigh the harvested maize at the time of harvest (in grain form). **Moisture meter:** This will be used for obtaining the moisture level of the grain.

4.4 Trainings, supervision and data quality control

4.4.1. Training

To effectively train fieldworkers to conduct crop-cutting, a structured training program is essential. This program should be designed to ensure that fieldworkers can accurately and consistently perform the tasks required for subplot selection, demarcation, and crop-cut harvest. The training should be comprehensive, covering both theoretical knowledge and practical skills, and should be structured around the following key components:

- **Theory.** The training should begin with a theoretical module that covers the background and purpose of crop-cutting measurements, the functionality and use of equipment, and the detailed steps of the measurement procedures. This module should also address common challenges and how to overcome them, as well as how to respond to typical questions from farmers. To make the theory tangible, include demonstrations by experts (agronomists) that show the correct use of tools and procedures. Trainees' understanding can be assessed through written tests to ensure they have grasped the essential concepts.

- **Practice Each Component.** The next phase of training should focus on practicing each component of the crop-cutting process. This includes setting up and handling equipment such as GPS devices for area measurement, compasses, measuring tapes, and digital scales. Trainees should practice these tasks repeatedly until they can perform them quickly and accurately. Breaking down the process into individual components helps trainees become familiar with each task without becoming overwhelmed. This approach also ensures that resources are used efficiently, as practicing individual components first can reduce the need for expensive full-scale practice sessions.

- **Practice Full Measurements.** Once trainees are proficient in each component, they should practice the entire crop-cutting process in a real-world setting. This involves visiting actual farm plots to measure and demarcate subplots, and to conduct the crop-cut harvest. Trainees should be exposed to a variety of scenarios to ensure they can adapt to different conditions. During these practice sessions, trainers should provide immediate feedback and address any issues that arise. This hands-on experience is crucial for developing a routine and ensuring that trainees can implement the entire measurement procedure correctly.

- **Standardize.** The final stage of training involves standardization exercises to enhance the accuracy and precision of measurements. In these exercises (which could be conducted during the full practices), trainees' measurements are compared to those of an expert to identify and correct any deviations. This process helps eliminate idiosyncratic practices that could lead to measurement errors.

By following this structured training approach, fieldworkers can be effectively prepared to conduct crop-cutting measurements with the accuracy and consistency required for reliable agricultural data collection. This training program not only equips fieldworkers with the necessary skills but also ensures that the data collected is of high quality, supporting better agricultural policy and decision-making.

4.4.2. Supervision and data quality control

To effectively monitor crop-cutting measurements operations in agricultural surveys, a comprehensive data monitoring strategy should be implemented in conjunction with the rest of the data monitoring of the survey. This strategy should encompass real-time data validation, in-person monitoring, remote monitoring, and the use of dashboards and paradata. Here’s how these components can be adapted to the context of crop-cutting measurements:

- **Monitoring through Data Entry Program.** Utilize a Computer-Assisted Personal Interviewing (CAPI) application, such as Survey Solutions or SurveyCTO, to facilitate real-time error checks and validation conditions for the crop-cut modules. Examples of the types of checks include.
    - Range Checks: Establish reasonable minimum and maximum values for numeric data, such as plot size and crop weight, to flag any outliers for confirmation.
    - Internal Consistency Checks: Ensure that responses are consistent across related questions. For example, the weight of harvested crops should align with the reasonable yield based on plot size.
    - Completeness Checks: The program should flag any unanswered questions that are mandatory for the crop-cutting process.

- **In-Person Monitoring.** It will be important to develop templates for field monitors to use during in-person visits. These templates should outline the activities to be observed and key questions to be checked, ensuring consistency across different monitors and field teams. In person monitoring will also include the conduct of supervision missions at critical times, such as during the initial stages of fieldwork, to observe the crop-cutting process directly. Early feedback can help address any issues promptly.

- **Remote Monitoring.** After data is sent to the server, data monitors should review each completed crop-cutting record. Here the use of the GPS features of the tablet could be particularly useful as checks can be made to ensure that the plot location is within the EA or within a reasonable distance of the EA boundaries. In general, in remote monitoring any errors identified should be communicated back to the field teams for verification and correction while they are still in the field. It could be useful to develop error check syntax in statistical software (e.g., R, Stata) to perform complex consistency checks on incoming data. This allows for immediate flagging of errors for review based on large set of data. For example, checks can be implemented on the basis of mean yields in a district to flag potential outliers for verification. Remote monitoring is also enhanced with a dashboard that can track each team's progress, including the number of plots measured, the speed of data collection, and the quality of data. Finally remote data monitoring can rely on paradata to gain insights on data quality such as interview time or the time the subplot was established to flag cases that are improbable (at night for example).

