Agricultural Productivity Indicators Measurement Guide

January 1999

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1 Purpose of Guide

Box 1: About this series...

This series of Title II Generic Indicator Guides has been developed by the Food and Nutrition Technical Assistance (FANta) Project and its predecessor projects (IMPACT, LINKAGES), as part of USAID's support of the Cooperating Sponsors in developing monitoring and evaluation systems for use in Title II programs. These guides are intended to provide the technical basis for the indicators and the recommended method for collecting, analyzing and reporting on the generic indicators that were developed in consultation with the PVOs in 1995/1996.

Below is the list of available guides:

1. *Food Security Indicators and Framework for use in the Monitoring and Evaluation of Food Aid Programs* by Frank Riely, Nancy Mock, Bruce Cogill, Laura Bailey, and Eric Kenefick
2. *Infant and Child Feeding Indicators Measurement Guide* by Mary Lung'aho
3. *Agricultural Productivity Indicators Measurement Guide* by Patrick Diskin
4. *Sampling Guide* by Robert Magnani
5. *Anthropometric Indicators Measurement Guide* by Bruce Cogill
6. *Household Food Consumption Indicators Measurement Guide* by Anne Swindale and Punam Ohri-Vachaspati

In addition to the above categories, other guides are under preparation:

7. *Evaluation Design Guide* by Frank Riely
8. *Water and Sanitation Indicators Measurement Guide* by Pat Billig

This guide discusses the subset of generic Title II indicators identified for agricultural productivity-related activities. These are listed below in Table 1, together with a summary of their measurement requirements and analytical concerns. The guide is divided into four chapters, plus appendices.

Chapter 2. Issues Related to Measurement and Interpretation of Impact Indicators. This chapter explores the many difficult issues and concerns that arise regarding the measurement and interpretation of the first six agricultural impact indicators shown in Table 1. These are considered *impact* indicators, as opposed to indicators 7 and 8, which are *monitoring* indicators and which are *relatively* straightforward to measure. This discussion is intended in part to help practitioners avoid pitfalls in measuring these indicators that may lead to misinterpretations of the resulting data. It also lays a basis for the recommended methods in the proposed data collection plan.

Chapter 3. Data Collection Plan. Chapter 3 recommends a data collection plan for the six indicators. The proposed methods are designed to minimize measurement problems and maximize the ability to make a *plausible* (if not definitive) case for demonstrating activity impacts within resource constraints for carrying out monitoring and evaluation activities.

Chapter 4. Calculating Indicators. This chapter describes how to calculate the values of the first six indicators listed in Table 1 below, based on the data collected.

Appendix 1 provides a discussion on the relative merits of crop cut versus farmer estimation methods for estimating crop yields. **Appendix 2** is a list of generic Title II indicators.

Table 1: Generic Agricultural Productivity Performance Indicators for Title II Food Aid Development Activities

Indicator	Data Needed for Measurement	Data on Causal Factors	Measurement Methods	Calculation	Units	Concerns/Issues
1. Harvested crop yields per hectare	Harvested output Area planted	Farm practices Rainfall	Farmer survey Area measurement Rain gauges	Output/area (with reference to rainfall)	Kgs. per hectare	Farmer estimate vs. cropcut Inter- and multiple cropping Economic considerations
2. Gap between actual and potential yields	Harvested output Area planted Demo plot yields	Farm practices Rainfall	Actual (as above) Potential- complete demo plot harvests	(1 - actual/ potential) x 100%	Percent	Harvest yield potential vs. economic maximization ("economic yield gap")
3. Yield variability under varying conditions	Yield time series (pre- and post-activity)	Farm practices Rainfall time series	Methods must be consistent with pre-activity methods	Range or standard deviation. (see Chapter 4.3)	Kgs. per hectare	Difficulty in having consistently collected pre- and post-activity data
4. Value of crop production per household	Harvested output Income from sales Input costs Month stocks run out Prices/inflation rate	Farm practices Rainfall	Farmer survey Market prices (if possible secondary) Rain gauges	(Sales income + monthly cons. x prices-inputs) / (1 + inflation rate)	(Inflation-adjusted) units of money	Different transaction levels Price seasonality/inflation Non-marketed crops Valuing crop by-products Labor costs
5. Months of household food provisions	Month of harvest Month stocks run out Month last tuber harvested	Farm practices Rainfall	Farmer survey Rain gauges	Time between harvest and stock depletion	Number of months	Crop sales, nonfarm income and market food purchases
6. Percent of crop losses during storage	Amount crop stored Amount of crop lost Time in storage	Storage practices Number storage facilities built	Farmer survey Counting/weighing (demo. plots)	Loss rate per time period x amount stored	Percent	Losses in nutrition/quality Differences between demo facilities and actual
7. No. of hectares (or hhs.) with improved practices	List of practices Area (or # of hhs) where practices used	(none)	Farmer survey Area measurement (optional)	(none)	Number hectares or hhs	Partial applications of improved practices
8. Number of crop storage facilities built and used	Number facilities built Number facilities used	(none)	Farmer surveys Project records	(none)	Number of facilities	Volume of facilities Quality of facilities

2 Issues Related to Measurement and Interpretation of Impact

This chapter discusses issues relating to the measurement and interpretation of the six generic agricultural productivity performance impact indicators listed in Table 1. Ultimately, many of these issues cannot be resolved adequately, particularly given the limited resources available to PVOs and USAID for data collection. These measurement problems will inevitably impede the ability to draw definitive conclusions with statistical confidence on the ultimate impacts of Title II activities on agricultural productivity. A clear understanding of the measurement problems is nevertheless important for identifying data collection approaches that minimize measurement biases, avoid misinterpretations of data, improve causal links between activities and outcomes, and thereby improve the possibility of drawing sound conclusions about the impacts of the activities.

1. Impacts on Crop Yields

Crop yield per area (amount of crop harvested per amount of land planted) is the most commonly used impact indicator for Title II agricultural productivity activities.[1] Trying to assess impacts of interventions on crop yields over time, however, raises a number of important data measurement and interpretation concerns. These include (1) rainfall and other exogenous factors; (2) choice of data collection methods; (3) sample size requirements; (4) data collection biases; (5) mixed (inter-) cropping; (6) multiple or continuous harvesting; and (7) non-standard units. Each is discussed below.

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1. Some Title II activities also use production per household (or target area) — i.e., the total amount in terms of weight of a crop that a household (or target area) produces — as an indicator, disaggregating this indicator by crop type. This is generally a poor choice. One reason is that changing economic or environmental conditions (e.g., changes in relative market prices or the timing of rainfall) may (and should) lead farmers to adjust relative crop mixes based on expected returns. Since these conditions will not be known in advance of the project, setting specific crop-disaggregated targets for increased production is complicated in that it involves predicting not only yield increases from project interventions, but also changes in relative cultivated areas. Another reason for not setting crop-specific production increases as targets is that this may be counterproductive, since in some situations it may be better to reduce production of one crop in favor of another. A third reason is that most Title II agricultural activities are focused on yield-related interventions rather than area-planted-related interventions. Consequently, production targets are less well linked to project activities than yield targets. A final complication is the need to disaggregate crop types; if disaggregation is not done, more comparable units of measurement will have to be established since using crop weights results in "comparing apples and oranges" (e.g., a pound of sorghum and a pound of teff are not equivalent nutritionally or economically). Using calories as the standard for comparison may be appropriate in a predominately subsistence economy. Market value would be the best choice otherwise, but this would simply convert this indicator into Indicator #4 on Table 1 — "Value of agricultural production per household."

Rainfall and Other Exogenous Factors Affecting Yields

Crop yields are inevitably affected by many factors beyond the control of Title II food aid activities, such as weather, input prices, locust cycles, etc. These factors, and their effects on yields, may vary from year to year. The question is how to control for changes in yields resulting from such factors.

Weather, especially rainfall, is the most important factor. Most Title II activities are implemented in areas dependent on rainfed agriculture. In such systems, variations from year to year in the amount, timing and distribution of rainfall can have a greater effect on yield levels than project-related factors, such as changes in farming practices, amounts of fertilizer used, quality of seed varieties, and even use of irrigation.

The importance of weather is so great that, unless weather data are referred to when comparing yields at two or three points in time, a plausible case for the impacts of project activities on yields cannot be made. An exception is if weather factors are similar between years. The problem can be reduced (but not eliminated) by tracking yield trends over a longer period of years than the five-year life span of most Title II activities (Kelly et al., 1995). The greater the yield variation resulting from exogenous factors, the greater the number of years of data needed.[2]

One approach to control for weather and other exogenous factors is to collect yield data on a control group of non-project participants (Riely & Mock, 1995). The difficulty of identifying a suitable control group and the costs involved, however, generally make this approach unlikely. A simpler and less costly (though less persuasive) approach is to collect data on rainfall (or other climatic factors) and explicitly relate yield data to the climatic data (i.e., report them side-by-side). Title II activities generally do not do this. Instead, results reports have tended to note adverse climate factors anecdotally and only in cases where yields have not risen as expected. When yields have increased at or above targeted levels, however, the credit is given to project activities, not the weather.

Many developing countries do collect regionally disaggregated rainfall data, which are recorded annually and sometimes seasonally. Such data are rarely made available systematically in a sufficiently disaggregated form (Kelly et al., 1995), however. A better alternative is to have Title II PVO staff collect primary rain data. This is already done in some cases. The approach is simple, involving distribution of rain gauges to farmer participants (see Chapter 3, Section 2.2.2).