By implementing these monitoring strategies, the accuracy and reliability of crop-cutting measurements can be significantly enhanced, leading to more precise agricultural data and better-informed decision-making.

5. COST CONSIDERATIONS

Preparing a budget for agricultural and household surveys that include crop-cutting operations is a complex and iterative process, deeply intertwined with overall survey planning. Crop-cutting operations require careful consideration of various cost factors. First, crop cutting generally requires additional labor, through crop cut monitors and/or assistants, as well as additional equipment, both of which come at a cost. Keeping households engaged and adhering to protocols (i.e., not harvesting the crop cutting subplots) can also require incentives. Furthermore, personnel engaged in the survey are required to remain in the enumeration areas for extended periods to adequately cover peak harvest times. The duration of their stay and the associated costs vary depending on the survey's scope and geographic dispersion. Thus, the inclusion of crop-cutting operations in surveys demands a detailed assessment of labor costs, logistical requirements, and the potential need for extended fieldwork, all of which must be carefully balanced against the survey's budgetary constraints.

Monetizing the benefit of increased accuracy in yield measurement as a result of crop-cutting is complex. One needs to gauge the benefit of increased accuracy in yields, which is rather intangible, against the additional cost of organizing fieldwork to include crop cutting. Nevertheless, a qualitative assessment can be made if we consider specific scenarios.

In scenarios where resident enumerators are already used in the survey—each responsible for a specific enumeration area(s)—the marginal cost of implementing crop-cutting is relatively low, since enumerators are paid monthly and plots are within the same enumeration area(s). However, the new operations can stretch enumerators' capacity, potentially reducing overall data quality if they are overly stretched and have insufficient time to dedicate to implementation and harvesting at each selected household. Depending on the share of plots selected for crop-cutting, survey planners should consider adding additional enumerators, which would lead to higher costs if required.

In contrast, when mobile teams of enumerators are deployed—a common approach in large-scale surveys—the cost implications of implementing crop-cutting operations may be greater. It may be necessary to deploy more or larger teams to ensure timely harvesting across multiple EAs, especially if the geographic spread is significant. This can drive up costs due to the need for additional personnel, transportation, and logistical support. The extent of these costs depends on the initial team configuration and the capacity of available vehicles to accommodate more staff.

Ultimately, the cost of including crop-cutting in surveys is shaped by a combination of sample size decisions, field staff organization, and logistical factors such as terrain and geographic dispersion. Survey planners must weigh the gains in data accuracy against the additional costs, aiming for a balance that supports robust data collection within budgetary constraints.

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Annex 1. Subsampling for Crop-Cutting

1. Estimation of subsample size for crop-cutting

The subsample size refers to the minimum number of plots selected for each crop for crop-cutting. The recommended approach for subsample size calculation is based on the requirement for reliable estimations of crop yields, as presented in Section 1.1. These calculated numbers would be adjusted as needed to accommodate budget limitations. Alternative options for subsample size are also presented, along with the relevant caveats.

1.1 Calculation based on the precision of the domain's crop yield

The yield of crop c in each domain is computed as the ratio of the crop's total production to the crop's total harvested area.

Let's consider a given domain:

P_{cj} production of crop c on the plot j

A_{cj}: harvested area of crop c on the plot j

w_j: final sample weight of plot j

The ratio yield is estimated as follows:

$$\widehat{y_{Rc}} = \frac{\hat{P}_c}{\hat{A}_c} = \frac{\sum w_j P_{cj}}{\sum w_j A_{cj}} \quad (1)$$

With a simple random sampling without replacement (SRSWOR), from Särndal et al. (1992, p. 179), the variance of $\widehat{y_{Rc}}$ can be estimated by:

$$V(\widehat{y_{Rc}}) = \frac{1}{n\hat{\hat{A}}_c^{\,2}}\left[\hat{V}(\hat{P}_c) + \widehat{y_{Rc}}^{\,2}\hat{V}(\hat{A}_c) - 2\widehat{y_{Rc}}\widehat{cov}(\hat{P}_c, \hat{A}_c)\right] \quad (2)$$