The other aspect of controlling for weather is to have strong data that document that farmers have indeed adopted the farming practices advocated in the project. This is essential to the case that it is these practices — and not the weather — that have affected yield levels. Monitoring the adoption of Title II-activity-promoted practices is thus crucial.

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2. Poate & Casley (1985) illustrate this using hypothetical figures. They show that to calculate a linear trend slope of 10 percent, with a standard deviation of 2 percent of base yield and a random variation from exogenous factors of 15 percent, approximately nine years of data would be required. In this case, if the annual increment in yield being estimated is 100 kilograms per hectare, the confidence interval with nine time points would be approximately 60-140 kilograms. With only four to five years of data, it would be difficult to detect a yield trend that is rising even at 10 percent a year and be sure that it is significantly higher than zero; under such circumstances, data on year-to-year changes in crop yields would be only “indicative.”

As discussed below, three other Title II generic indicators are also affected by weather factors: yield gap, value of agricultural production per household, and months of household grain provisions.

Choice of Data Collection Methods

Several methods are available for estimating harvested yields of farmer plots. The two most common are *crop cutting* and *farmer estimation*.

- *Crop cutting*, the more traditional, involves direct physical measurement (weighing) by the enumerator of crop(s) taken from one or more selected (ideally randomly) subplots within farmers' fields harvested by or in the presence of project staff.

- *Farmer estimation* involves surveying farmers to obtain their estimates of the total crop they harvested and dividing this by estimates of how much land they *planted* (ideally obtained by direct land area measurements) to calculate estimated yields. In this case, yield estimates are based on the entire area planted by a farmer rather than on a subplot.[3]

Which of these methods is more appropriate is a matter of debate. Crop cutting has long been considered more accurate, and most agricultural surveys rely on it (Murphy et al., 1991). The risk is that it can result in significant overestimates of yields (e.g., Casley & Kumar, 1988). Studies in several countries have suggested that post-harvest farmer estimates of cereal crop yields may be just as accurate (or even more so). In addition, obtaining farmer estimates is simpler, less costly, and permits greater sampling efficiency than crop cuts. (For more information, see Appendix 1).

Evidence in the literature points to the conclusion that farmer estimates of output divided by direct measurements of planted areas is the best way to estimate cereal crop yields in most contexts. Certain conditions, however, would preclude use of the method or bias the results:

3. Other methods not discussed here but which may be applicable in certain situations include "complete harvesting" in which entire farmer plots would be harvested under project staff supervision; "expert assessment" in which teams of experts familiar with crop production in the region visit fields prior to harvest and make subjective estimates of yields; and "sampling of harvest units" in which a sample of harvest units is weighed and the total units harvested is estimated (Casley & Kumar, 1988). The complete harvest method is considered the most accurate and often used as a standard for comparison, but is too costly for large samples of farmers. It may be applicable, however, for case study evaluation approaches, and for estimating demonstration plot yields. The expert assessment method, which is more applicable for rapid assessment and early warning purposes than for evaluation purposes, would be a last resort option if other measurement methods are infeasible. In one study in Zimbabwe, expert assessments of harvest yields were found to be closely correlated with farmer estimates (Casley & Kumar, 1988). For the harvest unit sampling method, two ways of estimating the total number of units are inspection (counting) or questioning the farmer. The inspection approach has the constraint that all crops need to be harvested at one time and the enumerator must be present precisely at that time. If estimates of units are obtained by questioning the farmer, this method is virtually the same as the farmer estimation method.

1. Farmers have or perceive incentives to inflate or deflate production estimates (e.g., taxes, status, eligibility for program benefits).[4]

2. Crops are not harvested within a short defined time period but rather harvested continuously over long periods, particularly root and tuber crops (e.g., cassava). This is discussed further below under the heading "Multiple (or Continuous) Harvesting."

3. Farmers are unable to express estimates in units that are or can be standardized. This is discussed further in this chapter under the heading "Non-Standard Units" and possible solutions are proposed in Chapter 3, Section 2.2.4.

4. Accurate estimates of land area cannot be obtained either by direct measurement (e.g., due to widely scattered plots or difficult terrain) or farmer estimates. Chapter 3, Section 2.2.1, provides information on how to carry out measurements in most cases.

5. Logistical or other constraints prevent enumerators from visiting farmers shortly after harvest. This would mean the recall period would be longer and farmer estimates of production would be less likely to be accurate.

Sample Size Requirements

Sample size is another concern in measuring changes in crop yields over time. Three factors affect sample size requirements: the amount of variance in the data (which is unknown in advance); the level of confidence desired; and the level of sampling efficiency. (For further guidance on sampling issues and methods, see the FANta project's *Sampling Guide*.) Poate & Casley (1985) point out that if the intention is to measure small changes from year to year or to present findings for each geographical sub-population, several hundred households is too small a sample on which to base the kind of comparisons and conclusions desired. This point is relevant to Title II agricultural activities which in some cases have annual yield increase targets of only 3 percent.

As a general rule sample size should be kept as small as possible in order to save time and money. Therefore, Title II evaluators should focus only on the yields of crops that are planted by most farmers. In addition, data collection methods should be chosen that reduce or eliminate the need for clustered sampling and use instead simple random sampling.[5] Since farmer estimation allows for use of less highly clustered samples (i.e., greater number of sample areas with fewer households per sample area), sampling considerations provide another argument in favor of using farmer estimates rather than crop cutting (see Appendix 1).

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4. Remington (1997) cites three situations in which this problem may occur. The first is the use of baseline data for determining which areas or population groups to target. The second arises when data on improved food security is to be used for decisions to phase out activities. The third occurs when data would be used to reduce quantities of food relief in areas recovering from disasters as production recovers. In all cases, the population may be motivated to under-/over-report information in order to gain access to project benefits.

5. Poate & Casley (1985) point out that the loss in sampling efficiency in clustered samples may require the sample size to be increased by a factor of two or three.

Data Collection Biases

Title II activity evaluators are also faced with problems of data collection biases (or biases that are introduced by the way the data are collected). The presence of such biases further impede the ability to draw valid conclusions on activity impacts on crop production and yields. The crop cutting method tends to overestimate total production since the subplots selected may not be representative of the total plot area and may be harvested more thoroughly than the typical farmer plot (see Appendix 1 for further discussion). For the farmer estimation method, a potentially major source of bias is "strategic responses" in which there are perceived incentives to under- or over-report crop production. In particular, farmers may choose to under-report their production if they believe their responses may be linked to personal costs (e.g., taxes, marketing quota enforcement) or gains (e.g., food aid benefits).

Mixed Cropping

Mixed cropping (or intercropping), common in many developing country agricultural systems, presents another challenge for measuring and interpreting data on crop yields. Casley & Lury (1981) found in Ghana that 84 percent of the area under seasonal crops contained a mixture of crops, and in Botswana that 90 percent of the area under millet and more than two-thirds of the area under sorghum contained other crops. Unless the implications of mixed cropping are accounted for, crop yield and area data will be misleading.

Mixed cropping takes different forms: one crop may occupy space within the plot that would otherwise be occupied by another; one crop may be added between rows of another crop which has been planted at its normal density; or two crops may share a plot for only a brief part of the growing season or occupy it at entirely different times of the year (Kearle, 1976; Kelly et al., 1995). In any case, joint (or sequential) occupation of different crops on the same land can significantly affect (positively or negatively) measured yields of both crops. A secondary crop might, for example, reduce yields of a primary crop due to displacement or competition for nutrients. Yields of the primary crop could be seriously underestimated if such intercropping effects are not taken into account (Kelly et al., 1995).

A number of approaches can be used to address this problem, none entirely satisfactory (Poate & Casley, 1985; Stallings, 1983).[6] Poate & Casley suggest that the most reliable approach is to present

6. In the simplest of these approaches, crop areas are divided by the number of crops grown on them. For example, if two crops are grown together on one hectare of land, the area assigned to each crop would be 0.5 hectares. In most cases, crops do not share the land equally, seriously impairing the validity of this approach. Another overly simplistic approach has been to give the whole area to each crop, dividing total production of crop x by the whole area planted to both crops, thus overestimating the area planted to crop x and underestimating the yield of crop x. The FAO, for instance, has used this approach for some crops, while acknowledging the consequent underestimation of yields (Kelly et al., 1995). More important for Title II evaluations, these simplistic approaches, by reporting complex cropping mixtures as if they were grown in pure stands, do not account for changes in relative amounts of land planted to the mixed crops. More complex

at least two levels of detail. First, the overall land area on which the principal crops are grown, together with crop yields. Second, for each crop a breakdown of the area into the types of cropping systems — for example, maize in pure stand, maize with other cereals, maize with beans and pulses, maize with permanent crops, or maize with all other crops. Although this would seem an improvement over other commonly used methods, it too has problems: (1) the number of indicators is increased, as multiple indicators are needed for each crop that is intercropped; and (2) more serious, meaningful conclusions still cannot be drawn about changes in yields for all except the pure stand indicators, unless the yields for the secondary crops in mixed cropping systems remain constant. An additional concern is that where a particular crop is planted in more than one type of cropping system (i.e., pure stand and mixed cropped or multiple mixed cropping patterns) farmers may be able to estimate total production of the crop, but find it difficult to disaggregate by individual plots or cropping systems (Murphy et al., 1991).

For these reasons, where mixed cropping is common and where reliable, relevant price data are available or can be collected for each crop, the best approach for Title II purposes may be to change this indicator from weight yield to value yield. As explained in Chapter 4, Section 4, this would mean that instead of calculating two indicators (i.e., the weight yield of corn and beans, the total value of both the corn and bean production would be calculated and then divided by the area planted).