And after a few algebra steps with equation (2), we have

$$CV\widehat{(y_{Rc})}^2 = \frac{V\widehat{(y_{Rc})}}{\widehat{y_{Rc}}^{\,2}} = \frac{1}{n}\left[\widehat{CV}(\hat{P}_c)^2 + \widehat{CV}(\hat{A}_c)^2 - 2\widehat{cov}(\hat{P}_c, \hat{A}_c)\right] \quad (3)$$

If $\hat{\rho}$ is an estimate of the correlation coefficient of P_{ci} and A_{ci}, we have $\widehat{cov}(\hat{P}_c, \hat{A}_c) = \hat{\rho}\widehat{CV}(\hat{P}_c)\widehat{CV}(\hat{A}_c)$

Fixing a maximum coefficient of variation of the estimate of the ratio as CV^*, we can deduce a minimum size for an SRSWOR as follows

$$n_{srs} = \frac{\widehat{CV}(\hat{P}_c)^2 + \widehat{CV}(\hat{A}_c)^2 - 2\hat{\rho}\widehat{CV}(\hat{P}_c)\widehat{CV}(\hat{A}_c)}{CV^{*2}} \quad (4)$$

The sample size n_c of plots for a crop c with a complex sampling design should consider the design effect of the ratio estimate ($Deff$), and as usual an oversampling for non-response can be performed considering an expected response rate g

$$n_c = Deff\,\frac{\widehat{CV}(\hat{P}_c)^2 + \widehat{CV}(\hat{A}_c)^2 - 2\hat{\rho}\widehat{CV}(\hat{P}_c)\widehat{CV}(\hat{A}_c)}{gCV^{*2}} \quad (5)$$

The parameters required for formula five can be estimated from a previous farm survey.

1.2 Using a two-phase design for stratification scheme

The subsample size of plots for the crop cutting can also be calculated by supposing this:

- Crop yield (or any proxy strongly correlated to yield) will be first collected by declaration from all eligible plots of the main sample
- The complete list of eligible plots will then be stratified by the declared yield (or proxy)
- A stratified subsample of plots will then be selected for the crop cutting survey

From that perspective, Fuller (2009) proposes a formula to calculate the optimal subsample size. For instance, let us suppose that the subsampling is performed for objective measurement of the yield and let y be the yied collected through declaration. If the sample is stratified into H strata, the optimal sample size of the subsample, following Fuller (2009), will be:

$$m_{subsample} = m\sqrt{\frac{\sigma_w^2 C_1}{\sigma_b^2 C_2}} \quad (6)$$

Where:

$$\sigma_w^2 = \frac{\sum_{h=1}^{H} \sigma_{yh}^2}{H} \quad (7)$$

$$\sigma_b^2 = \sigma_y^2 - \sigma_w^2 \quad (8)$$

σ_y^2 and σ_{yh}^2 are the variances of y in the full sample and in the stratum h, respectively.

m is the sample size of the survey.

C_1 and C_2 are the costs of the interview by declaration and objective measurement, respectively. In case reliable information on unit costs C_1 and C_2 are not available, a proxy value of $\frac{C_1}{C_2}$ can be considered here based on expert opinions and cost simulations.

1.3 Calculation based on average yield

In domains where the population variance of crop yield at the plot level is relatively low, the average plot's yield and the domain's ratio yield (formula (1)) have close values. Therefore, the standard formula of sample size for mean estimation can be considered if the yield variability in the domain's population plot can be estimated from a previous survey:

$$n_c = \frac{1}{g}\widetilde{deff}_d \frac{\widehat{cv}_{yd}^2}{cv_d^{*2} + \frac{\widehat{cv}_{yd}^2}{M_{cd}}} \quad (9)$$

Where:

- $\widehat{cv}_{yd}$ is an estimate of the population coefficient of variation plots' yield in the domain *d*
- $\widetilde{deff}_d$ is an estimate of the design effect of the final subsampling design
- M_{cd} total number of plots of the crop c In the domain *d*
- g is the expected response rate

1.4 Subsampling for modelling

If the main objective is to elaborate a model with crop cutting and self-reporting production data for imputations or adjustment of self-reported yields, the subsample size should be determined accordingly and with consideration for the specific applications. As an example, if a multivariate regression model is planned to be applied, the formula below from Green (1991) could be considered:

$$n_c = Max(50 + 8m, 104 + m) \quad (10)$$

Where m is the number of predictors.