Multiple (or Continuous) Harvesting

Another problem for measuring crop yields is multiple harvesting. For instance, a portion of maize crops is often harvested in advance of the main harvest and eaten as *green maize*, with the amounts varying from year to year. Roots and tubers, on the other hand, may remain in the ground for a long time after reaching maturity and be harvested on an ongoing basis as needed. In both cases, yield measurement is difficult. Murphy et al. (1991) suggests for crops such as cassava and potatoes, the only alternative is a case study approach in which agreement is made with a small sample of farmers to harvest their plot at a specified time. Since harvesting the crops at one time like this would not be in their best interests, some compensation (monetary or in-kind) should be paid to these farmers.

Non-Standard Units

A final issue is that developing country farmers often measure crop yields in non-standard measurement units. This problem has four aspects: (1) conversion from local units to internationally recognized units; (2) variations in local units; (3) accounting for crops at different stages of growth or processing (e.g., green maize); and (4) conversion from volume to weight measures (Rozelle, 1991). Whereas conversion from local to internationally recognized units is generally straightforward, variations in local standards is more problematic. Small-scale farmers in many developing countries use a wide variety of

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approaches have also been tried, such as using seeding rates or crop densities to assign area proportions. The plant density method has the advantage in theory of approximating product-specific yields, but its costs and difficulties are high (Kelly et al., 1995), and it is still subject to problems of interpretation.

reporting units, which may vary by crop, by area, or even among farmers in the same area. Sometimes different terms are used to describe the same unit, or worse, the same term may be used in different areas to represent different units (Verma et al., 1988).[7]

2. Gaps in Actual vs. Potential Yields

Gaps in actual vs. potential crop yields are assessed by comparing yields in demonstration plots with yields obtained by other farmers in the project areas. Neither the crop cut nor farmer estimation techniques are adequate for estimating average demonstration plot yields, however, since the samples are too small.[8] Instead complete harvesting is far more accurate and statistically efficient (Casley & Kumar, 1988). Moreover, though it would not work for large numbers of areas, complete harvesting is practicable for the relatively few demonstration plots at issue (Murphy et al., 1991).

The problem is that measurements in the comparison will have been done by two different methods (i.e., complete harvest vs. farmer estimation) and estimated yield gaps will likely be influenced also by differences in biases between the two measurement methods.[9] It will be important, in interpreting absolute values of yield gaps, to keep these different biases in mind. On the other hand, it may be reasonable to assume that differences in measurement biases remain fairly constant and therefore do not affect *changes* in yield gaps over time.

3. Changes in Yield Variability

7. For instance, Rozelle (1991) observes in Malawi that harvest size was counted by the number of baskets that were used to carry the harvested products, but that these varied in shape and size. Similarly, Filipino farmers reported crop outputs by numbers of bags, numbers of cans, or other volumetric measures that varied from household to household. Verma et al. (1988) observed in Central African Republic that the same unit (cuvette) is used throughout the country, but the manner in which it is filled varies by region, necessitating calculation of a different conversion factor for each region. In Niger, Verma et al. found that instead of being placed in containers, harvested crops were tied into bundles, which varied considerably in size from region to region.

8. Casley & Kumar (1988), for instance, cited studies in Niger and Nigeria which found that within-plot variation accounted for 40-60 percent of total observed variations in yields, suggesting that crop-cutting estimates are subject to about twice as much variation as estimates based on complete harvesting of plots. Murphy et al. (1991) also observes that “even strong advocates” of the crop-cutting method do not claim that random cuts provide accurate estimates of *individual* plots, only that a sufficient number of cuts in a sufficient number of fields provides a valid estimate of *average* yields. Similarly, advocates of farmers' estimates accept that there is considerable variation in the accuracy of estimates by individual farmers.

9. Verma et al. (1988) explores the likely biases that arise with complete harvesting.

Whereas measuring crop yields *may* need more than the normal five-year Title II project lifespan, measuring whether projects have reduced the variability of yields from year to year will be impossible within the five-year project period. This is because the changes during the project will need to be set in the context of a farmer's production before and after the project. Thus, several years of both pre-activity and post-activity (or follow-on activity) yield data will need to be collected among targeted farmers in the project area. Methods for collecting yield data during and after the activity will have to be consistent with the methods used for collecting the pre-activity data.

4. Values of Crop Production

Increases in the value of household crop production may be the best way to reflect the ultimate impacts of activities on the welfare of targeted households, assuming that other sources of income are not significantly reduced as a result of the agricultural activities. Not only may it be a better indicator than increased crop yields,[10] but it also has fewer difficulties (i.e., there is no need to deal with intercropping or to measure land areas planted). On the other hand, the indicator has its own set of difficulties: (1) identifying appropriate transaction level prices for non-marketed crops; (2) adjusting for price inflation; and (3) accounting for crop by-products, including inputs to other household production processes. (Exogenous factors will affect values as they do yields.)

Non-Marketed Crops and Appropriate Transaction Level Prices

It is easy enough to value crops that are sold. The values will be simply what the farmer states he sold them for (see Chapter 3, Section 2.2.1). A significant portion of crops produced by farm households in Title II activity areas, however, is not sold in the market but rather is either consumed by family members, used as seed, transferred as gifts or compensation for labor, and/or fed to livestock. The question is how to value non-marketed crop production. Two scenarios are discussed below: the first in which local competitive markets for the non-marketed (home-consumed) crops exist and the other which there is no such market.

Valuing home-consumed crops that are available in local competitive markets

When home-consumed crops are also sold in local markets, one way to value them is to equate their value with the price that farm households would have received for their product in the market (i.e., the

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10. It is important to recognize that it is *not* maximization of harvest yields that matters to farmers, but rather maximization of net economic *value* yields. Often, farmers are able to increase their yields, but the costs involved in doing so may exceed the value of the additional output. A way to anticipate whether this will be the case is to see whether the technological applications used in demonstration plots are oriented towards economic value rather than harvest maximization; such an analysis would be based on estimates of the average input costs to farmers (including credit, transportation) and output market values. These findings should affect not only monitoring and evaluation but also project design and implementation. Minimizing risk is another factor that needs to be taken into account in anticipating farmer behavior; though the level of risk is not measurable, the level of risk can determine whether or not a farmer will adopt a certain practice.

market producer price) (Levin, 1991; Rozelle, 1991). Using market producer prices in such cases, however, may overestimate the value of crops if transport and other transaction costs are not subtracted. In other words, the real value for crops sold by households is the farmgate price. Farmgate prices may differ widely among households due to differing transaction costs resulting from unequal access to markets. Thus, although two households may face equal nominal prices in markets, the effective price for one household may be considerably higher than for the other (Rozelle, 1991).

At the same time, using the market producer prices in well-targeted Title II activities where most participant households, at least initially, are likely to be "net deficit" producers (or "net buyers") of food may result in underestimating the value of the crops. For these households, the real value of increased crop production to the household is not what they would earn if they sold it, but rather what they would have to pay to buy it if they had not produced it. Therefore, the *consumer* (retail) price may be a more valid estimate of the value of home-consumed crops.

A combined *producer-consumer* price approach has been tried in some cases: this uses producer prices for net surplus households and consumer prices for net deficit households (Levin, 1991). This too is problematic, however. Not only is it burdensome to collect two sets of prices, but households that switch from being net deficit to net surplus producers (perhaps as a result of the success of the Title II activity) might appear (wrongly) to have a reduced value of agricultural production because of using the lower (producer) price for valuing the production. In addition, being either net surplus or net deficit does not imply that the households only buy or only sell. Households in both groups may both buy at certain times of the year and sell at other times depending on seasons, cash needs, and prices.

Given the problems described above, using producer prices may be most practical option. The reasons are that (1) secondary price data, with sufficient quality and disaggregation, may be more readily available for producer prices, thus obviating the need for primary price data collection (see Chapter 3, Section 2.2.2); (2) the extra effort of collecting both producer and retail prices may be prohibitive; and (3) retail price data may, in some cases, be more difficult to collect and interpret: producer prices tend to be more uniform, with more standardized units and more centralized markets. If producer prices are used, however, potential biases need to be explicitly recognized to avoid misinterpretations in assessing the relative benefits of the agricultural productivity activities.

Valuing home-consumed crops that are *not* sold in local markets

Valuing crops consumed at home or only sold at certain times of the year when they are *not* sold in local markets has its own set of problems. Possible approaches are obtaining prices from other markets where the crop is sold and making a regional adjustment or using prices for close substitutes that are sold in the market (Rozelle, 1991). In either case, the problem is that prices change over time, usually increasing significantly during the course of a cropping season from the time of harvest until shortly before the next harvest. Households may sell parts of their crop at several times during the year at different prices and may store the rest and consume it on a continuous basis over several months

(Levin, 1991). This suggests that it is necessary to know both when crops were sold and when they were consumed, and what the prices were at those times. Farmer recall may provide information on sales, but it is highly unlikely that enumerators can visit frequently enough to glean good data on crops consumed at home, whether as food, seed, labor payments, or feed (Rozelle, 1991). The approach suggested in this guide to account for changing values of home-consumed goods is to ask farmers which month their stocks from home-produced crops ran out and assume home-consumed quantities are consumed at a constant rate over the course of the year, from the time of harvest until the time stocks are depleted.

Inflation's Effects on Prices

Effects of general economic inflation on crop prices must be taken into account in comparing values of household agricultural production from year to year. In economic language, it is *real prices* as opposed to *nominal prices* that must be used in estimating values. Since most developing countries have double-digit inflation, the use of nominal prices would indicate substantial increases in values of agricultural production for Title II activity participant households, even if the activity accomplished nothing at all. To find the real prices, nominal values of agricultural production must be deflated using an appropriate price index (Riely & Mock, 1995). Normally, price indices can be obtained from secondary sources; the best would be one specific to rural households in the country. If these are not available, the PVO would need to obtain advice on how create a price index.

Crop By-Products

Another important issue is the valuation of crop by-products. Failure to account for their value can cause serious downward biases in valuing crop production.[11] Such valuation is difficult when by-products are not sold but rather used by the household as inputs into other activities, such as fodder for livestock (Kelly et al., 1995; Malik, 1993). Specifically, measuring values of fodder and straw can be difficult since the proportion of these by-products to the grain itself varies by variety and climate (Malik, 1993). One approach is to change the indicator to include the value of crops and livestock (or total farm enterprise). This, however, entails difficulties, as livestock numbers are sometimes considered the most difficult agricultural statistic to obtain since the holder may not know how many he owns or may be reluctant to give away such information (Casley & Lury, 1981). Even if numbers of livestock are known, there is further difficulty in classifying them by age, sex, weight, milk yield, grade, or breed, all of which may affect their value.

11. For instance, Kelly et al. (1995) cites research that found that peanut hay accounted for 39 to 47 percent of the gross value of output from peanut fields in Senegal's central Peanut Basin and cowpea hay accounted for 35 to 59 percent of the gross value of cowpea output in Niger when cowpeas were produced as part of a mixed-cropping enterprise. Malik (1993) reports for a sample of farmers in Pakistan that fodder accounted for a range of 10 to 30 percent of the value of overall crop production and that the value of wheat straw was approximately 20 percent of the value from wheat crop revenues.

5. Number of Months of Food Stocks

Months of food self-provisions have been included in the list of generic Title II indicators as a proxy for the crop yield and value of production indicators. This indicator should be used only in subsistence areas, however, where production is mostly for home consumption and households do not make significant sales or purchases in the market. It should cover both grain, roots, and tubers, if commonly consumed.

6. Measuring Crop Storage Losses

Post-harvest crop losses have many causes and take many forms. For Title II activities, however, the *source* of post-harvest loss addressed in this guide is what occurs during storage by farm households (i.e., losses from other sources such as threshing, transport, milling, etc., are not considered). Activities to stem these losses therefore relate to farmer storage practices or construction of improved farm household grain storage facilities. Little work has been done on developing methods to assess on-farm storage losses in developing countries, although a significant portion of food is estimated to be lost during storage. This is partly because storage loss is difficult to measure even for those skilled in the area.[12] Among issues that need to be examined are (1) losses in quality; (2) costs of reducing losses; (3) changes in moisture content; (4) effects of climate; (5) accessibility of samples; and (6) the timing of measurements. Each is discussed below.

- **Losses in nutritional or other quality factors**. Losses such as those that result from mold toxins are very important but too difficult to measure to include in evaluation or monitoring of Title II (Harris & Lindblad, 1978).[13] All that can reasonably be measured are losses in quantities.

- **Costs of reducing losses** need to be incorporated in calculations of losses during storage if positive impacts on farm households are to be demonstrated. If costs exceed benefits, then reducing losses is not beneficial to farm households.

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12. Most work on storage loss assessment methods was done during a several-year period after a United Nations resolution in 1975 to reduce post-harvest losses in developing countries by 50 percent. At that point, it was recognized that not only was there no agreement on the extent of post-harvest losses in various countries, but also there was no agreement on appropriate methods for measuring such losses (Boxall, 1979; Harris & Lindblad, 1978). It also became evident that due to the variability of local post-harvest situations and the types of crops harvested, no one definitive loss assessment methodology can be universally applied. Instead, methods need to be adapted to local contexts (Harris & Lindblad, 1978).

13. The U.S. Food and Drug Administration uses a number of procedures for assessing qualitative losses, but all are too time-consuming, require a laboratory setting, and require judgments that are difficult to standardize (Harris & Lindblad 1978).

- **Changes in volume and weight due to moisture/effects of climate** need to be accounted for when tracking on-farm storage losses over the course of a season or between seasons. This is because the weight per volume of grain varies according to increases or decreases in the moisture content, though food value may not change. Farmers, however, may not have access either to the equipment (e.g., moisture meters, drying ovens) or expertise needed to standardize moisture contents (Harris & Lindblad, 1978). Differences in moisture contents also have an effect on the susceptibility of stored crops to losses; in other words, they are a confounding factor when measuring the amount of storage loss. Therefore, a measurement approach is needed that controls for changes in rainfall and humidity when differences in storage losses from year to year are compared. Harris & Lindblad (1978) point out that losses to insects remain small to non-existent as long as moisture levels are low: losses are minimal when moisture is only 6 to 8 percent; at 10 percent, insects still have serious difficulties surviving; and even at 12 percent moisture or less, grain insects have a hard time feeding and reproducing. The cross-sectional, as opposed to longitudinal, approach for monitoring changes in storage losses that is prescribed in the next chapter reduces the problem of needing to account for changes in crop moisture.

- **Accessibility of samples** can be a problem when stored crops (in whatever form, e.g., cobs, shelled grain) are at the bottom and rear of storage facilities. Even if bags are used and can be selected randomly, sampling within bags is difficult. The method of measuring only a limited number of demonstration sites helps reduce this problem significantly (see Chapter 3).

- **Timing and frequency of storage loss measurements** will affect the amount of loss. This is because the percentage of storage loss normally increases over time from the time of harvest to stock depletion. If storage losses are measured at just one point in time, under- or overestimates are likely, i.e., loss measurements early in the storage period will give estimates that are too low, and measurements made late in the storage period will give estimates that are too high.[14] This implies a need for multiple measurements during the storage period. Both Boxall (1979) and Harris & Lindblad (1978) suggest that monthly measurements are ideal. Boxall concedes that this may not be feasible and suggests an alternative approach in which estimates are made on three occasions: at the time of storage, halfway through the season, and during the last month of the season. Variations between farmers and between years, however, may make it almost impossible to predict the halfway point and the end of the stocking period. If, for instance, a farmer has a bad year and puts little food into storage, stocks may be depleted before the time of the second visit. On the other hand, in a good year the visits may come too early. In other words, the alternative to monthly visits may be equally unworkable. The solution, therefore, may be a significantly reduced sample size, though this will reduce the statistical confidence of the results.

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14. As Boxall (1979) explains, the problem lies in making an accurate estimate in a situation in which there is a decreasing quantity of grain and a potentially increasing degree of loss. It is important, therefore, to relate losses in a sample to the pattern of grain consumption. If an entire consignment of grain remains undisturbed throughout the storage period and at the time of removal the estimated loss is 10 percent, then this represents the total loss due to insects over the storage period. In most cases, however, and particularly in farm stores, grain is removed at intervals and each quantity removed will have suffered a different degree of loss since it will have been exposed to insect infestation for a different length of time. This factor will need to be taken into account when determining the total estimate of loss.

3 Data Collection Plan

This chapter provides an overall plan and specific methods for collecting data for measuring the Title II generic indicators for agricultural productivity. It also notes advantages and disadvantages of the approaches depending on the context.

1. General Principles

Data collection must be ongoing throughout the growing season; data collected during monitoring will make possible evaluations of project performance vis-a-vis appropriate indicators at a later date. Six general principles should guide PVO personnel during data collection.

1. **Be consistent**. Consistency in methods from year to year is essential. Despite the adage that two wrongs don't make a right, for assessing impacts over time, it is usually better to repeat “inadequate” methods than to change methods between years. Consistency in survey timing from year to year is also important; for example, it is best to visit farmers each year as soon after harvest as possible (see below, Section 2.2.4).

2. **Document methods thoroughly**. The methods used for collecting and analyzing data must be documented in order to ensure consistent repetition of the methods in subsequent years and to avoid misinterpretations of results by data users. Project records should fully describe measurement methods and include copies of questionnaires and sampling frames used, and results reports should summarize these methods and key assumptions and omissions in the data. Currently, most Title II results reports include little, if any, of this information.

3. **Account for exogenous factors affecting outcomes**. To strengthen attribution of causality between project activities and changes in impact indicators, data should be collected on other factors (e.g., rainfall) likely to affect these indicators, particularly given the difficulty of using control group methods in most cases.

4. **Build trust with farmers** through courteous introductions, explaining survey objectives and sharing survey results (Puetz, 1993). To avoid strategic responses, make it clear that responses are not linked to personal costs (e.g., taxes, marketing quota enforcement) or gains (e.g., food aid benefits) for respondents. Respondents should be assured, *and it must actually be the case*, that data will not be disseminated to others in such a way that the names of individual respondents can be linked to the responses they provide. Ask less sensitive questions first, leaving the most sensitive until the end.

5. **Integrate monitoring and evaluation activities with implementation activities** in order to (1) reduce costs; (2) promote usefulness of data; and (3) benefit from implementors' knowledge of local practices and rapport built with the farmers. Farmers are less likely to give candid responses if surveyors are outsiders with whom they have had no previous contact.

6. **Train and supervise enumerators thoroughly**. Where feasible, review completed questionnaires on the same day in the vicinity of the sample households to permit revisits for correcting errors where necessary. High quality-data depends on enumerators who are motivated, well trained, and well supervised (Puetz, 1993).