2. Clustering of crop-cutting subsample

Once the total subsample size has been determined, using one of the approaches above, the next step is to determine the number of clusters needed. Section 2.1 describes the case in which plots are subsampled within cluster (for example, enumeration area or household), while Section 2.2 describes the case in which a subsample of clusters is selected (with all eligible plots in those clusters subject to crop-cutting).

2.1 Number of clusters (EA, households): subsampling plots within clusters

If the plan is to select a subsample of clusters, either in terms of selecting plots from a full list of eligible plots at the enumeration area level or at the household level, the size of the subsample of clusters for crop c (m_c) should be calculated. If n_c^* is a fixed number of plots planned to be selected per cluster, or the average number of plots to be selected per cluster, and the number of clusters can be calculated by dividing the sample size of plots by n_c^*:

$$m_c = \frac{n_c}{n_c^*} \quad (11)$$

Note:

- In practice, the frame of clusters should be well prepared to ensure that units with no eligible plots are removed before selecting the subsample of clusters.
- If at the time of the selection of the subsample of clusters, there is no information on the existence of eligible plots in clusters, an oversampling is necessary: the number of clusters calculated in formula 11 can be multiplied by the inverse of an estimate of the proportion of clusters with at least one eligible plot (δ):

$$m_c = \frac{1}{\delta}\frac{n_c}{n_c^*} \ (12)$$

2.2 Number of clusters (EA, households): cluster subsampling

In the case of cluster subsampling, all eligible plots within the selected clusters are planned to be covered by the crop cutting operation.

Let's consider:

- $\overline{n_c}$ as the average number of eligible plots per cluster computed from a previous survey with the full population of clusters, including those without any eligible plots
- $\overline{n_{c\_el}}$ as the average number of eligible plots per cluster computed from a previous survey with only clusters with at least one eligible plot

The formula for the number of clusters to be subsampled would depend on the units included in the frame of clusters:

- **Case 1:** At the time of selecting the subsample of clusters, there is no information on the existence of eligible plots in clusters. This is a common situation with households: information on plots and crops might not be available when selecting the subsample of households. The number of clusters is calculated as follows:

$$m_c = \frac{n_c}{\overline{n_c}} \ or \ m_c = \frac{1}{\delta}\frac{n_c}{\overline{n_{c\_el}}} \ (13)$$

- **Case 2:** When the subsample of clusters is selected, there is enough information to remove clusters with no eligible plots before selecting the subsample of clusters. The number of clusters is calculated as follows:

$$m_c = \frac{n_c}{\overline{n_{c\_el}}} \ (14)$$

Annex 2. Crop-Cutting Protocol

This example protocol is adapted from the protocols implemented in methodological studies conducted by the LSMS team in collaboration with country partners. In this example, a single 8mx8m subplot is selected for crop-cutting from each household.

Crop cutting is a method that allows us to estimate the quantity of production of an entire plot by measuring a small randomly selected section of that plot (referred to as a “subplot”), and then use this information in conjunction with the area of the entire plot to estimate the total production quantity. Crop cutting is normally considered the gold standard for measuring crop production. It is important that you follow the instructions carefully. You will need the assistance of the **Crop Farmer** to conduct this exercise.

Crop-Cutting is only conducted on the <u>maize plots randomly selected by the CAPI program</u> [or other approach as defined for the particular survey].

There are two aspects to this exercise – the first is conducted with the post-planting questionnaire and the second is conducted at the time of harvest:

1) The first aspect is the demarcation of a random 8m x 8m crop-cutting subplot [or other predetermined subplot size for the given study; this example uses an 8x8m subplot]. This will take place as part of the post-planting questionnaire.

2) The second aspect of this exercise is the harvesting of the maize once it is ready for harvest. This should be done at a time that is convenient for the farmer. **It is very important that the farmer does not harvest the land before you arrive** – therefore, please coordinate with the farmer and the local crop-cut monitor to learn the time at which he/she would like to harvest and be sure to arrive without delay. The crop will be weighed at the time of harvest.