2. Data Collection Plan

2.1 Overview

This guide provides an overview of a data collection plan that covers the entire set of generic Title II agricultural productivity indicators. As shown in Table 2, data will be collected on 11 aspects of agricultural activity, ranging from farmer practices to sales and storage. As is evident from viewing Table 2 horizontally, some information is used more widely than other: information on farmer practices (collected both after planting and after harvest) and on the amount of rainfall will be necessary for most of the indicators whereas information on market prices and input costs/crop sales will be needed for only one — the value of agricultural production. Looked at vertically, Table 2 shows a similar variation among indicators: for example, measuring the value of agricultural production will require gathering 10 different types of information whereas measuring months of stocks will require only three. Generic recommendations may not be appropriate in all situations and project staff may need to adapt them based on the context and nature of their activities.

The plan is divided into four groups of activities based on their timing. To determine the approximate dates on which these activities need to take place, preliminary information must be known on the usual planting and harvest times of area farmers.

1. **Post-Planting Farmer Visit**[15] (approximately 1 to 2 months after planting)
   - Farmer pre-planting/planting/post-planting practices
   - Agricultural input costs
   - Additional crop sales since post-harvest survey (except first post-planting visit)
   - Months of self-provisioning from previous harvest
   - Measurement of area planted for each crop or mixed crop system

2. **Monthly Data Collection** (collected monthly if secondary data not available)
   - Rainfall data from rain gauges
   - Local market crop price data if adequate secondary data unavailable
   - Storage loss measurements at experimental (or demonstration) facilities

15. The *farmer* is defined as the person who works the plot. This is not necessarily the landowner or the head of the household.

3. **Harvest of Demonstration Plots** (on agreed upon harvest days)
   - Complete harvest and weighing of demonstration plots by or in presence of monitoring and evaluation staff

4. **Post-Harvest Farmer Visit** (approximately 2 to 4 weeks after harvest)
   - Farmer pre-harvest/harvest/post-harvest practices
   - Farmer estimates of production
   - Additional input costs since post-planting visit
   - Crop sales income from current harvest
   - Number and type of crop storage facilities
   - Amount of crops in storage

The data collection plan includes at least two visits to farm households per year, once just after planting and the other after the harvest. Both visits are essential for measuring the yield: the best time to measure the area *planted* is early in the planting season; the best time to collect data on *production* is shortly after the harvest, when farmers have the clearest recollection of the amount harvested. If there are two cropping seasons per year, the number of farmer visits will need to be doubled.

Table 2: Summary of Data Collection Plan for Measuring Title II Agricultural Productivity Indicators

Data Collection Timetable	Type of Data Collected	Title II Indicator Being Measured							
		Yield per hectare	**Yield gap**	**Yield variability**	**Value ag. production**	**Months of stocks**	**Storage losses**	**Adoption of practices**	**Storage facilities**
Post-Planting Farmer Visit (1-2 months after planting)	Farmer practices	X	X	X	X			X	
	Input costs/ crop sales				X				
	Months of stocks				X	X	X		
	Areas planted by crop type	X	X	see * below					
Monthly Data Collection	Rainfall	X	X	X	X	X			
	Market prices				X				
	Storage losses (demo. sites)						X		
Demo harvest (harvest time)	Yields of demo. plots		X						
Post-Harvest Farmer Visit (2-4 weeks after harvest)	Farmer practices	X	X	X	X	X	X	X	
	Farmer prod. estimates	X	X	see * below	X				
	Input costs/ crop sales				X				
	Storage facilities				X		X		X
	Crops in storage				X		X		

C Estimating changes in yield variability requires comparison with pre- and post-activity yield data. Because data collection methods need to be consistent across these years, the methods used for collecting yield data for this indicator should be the same as those used in collecting the pre-activity yield data.

2.2 *Data Collection Timetable/Type of Data to be Collected*

2.2.1 Post-Planting Farmer Visit

The post-planting farmer visit should take place approximately one to two months after planting. Depending on which indicators are being tracked, the types of data collected may include farmer planting practices, input costs, income from crop sales, months of food stocks from previous harvest, and areas planted for each crop or crop mix system.

Farmer Practices (Early Planting Season)

Data on the adoption of improved farming practices should be collected through farmer surveys.[16] The types of questions will vary depending on which practices the Title II activity is promoting, other practices of key interest to activity designers and implementors, and the contextual factors that affect the adoption of practices.[17]

The practices in question for this survey are those that take place early in the planting cycle. Eleven potential topic areas are listed below. Although specific practices will vary depending on the activity and context, they will be related to one or more of the areas listed below. Although most of the questions will be used to monitor farmer adoption of practices (indicator #7), two of them — types of crops planted and whether they are planted in pure stands or mixed with other crops — will be needed to group data on areas and yields.

1. Land preparation
2. Seedbed maintenance
3. Plowing techniques
4. Types of crops planted
5. Pure stand and mixed cropping systems
6. Planting practices

16. An alternative approach which has been used with success is a record-keeping approach in which farmers write down on a regular (perhaps daily) basis what practices they employ and what inputs they use. While record keeping has the advantage of shorter (and thus more accurate) farmer recall, disadvantages include (1) the need for a literate, well-motivated sample; (2) the greater time and costs per farmer needed for frequent visits to check records and for data analysis; and consequently (3) more limited sample sizes and area coverage (Rozelle, 1991). Due to these disadvantages, the survey method is preferred for Title II monitoring and evaluation purposes.

17. Unlike health and nutrition projects, where surveys on adoption of practices (i.e., knowledge, practices, and coverage or KPC surveys) can be relatively standardized, surveys on adoption of farmer practices (often called knowledge, attitude, and practices or KAP surveys) cannot. That is because best practices for child health are basically the same from place to place, but best practices for agricultural production vary greatly depending on the geographic and economic context.

7. Types of seeds used
8. Fertilizer application[18]
9. Weeding
10. Insect and disease control measures
11. Irrigation and other water control measures

An important issue is the completeness and quality with which farmers adopt these practices. Many farmers will partially adopt practices or adopt them in a lower-quality fashion. For example, in an activity that promotes the use of a particular fertilizer, some farmers may use the fertilizer but at doses different from those recommended, or at different times from those recommended. For each farmer practice being monitored, therefore, to avoid ambiguity it is essential to be precise in defining what constitutes satisfactory adoption (Krimmel et al., 1990). For fertilizer, for instance, adoption could be defined as "application of the fertilizer within ___ percent of (recommended amounts) within ___ week of (the recommended time)."

To increase their usefulness for activity designers and implementors, the farmer practice surveys should also ask about reasons for non-adoption. Knowledge is a necessary but not sufficient condition for adoption of practices (Kearle, 1976). On the other hand, a number of factors may weigh against a farmer adopting various practices: not only may they lack knowledge but they may lack confidence in recommended improved practices, believe that to adopt them would not be cost-effective, or lack access to inputs, credit, or labor.

Additional principles that should be followed in collecting data on farmer practices include:

(1) Do not ask unnecessary questions.
(2) Avoid open-ended questions; use questions with yes/no answers where possible. For example, do not ask "what practices do you use when planting?" Instead ask "do you plant in rows?".
(3) Do a pre-survey to test whether questions make sense and solicit the desired information.

Input costs/crop sales

Questions on input costs are needed when the value of agricultural production indicator is being tracked. These questions would be asked during both the post-planting and post-harvest visits. During

18. A number of Title II activities have established, and are attempting to measure, crop-disaggregated fertilizer use targets. Where farmers plant many crops or engage in intercropping, such disaggregation can be extremely difficult, raising the question as to whether the value of the information is worth the measurement difficulty. The recommendation, therefore, is generally to ask for total fertilizer use only. The same is true for other inputs such as herbicides or pesticides. It may be useful also to estimate input use per land unit. The enumerator, however, should not directly ask the farmer how much input is used *per land unit*, as this information is likely to be unreliable. Instead, the amount of input per hectare should be calculated by dividing farmer estimates of total input use by direct area measurements made by the enumerator.

the post-planting visit, costs of inputs used in the current planting season up to the time of the visit would be ascertained. Farmers should be asked for the total amount of input expenditures or inputs used, including the costs of purchased labor inputs (non-purchased labor inputs are also important but difficult to measure). Inputs *used* instead of input *expenditures* are appropriate when some inputs are carried over from year to year or obtained from non-commercial sources. In such cases, price data for these inputs must be obtained in order to derive expenditure equivalents. It is not necessary for measuring this indicator to disaggregate input expenditures or usage by cropping system or per land unit. Some farmers may find it easier to separate out input costs for each type of input (which the data analyst can add together later) and others may find it easier to simply report total input costs. Therefore, the questionnaire should allow for both options.

Illustrative Questions for Inputs:

1. Did you use any fertilizer that you purchased on your crops? [ ] yes [ ] no
2. Did you use any herbicide that you purchased on your crops? [ ] yes [ ] no
   Repeat for insecticide, etc.
3. How much did you pay for these inputs?
   Fertilizer [ ] Total [ ] (reported by farmer or calculated by analyst)
   Repeat for herbicide, insecticide, etc.

Questions on crop sales income are also needed for measuring the value of crop production. These questions would be asked first during the post-harvest visit, to capture sales immediately after harvest, and followed up during the post-planting visit to capture subsequent sales from the previous planting season. Thus, questions on sales income would be asked in the post-planting visit starting only in the second year of data collection. Questions on income from sales are relatively sensitive and should be asked toward the end of the visit (Spencer, 1972). Below is a list of illustrative questions:

Illustrative Questions for Sales:

1. How many different times did you sell some crops since (date of last visit)?
2. Transaction 1:
   a. In what month did you make the sale?
   b. How much did you sell?
   c. How much money did you receive?
   d. Did you have to pay any transportation costs?
   Repeat for each subsequent transaction.