The materials that you will need for use in this exercise are:

- Survey Questionnaire: One module to be included as part of the Post-Planting Questionnaire and one module administered at the time of the Crop-Cutting Harvest.
- Compass: A device used for capturing geographic bearings in degrees (00).
- Sticks for Subplot Demarcation: These will be used to mark the four corners of the areas selected for crop cutting (4 stick for each plot).
- Rope: Rope will be used to demarcate the area of the crop-cutting subplot. Enough rope is needed such that it can be tied around the 4 sticks at the corners of the subplot. The rope will be left in the field until the time of harvest, so this quantity of rope is needed for each plot.
- Measuring Tape: This is a distance-measuring instrument marked in metric-units (segments), which will be used in determining the location of the crop-cutting subplot within the plot.

- Digital Weighing Scale (with batteries): This will be used to weigh the harvested maize at the time of harvest (in grain form).
- Moisture meter: This will be used for obtaining the moisture level of the grain.
- Writing Materials, e.g., Pen, Pencil, etc.
- Random number tables: Field teams should have a unique set of random number tables for each EA. These are used to guide the random selection of the crop-cutting subplot. An example showing the structure of the random number tables is available in Annex 3. Alternatively, random number generation could be explored using the CAPI application.

Procedure For Crop Cutting

We will be conducting crop cutting on an 8m x 8m subplot. Here, we describe in further detail each of the main aspects to the crop cutting exercise.

1) **Crop Cutting Sub-Plot Selection & Demarcation – Completed during the Post-Planting Visit (i.e., first visit)**

   a. Use Random Number Table #1 to identify the corner from which you will start (see example in Annex 3). The corner in which you started the area measurement, the northwest corner, is corner #1. Corner #2 is the next corner of the plot, moving around the plot clockwise.

      Use the first number in Random Number Table #1 that appears on the row designated for your household (i.e., HHID) and that is less than or equal to the number of corners of your plot. This number identifies the corner from which you will start.

   b. Measure the distance of the two sides along the selected corner with the measuring tape. Identify which is the longer side and which is the shorter side.

   c. Using your compass, take the bearing from the start corner down the shorter side. Note this in your notebook.

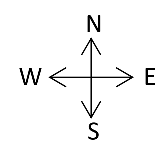
   d. Use the Random Number Table #2 and the row designated for this household (see example in Annex 3). The first number should be the number of meters that you will walk along the length of the longer side of the plot. The first number that is less than or equal to the length of the longer side determines the number of meters you will walk along the longer side. For example, if the length of the longer side is 25 meters and the first random number in the list is 28, move on to the next number.

   e. Beginning at your starting point and continuing along the longer side of the plot, walk the number of meters indicated by your random number.

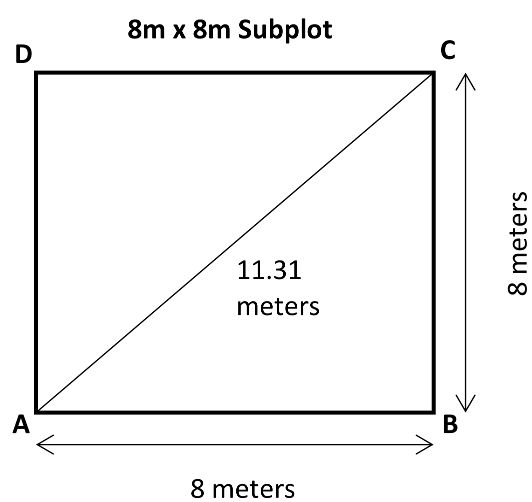
f. Turn into the plot so that your bearing is the same as the bearing you measured down the shorter side of the plot. This means you will be entering the plot parallel to the shorter side. Choose the next random number from the Random Number Table #2 and the row designated for this household that is less than or equal to the length of the shorter side and walk (into the plot) the number of meters indicated by this second random number. You should be walking in a direction that is parallel to the shorter edge of the plot. Walk in a straight line. Try not to veer to the right or left to avoid shrubs or wet spots.

g. The corner of the crop cutting subplot is located where your foot lands on the last step: this is point A.

h. At point A, insert the first stick firmly into the ground, measure 8 meters directly to the east, label this point Point B. From Point B, measure 8 meters directly to the north, label this point Point C. From Point C, measure 8 meters directly to the west, label this point Point D. From Point D, measure 8 meters directly to the south to arrive back at Point A. Demarcate the sub-plot with rope connecting the sticks at Points A, B, C, and D.



i. In order to make sure that the subplot size is correct, check to make sure that the diagonal line (Line A-C) is 11.31 meters on the 8m x 8m subplot (see figure below).