Months of Food Stocks for Home Consumption

Farmers should be asked whether they still have food stocks remaining from the previous year's harvest.[19] For cereals, farmers are asked for stocks kept in storage facilities. For crops that are stored in the ground and harvested as needed (particularly roots and tubers), farmers are asked about stocks kept in the ground. If the household still has stocks, the respondent is asked how many more weeks or months the food stocks are expected to last. If they are all gone, the respondent is asked when they ran out.

Illustrative Questions for Food Stocks:

1. What staple crops does your family consume? (This question is unnecessary if the answer is obvious).
2. Do you still have food stocks remaining from last year's planting season? [ ] yes [ ] no
3. If yes, how many more weeks do you expect the stocks to last? [ ] weeks
4. If no, in what month did the stocks run out? month [ ]

Measurement of Planted Areas

Since most farmers in developing countries do not know the amount of planted areas for their crops (FAO, 1982; Kearle, 1976; Stallings, 1983), direct measurement of *planted* areas (not land area *owned* or land area *harvested*) is necessary (see Chapter 2, Section 1). Likewise, *plots*, not holdings or fields, should be measured. A plot is defined as a contiguous piece of land in which only one type of crop or mixed cropping system has been planted (Casley & Lury, 1981). A farmer's parcel (field) thus may contain a number of separate plots according to the variety of crops or crop mixtures planted. The enumerator must measure and note the crop types planted for each of these plots. Plots may or may not be marked by fences or paths. If unmarked, the dividing line between the crops becomes the boundary of the plot. In addition, when a farmer plants crops on multiple parcels in different locations, each should be visited if possible.

The farmer's holding must be separated into the different pure stand and mixed crop plots for which yields will be measured; these will have been ascertained during the farmer survey. Because of the complications of measuring and interpreting crop yield data (see Chapter 2, Section 1), in areas where many types of crop and mixed crop systems exist, concentration should be limited to a few principal crops or crop mixes (Casley & Kumar, 1988). The area for each of these plots must be measured. If two or more plots contain the same crop or crop mix, these should be added together. (As suggested above, another, better alternative would be simply to measure value, not yield.)

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19. Frankenberger (1992) notes that a study in Mauritania found that female heads of households were able to estimate quite accurately how many months their food stocks from their previous harvest would last. Asking about number of months stocks last is usually more accurate, easier, and more culturally sensitive than calculating numbers of months of stocks by dividing estimates of food in storage by estimates of household food requirements. Not only is this latter method difficult and subject to error, but some people may be reluctant to discuss food in storage due to cultural beliefs.

Land area measurement should take place during the post-planting farmer visit when crops have been planted but are still at an early stage. If only a post-harvest visit is possible, area measurement can be done at that time, though this would result in measuring areas harvested areas rather than those planted.

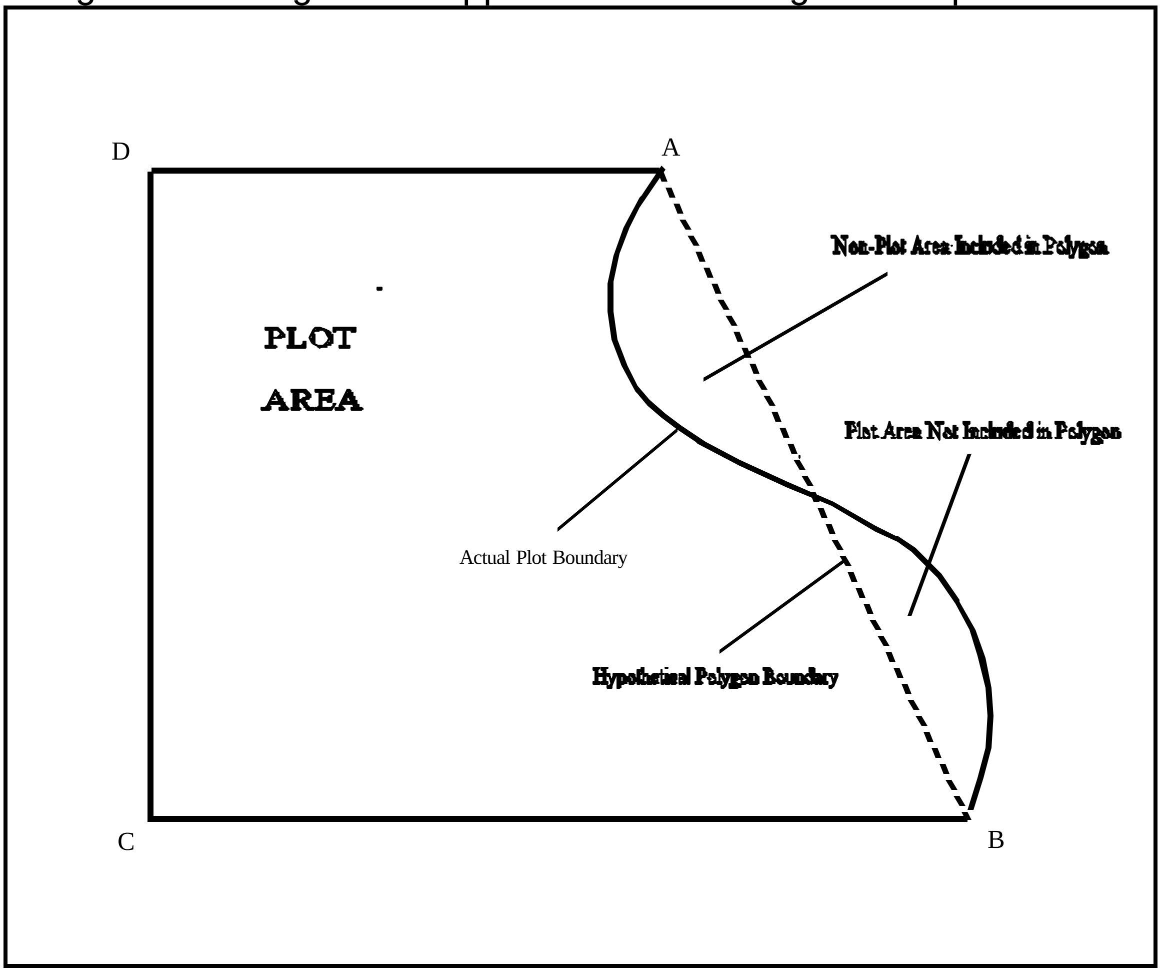
A number of approaches with different types of equipment can be used for the actual measurement, but use of measuring tape and compass are recommended.[20] This is because (1) the equipment is cheap and easy to acquire and use; (2) the method is applicable in most situations; and (3) the calculation of *closing errors* limits measurement error (see below). If aerial photographs are a feasible option, they can serve as a cross-check; they would also serve other useful purposes for activity implementation and monitoring/evaluation.

Plots will often not be shaped as simple polygons. In such cases, the first step is to transform the plots to be measured into approximate polygons and demarcate the corners of the polygons with stakes in the ground. A rough drawing of each plot should be made. The drawing should give some indication of the position of the plot within larger parcels and the distance and direction of the field from key landmarks, including the farmer's house (Casley & Kumar, 1988; Murphy & Sprey, 1986).

The number of sides of the polygon for each plot will depend on the plot shape. For plots that have curved or otherwise irregular shapes, straight-edged approximations of polygon sides need to be made. In identifying such polygon sides, pieces of the plot that are excluded from the polygons need to be compensated for. This can be done by including approximately equal pieces of land that are not part of the plot. Figure 1 below illustrates how to do this. In this figure, one side of a farmer's plot is curved (imagine that it borders a stream or a road). A straight line connecting points B and D would result in a good approximation of the plot area, since the amount of the plot that would be excluded by the polygon is roughly equal to the amount of non-plot area that is included. The area of this irregularly shaped plot can then be measured as a simple four-sided polygon.

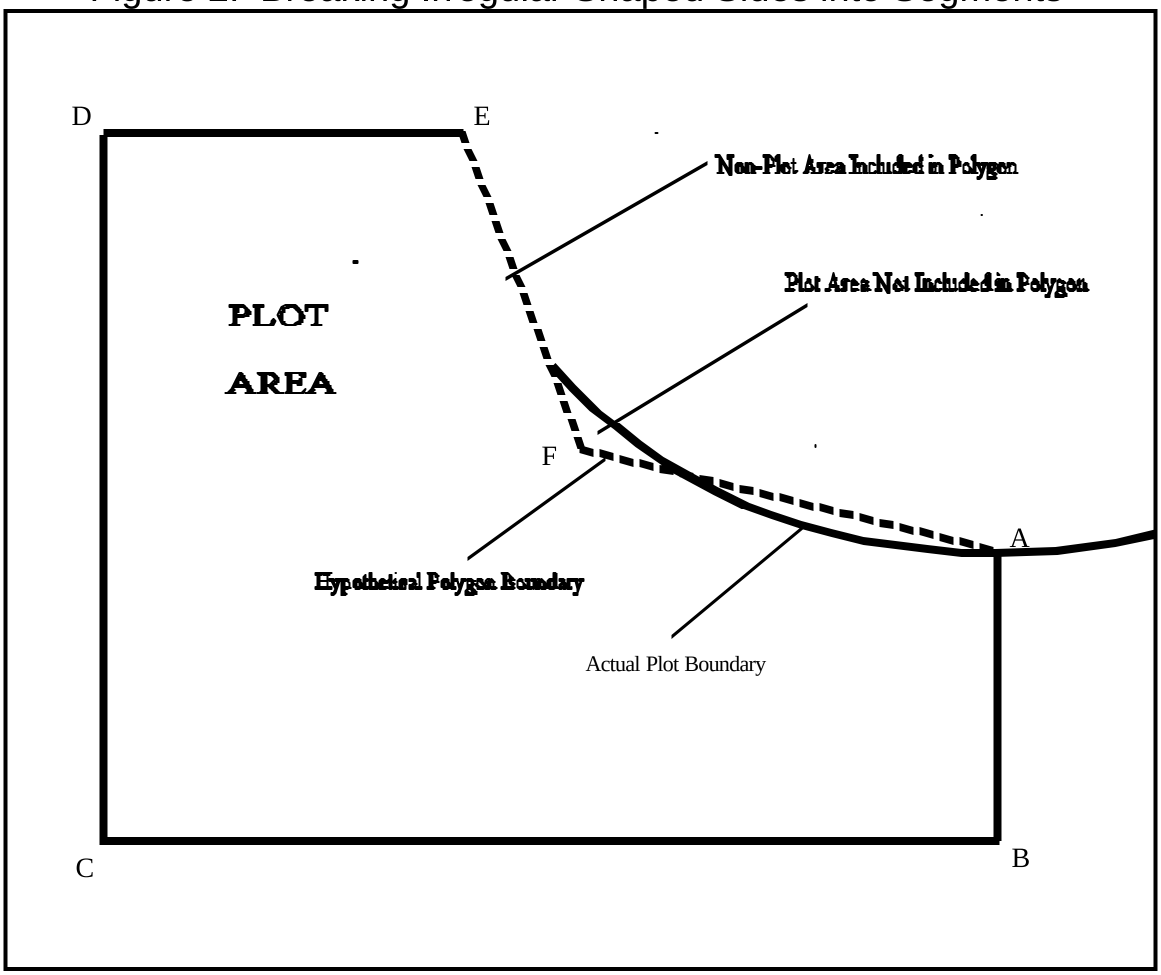
20. Other technique and equipment options that have been used include measuring wheels, measuring chains, and range finders. Measuring wheels have the advantage of needing only one operator but are difficult to use on many types of land (especially forests and rocky or wet surfaces) and are generally considered less accurate (Belbase, 1991; FAO, 1982; Kearle, 1976; Poate & Casley, 1988). Measuring chains are more sturdy than measuring tape but are less easy to use, heavier and even more prone to error (FAO, 1982). Range finders can save measurement time but are more expensive. Also, Kelly et al. (1995) and Riely & Mock (1995) have noted the potential for using global positioning system (GPS) technology to increase accuracy and reduce time in measuring field areas, although the accuracy and costs of this technique are not certain.

Figure 1: Straight Line Approximation of Irregular Shaped Plots



To reduce error resulting from making straight line approximations of curved plot shapes, curved sides may be broken into two or three measurements. This is illustrated in Figure 2 below. In this figure, connecting points B and E in a straight line would result in a large overestimate of plot area. Breaking the curve into two pieces and drawing two straight lines between points B and F and between points F and E, and compensating for excluded plot area by including some non-plot area, results in the area of the hypothetical polygon being roughly equal to the actual plot area. In this case the plot area can then be measured by the resulting six-sided polygon. The more irregular the shape of the plot, the greater the number of polygon sides that will be needed, though the number should not exceed ten (FAO, 1982).

Figure 2: Breaking Irregular Shaped Sides into Segments



Once the polygon shape is determined and each of its corners marked with stakes, the length of each side is measured and recorded in meters, and the compass bearings from corner to corner are recorded. Two people are needed for these measurements, but only one needs to be a trained enumerator. The enumerator holds one end of the tape and makes the tape and compass readings, while the assistant (perhaps a local extension agent) holds the other end of the tape. It is critical that measuring tape remains at full tension to reduce error.

The compass bearings are measured in order to calculate the angles between sides of the polygon, which are in turn needed to calculate the areas. To illustrate this, consider the angle at point B in Figure 2 above. First take a compass bearing from points B to A. To do this, the enumerator stands with the compass at point B while the measuring tape is held by the other person at point A. The enumerator holds the compass horizontally above the measuring tape facing point A and rotates the compass until the needle pointing north is aligned with the 0 degree mark. The enumerator then notes and records the compass reading in the direction of point A, using the line formed by the measuring tape. The same procedure is followed from points B to C. The angle at point B is then derived by calculating the difference between the two compass readings (Murphy & Sprey, 1986). For instance, if the reading from B to A is 150 degrees and the reading from point B to C is 60 degrees, the angle at point B would be 90 degrees.

Depending on which way the difference between the two readings is taken, the two sides can form two different angles, one of which will be greater than 180 degrees and one that will be less. Consider, for example, two compass readings of 30 degrees and 270 degrees. Going in a clockwise direction on the compass dial from 30 degrees to 270 degrees, the difference can be seen as 240 degrees. Going in a counter-clockwise direction, however, the difference is 120 degrees. The correct angle is easy to see from looking at the polygon shape. If the angle bends inward, as in the angle at point B, the correct angle is the difference in readings that is less than 180 degrees. On the other hand, if the angle bends outward, as is the case for the angle at point F, the correct angle is the one that is more than 180 degrees.

To reduce errors, compass readings should be taken in both directions for each side of the polygon and the average of the resulting angles taken (Casley & Kumar, 1988; FAO, 1982). This is especially important as the measurement of angles from compass readings is likely to be the greatest source of error in area measurements (Ariza-Nino, 1982). The extra step of measuring in both directions helps avoid the need to repeat area measurements and reduces errors in yield estimates. The two readings taken in opposite directions would be approximately 180 degrees different. Before taking the average of the two readings, it is necessary to add (or subtract) 180 degrees from the second reading. Considering angle B in Figure 2 once again, suppose that the compass reading from point B to A is 92 degrees and the reading from point A to B is 270 degrees. Subtracting 180 from the second reading would convert this reading to 90 degrees, and the average between the two readings would be 91 degrees.

Some amount of *closing error* is likely during calculations as a result of inaccuracies in measuring the lengths and compass bearings of the polygon sides. This is illustrated in Figure 3 below. In this example, imagine measuring a four-sided polygon starting from point A to B, from B to C, from C to D, and from D back to A. When plotting on graph paper the distances and angles derived from the measurements, any inaccuracies in the measurements will cause the plotted polygon (the dotted line) to deviate from the true polygon (the solid line), and this will cause the final measured point (A') to differ in position from the starting point (A). This difference between A and A' is referred to as the closing error.

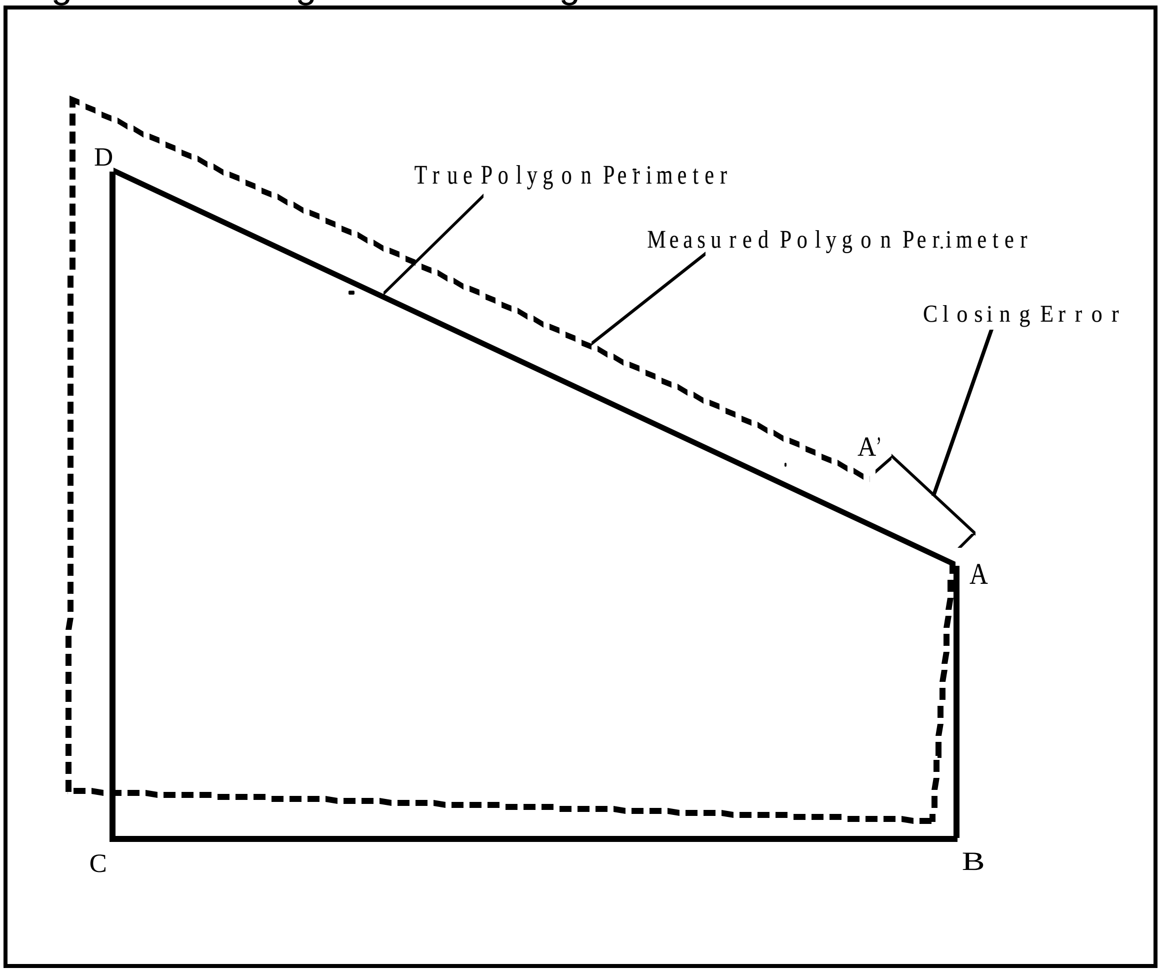
Calculations of the plot area and closing error should be done in the field when the measurements are completed and verified later in the office by monitoring and evaluation staff. Calculating closing errors in the field is crucial to allow immediate remeasurement of plots if the closing error exceeds a certain percentage of the perimeter of the polygon. Otherwise, data collected on households for which area measurement errors are discovered later will have to have to be dropped from the sample (Ariza-Nino, 1982; Casley & Kumar, 1988).