Special Circumstances

If the random numbers obtained from the random table for long and short sides of the plot do not fall in the crop plot area, drop both random numbers and start over again.

Each time when one or both of the random numbers fail to fall in the plot, drop both and start again until both random numbers fall on the plot.

If there is an obstacle in one or more of the crop-cutting subplots, such as a large tree stump, a boulder, large ant hill, etc. re-select the subplot by starting with a new random corner.

If there is maize damage in the selected 8m x 8m sub-plot, DO NOT re-select the subplot. Leave it as is and record the damage in the crop-cut questionnaire.

3) **Harvest of Demarcated Section – Completed at the time of harvest (i.e., second visit)**

With the consent of the farmer, harvest all the maize contained within the demarcated sub-plot. Count the number of plants and cobs that are harvested from the subplot, as well as the number of plants that were damaged and the number of plants that were harvested by the household prior to the crop-cutting exercise (these will be entered in the questionnaire). Once harvested and shelled, the grain should be weighed carefully using the digital scales, and the data recorded in the Crop-Cutting Questionnaire.

After the shelled grain is harvested, measure the moisture level of the grain using the moisture meter. For operations in which the maize will be dried and re-weighed after drying, place the grain (or a subsample of the grain) in a paper bag, place a barcode on the bag and scanned it in the CAPI application. The sample will then be moved to the drying location, where it will be re-weighed after drying (if drying only a subsample of the grain, the weight of that subsample before drying must also be taken and recorded).

Annex 3. Random Number Table Example

Below are examples of Random Number Table 1 and Random Number Table 2, which are used to guide the identification of the crop-cutting subplot. These are examples borrowed from a methodological experiment. Note that each enumeration area requires unique random number tables, each of which has a row of random numbers for every selected household in that EA. It is recommended to also include potential replacement households in the random number tables (not pictured below). In the example below, there were two crop-cutting subplots for every selected plot – one 4x4m and one 2x2m – so there are two rows per household. If there is only one subplot then only one row is needed per household/farm.

Random Number Table #1: Crop-Cutting Start Corner Selection

EA IDENTIFICATION

	NAME		NAME		
1. DISTRICT:		4. PARISH:		7. EA CODE FROM LISTING ASSIGNMENT:	2
2. COUNTY:		5. VILLAGE NAME:			
3. SUB-COUNTY:		6. EA NAME:			

CROP-CUTTING TABLES

HHID	SUBPLOT	Random Number Table 1: Crop-Cutting START CORNER SELECTION																																							
0201	4x4	3	7	13	13	5	9	6	15	5	10	9	9	15	3	7	9	10	3	14	11	1	11	9	7	11	8	4	8	10	15	7	7	15	9	2	12	8	7	14	4
	2x2	8	8	9	10	2	2	8	3	11	1	5	1	4	2	13	2	7	14	4	1	8	11	13	5	7	4	11	8	14	14	3	13	15	9	3	12	3	13	5	3
0202	4x4	8	12	6	4	3	9	9	3	12	1	3	8	5	13	13	15	5	14	4	7	6	6	3	11	8	3	4	4	8	9	3	11	14	7	1	2	3	5	5	7
	2x2	11	9	2	15	14	11	6	1	9	3	1	12	13	13	1	13	9	3	9	8	15	3	1	14	14	2	14	1	7	11	8	10	9	8	6	1	14	13	5	14
0203	4x4	4	11	13	8	14	9	8	15	8	12	11	8	14	6	11	3	8	5	9	12	8	13	15	11	4	1	7	12	9	12	11	9	2	15	14	8	11	12	5	1
	2x2	15	9	2	12	1	11	9	9	13	15	8	1	4	5	7	11	15	15	9	13	11	12	2	1	11	1	13	12	9	8	1	2	7	14	15	1	10	14	9	12
0204	4x4	8	3	13	14	8	3	6	6	15	15	5	5	11	15	3	9	2	7	12	9	6	10	4	10	5	5	12	8	3	13	8	8	9	4	3	4	2	2	9	14
	2x2	2	4	7	10	13	10	1	15	13	13	13	13	7	10	12	7	7	5	14	6	15	12	13	11	7	13	13	11	5	9	15	10	8	4	11	2	6	2	2	12
0205	4x4	9	11	10	7	10	4	5	7	6	11	15	3	15	8	1	1	2	5	6	9	13	9	15	8	1	12	4	10	7	14	10	2	14	14	3	7	15	2	13	12
	2x2	5	8	9	11	8	7	3	13	11	6	9	13	9	4	5	5	3	12	12	3	14	10	13	1	15	14	6	10	5	14	12	14	14	14	9	15	5	12	7	2
0206	4x4	13	12	12	9	8	3	13	10	12	8	14	9	12	2	14	10	15	12	11	10	9	15	5	1	13	8	1	11	9	4	11	3	15	3	7	9	9	1	3	11
	2x2	2	10	6	15	3	2	15	3	11	9	11	13	3	14	2	15	12	11	1	4	2	1	9	11	8	8	2	5	8	12	7	8	13	13	10	13	5	8	3	5
0207	4x4	7	11	13	15	5	5	9	11	6	4	11	7	11	6	9	12	6	8	8	12	6	11	14	11	6	5	15	2	3	8	6	1	1	4	1	15	13	11	5	9
	2x2	1	3	13	9	12	13	7	1	3	5	11	1	13	6	15	4	8	7	1	1	9	9	9	1	15	1	1	3	13	1	6	8	12	12	14	5	1	8	10	5
0208	4x4	10	3	9	13	8	11	9	1	13	3	4	9	9	11	8	12	7	8	15	7	12	4	12	13	12	8	2	9	7	13	11	14	8	1	3	11	12	5	7	13
	2x2	13	14	4	6	3	15	9	15	6	4	6	13	12	3	4	10	2	11	1	7	8	8	5	8	14	2	3	7	10	7	15	4	7	7	13	3	11	12	15	6
0209	4x4	15	4	1	8	6	6	1	7	10	1	2	13	14	13	1	2	7	4	9	10	13	8	14	10	14	3	12	10	10	15	11	9	8	8	8	10	7	10	14	8
	2x2	7	4	9	15	1	10	6	11	13	12	4	13	8	8	11	14	13	14	13	7	3	11	2	4	5	3	7	11	4	7	2	7	3	4	10	1	3	8	11	5
0210	4x4	12	10	4	7	4	11	10	2	4	15	14	15	13	7	8	6	15	11	5	1	14	10	15	9	5	1	14	12	6	7	10	13	15	15	7	14	12	12	13	13
	2x2	3	6	8	12	4	2	14	6	4	8	11	6	14	9	2	11	11	3	13	7	3	15	8	14	2	3	9	14	12	8	6	14	7	6	1	12	9	1	5	2
0211	4x4	11	3	1	13	7	3	12	14	12	14	11	2	13	2	1	13	2	10	14	11	2	14	9	7	6	14	8	2	12	2	6	15	5	2	5	14	15	1	1	6
	2x2	2	2	3	8	9	13	11	13	12	6	2	15	4	10	15	7	2	9	10	3	6	8	11	3	9	15	5	6	1	1	11	1	7	11	9	9	14	13	8	4
0212	4x4	6	7	6	6	14	1	6	9	5	3	7	4	9	8	7	15	15	3	3	11	12	13	11	13	11	8	5	4	8	8	2	13	10	4	6	7	5	8	2	10
	2x2	14	1	14	7	1	9	13	6	8	14	1	14	3	14	1	12	14	1	10	3	11	1	7	9	1	3	12	13	5	5	6	12	13	15	2	7	10	4	4	1

Random Number Table #2: Crop-Cutting Area Selection

HHID	SUBPLOT	Random Number Table 2: Crop-Cutting AREA SELECTION																																					
0201	4x4	39	7	47	26	38	12	33	25	9	37	29	22	24	48	39	47	24	48	33	27	14	44	38	5	9	4	17	37	39	27	34	31	42	4	41	39	24	34	42	15
	2x2	12	17	50	15	21	30	7	17	26	5	31	32	21	20	20	47	34	4	40	26	45	27	26	13	15	32	27	26	46	35	11	42	33	10	16	34	33	27	19	16
0202	4x4	19	5	36	18	45	6	35	9	25	19	17	18	38	18	25	9	42	42	48	45	27	15	9	17	38	12	17	34	21	28	40	30	10	17	12	4	29	36	47	13
	2x2	20	39	38	49	8	6	11	35	36	50	14	27	27	29	28	22	26	11	42	36	31	47	27	45	23	27	20	20	35	20	43	12	28	42	13	44	23	18	29	31
0203	4x4	34	16	21	45	9	19	46	48	31	41	31	33	40	9	7	30	17	39	44	14	11	40	36	16	24	7	10	27	34	38	36	23	33	39	36	43	37	11	49	13
	2x2	33	47	48	17	37	14	31	35	24	24	35	25	43	17	20	31	32	40	46	19	17	5	23	21	25	49	17	42	5	48	35	44	23	18	20	42	23	45	31	49
0204	4x4	41	31	27	34	16	8	44	10	18	6	11	7	41	31	46	9	29	50	35	27	7	12	19	18	30	8	10	4	13	27	43	25	17	45	6	45	16	39	31	40
	2x2	31	10	21	43	11	23	43	40	35	50	25	30	4	22	8	16	4	8	12	48	5	48	16	5	21	39	44	10	47	9	29	49	34	43	39	42	8	35	46	9
0205	4x4	33	21	38	18	29	15	13	7	9	22	22	12	25	40	27	33	22	44	31	11	31	36	20	28	21	12	9	34	29	14	36	19	19	28	17	12	23	9	23	49
	2x2	17	10	50	8	33	41	5	10	14	39	38	31	37	41	42	12	32	31	12	6	19	21	8	28	41	21	35	44	35	6	41	30	39	43	16	50	49	38	36	10
0206	4x4	16	9	4	18	38	48	33	12	43	7	49	41	49	31	8	37	44	27	7	49	31	42	26	49	40	22	43	10	39	11	15	21	19	8	23	13	49	35	6	23
	2x2	17	5	27	35	7	16	17	35	9	41	31	6	46	7	23	50	38	17	9	16	8	37	33	21	24	32	29	37	4	18	35	9	20	12	28	25	35	41	42	38
0207	4x4	4	19	48	29	29	44	10	41	18	38	37	7	44	37	17	13	48	15	29	39	6	26	35	38	8	26	9	6	34	15	31	17	32	21	25	9	46	23	13	30
	2x2	22	46	10	35	27	6	13	13	38	24	4	21	25	22	20	33	30	24	38	10	32	48	23	7	17	15	22	24	35	14	38	47	8	40	43	45	50	46	18	13
0208	4x4	19	22	19	35	17	7	26	23	4	13	26	27	20	35	32	40	32	46	21	36	5	9	25	41	12	19	27	6	28	20	12	15	43	33	45	30	33	33	15	46
	2x2	20	22	46	18	8	40	43	7	23	27	38	46	26	43	20	17	29	41	18	30	20	25	41	21	30	11	34	19	12	43	42	32	38	21	31	35	34	4	19	36
0209	4x4	24	7	47	11	36	7	30	35	48	10	7	5	13	17	46	6	34	18	18	5	48	8	46	48	11	13	49	4	38	15	26	7	43	10	14	31	6	23	22	48
	2x2	26	19	46	9	27	8	24	38	40	9	8	33	40	11	14	28	24	35	46	33	27	46	34	35	20	9	30	31	7	36	4	18	25	28	30	34	23	23	26	6
0210	4x4	21	22	8	28	13	43	25	24	36	43	48	22	8	45	33	11	38	26	33	33	36	28	40	11	50	48	24	27	14	49	42	26	20	44	27	9	39	49	13	37
	2x2	38	5	26	37	34	7	37	37	5	29	29	15	4	24	31	16	37	24	50	20	31	24	36	36	14	12	5	44	38	40	32	9	44	4	47	17	49	10	14	27
0211	4x4	42	25	27	21	49	4	29	50	13	15	41	10	31	48	16	15	26	19	29	10	30	45	7	12	46	43	30	7	38	18	36	5	14	9	10	44	18	44	32	39
	2x2	30	24	5	46	49	6	10	26	50	33	21	9	50	42	40	31	28	18	46	24	38	8	42	16	11	16	31	36	23	45	24	24	19	49	33	14	34	13	9	13
0212	4x4	42	14	50	46	20	22	25	50	44	48	12	8	17	47	11	23	34	32	14	19	42	12	38	39	41	26	16	24	25	21	12	45	27	13	26	45	6	27	14	14
	2x2	46	33	40	50	16	26	35	25	4	13	40	31	31	16	16	48	4	32	30	37	4	4	9	35	7	8	35	17	21	30	26	26	39	17	42	33	49	39	29	8