Monitoring and evaluation staff should decide in advance the maximum tolerated percentage of closing error. A 5 percent maximum tolerated closing error is recommended.[21] To determine the amount of closing error, the measurements can be plotted on squared graph paper (as in Figure 3) and the angles between the sides of the plotted polygon can be measured (using a protractor) between this sum and the calculation of (180 degrees) x (N - 2), where N = the number of sides. To allow quick calculations of areas and closing errors in the field (and avoid the need for plotting areas on paper in the field), the enumerator should be equipped with a programmable pocket calculator that has been programmed to make closing error calculations automatically (Casley & Kumar, 1988).

Finally, other sources of error must also be guarded against. Iron and steel objects near the compass (e.g., watches, steel-rimmed glasses) are a source of compass deviation and, if possible, should be removed to a safe distance to reduce error (FAO, 1982).

21. The allowable limit for closing error percentages is a matter of choice, and recommendations have varied among agriculture measurement experts. Poate & Casley (1985) suggest a maximum tolerated percentage closing error of 3 percent. Kearle (1976) suggests that up to 10 percent is acceptable. Hunt (1977) (cited in Casley & Lury 1981) suggests a range of 5 to 10 percent while Casley & Lury suggest the limit be close to 5 percent.

Figure 3: Closing Error Resulting from Measurement Inaccuracies



2.2.2 Monthly Data Collection

Rainfall Data

Rainfall data can be obtained by distributing simple, inexpensive rain gauges (as well as recording forms, pencils, etc.) to a number of farmers in the project areas and having extension workers collect the data during monthly monitoring visits. Farmers generally value having rainfall information and are eager to participate in this data collection and even to continue it after project completion. Remington (1997) reports that rain gauges can be ordered from a number of mail order companies (e.g., Ben Meadows, Forestry Products) and also possibly from large garden centers. The gradations should be in both millimeters and inches.

Market Price Data

As suggested in Chapter 2, Section 4, farmer reports of crop sales gathered during farmer surveys will provide the information needed on value of *marketed* crops, whereas the prices in local markets (market producer prices) will provide a basis to value crops that are *consumed at home*, assuming these crops are also sold in local markets. Reliable secondary price data should be used if they are available; if not, primary data should be collected for local markets once a month for each crop, a sample of local units weighed, and the unit price calculated. Price data should be obtained by observing and recording *actual transactions*. It would not work to simply ask sellers as they would most likely report the price they *want* to get rather than actually get.[22]

For practical reasons, wholesale producer price data should be collected (rather than data on farmgate or retail prices) as these tend to be most uniform in units, standards, and price. Different varieties of a particular crop having different prices may exist in the same market. In Ethiopia, for example, ten varieties of teff, four varieties of wheat, and three varieties of sorghum may be found (Tschirley et al., 1995). The enumerator must thus ensure that the variety being monitored matches with that being produced by the participant farmers. Differences in quality and moisture content also matter, but these will likely be too difficult to measure for Title II monitoring purposes and therefore can be ignored.

Prices for the same crop in the same market on the same day are likely to be fairly homogenous, but some price variation will almost certainly exist (particularly as the day progresses). Therefore, a number of price observations will need to be made. If possible, at least five transactions should be recorded for each crop being monitored, and the average price calculated. Random sampling for these observations is not possible, but enumerators should be sure that they are at least observing transactions for a variety of traders in the market.

Crop Storage Losses

As pointed out in Chapter 2, Section 6, monthly data collection on storage loss would be ideal but would be impractical for a large sample of farmers. Therefore, a proxy evaluation approach is recommended in which storage losses are measured and compared in a limited number of demonstration sites that have both improved and traditional storage facilities and practices.[23] To ensure

22. A third option is to include questions on prices in surveys of farm households. This has the advantage of more directly estimating the actual value of the crop to households either buying or selling the crop. A disadvantage is the imperfect recall of the farmers, due to the survey being conducted only twice a year or to the use of volume rather than weight units.

23. Currently, there is a lack of field-tested methods for calculating storage loss. This guide briefly describes a recommended but not fully developed method. Subsequent versions of the guide will contain a more detailed methodology for calculating storage losses.

valid estimates, two requirements need to be satisfied: (1) crops in the improved and traditional storage facilities must be of the same quality and selected in the same way; and (2) the storage facilities and practices in the demonstration sites must accurately reflect actual farmer facilities and practices (Harris & Lindblad, 1978).

The purpose is to learn what portion of the grain has remained undamaged, what portion is damaged but still fit for human consumption, and what portion is no longer edible. The point at which the grain is considered inedible may differ among different populations. Insect infestation may render grain inedible when not only are holes visible but the grain develops an unpleasant odor; likewise, when molds become visible, create an odor, or discolor the crop, the grain may have reached the point of being inedible (Reed et al., 1997).

In undertaking the study, if the crop is stored in bags, a sample of bags should be selected. Top layers, which are less prone to deterioration, should be removed so that bags in the middle and bottom layers can be accessed (Harris & Lindblad, 1978) and samples taken from each selected bag. If the crop is in the form of grain, a grain *trier* should be used (Harris & Lindblad, 1978; Reed et al., 1997). A grain trier (also called a sampler, spear, probe or bamboo) is a short pointed tube that can be inserted into a bag with minimal damage to the fibers of the bag. The grain kernels or other commodity pass through the hollow tube to be collected outside the tube (Reed et al., 1997).

The method prescribed for measuring losses is to *count and weigh* (Boxall, 1979; Harris & Lindblad, 1978; Reed et al., 1997). Once collected, the grain should be sieved and a handful of grains taken from the center of the sieve and placed on a hard surface. Then, 100 grains should be counted out. To ensure a random count, some *selection rule* should be used such as counting the grains in the order of their proximity to the person counting.

Each sample of 100 grains should be separated into (1) undamaged portions, (2) damaged but edible portions, and (3) portions unfit for human consumption that must be discarded (or fed to animals). The grains in the undamaged portion are counted and weighed, and this information used to calculate the percentage of loss represented by the remaining two portions.

Additional qualitative data should be recorded. This includes, for each sample: (1) evidence of rodent activity (e.g., fecal matter, damaged bags); (2) presence of odors; and (3) wetness or discolored areas (Reed at el., 1997).

2.2.3 Demonstration Plot Harvest

The *complete harvest* method recommended for estimating demonstration plot yields (see Chapter 2, Section 2) requires the presence of the project staff or evaluators. This is because the output, once dried, shelled, etc., must be carefully weighed and recorded (Murphy et al., 1991). This will mean that demonstration plot farmers and project staff need to agree on the harvesting schedule, keeping in mind when the crop is ready for harvesting (Murphy et al., 1991).

2.2.4 Post-Harvest Farmer Visit

The post-harvest farmer visit should take place two to four weeks after harvest. As during the post-planting farmer visit, farmer practices and input costs/crop sales should be reviewed. Data may also be collected on exclusively post-harvest issues, such as total production and storage plans.

Farmer Practices Survey (Late Planting and Harvest Season)

Similar to the post-planting visits, surveys of farmer practices will depend on the nature of improved practices that the activity seeks to promote, as well as other practices that are of key interest to activity designers and implementors. These could include practices such as weeding; insect and disease control and irrigation that are introduced during the planting season and continue while the crops are maturing; and practices specific to harvesting, such as harvesting techniques, threshing and storage, and marketing practices, as shown below:

1. Weeding
2. Insect and disease control measures
3. Irrigation and other water control measures
4. Harvesting techniques
5. Threshing
6. Storage and marketing practices

(See Section 2.2.1 on post-planting farmer practices survey for discussion of principles to be applied, as they will be the same during the post-harvest visit).

Farmer Production Estimates

During the post-harvest visit, farmers are asked to estimate their production in terms of locally understood units. Farmers should be surveyed as soon as possible after harvest to ensure accurate estimates of total production and yield (Malik, 1993). If feasible, farmer estimates should be cross-checked by visually checking the amount of crop in storage and adding that which has already been sold or consumed (Poate & Casley, 1985). Harvest times may vary considerably from region to region, as well as from crop to crop.

Local measurement units are often not well standardized and may vary considerably. This can lead to substantial errors in estimating yields. A solution is to weigh a sample of the contents of the containers each farmer uses for collecting/storing the harvested crops and multiply the average weight by the number of units harvested. However, this process is both time-consuming and subject to high measurement error (Rozelle, 1991). Moreover, it is not adequate for root and tuber crops, which are usually harvested in small portions over a long period with no standard harvest unit (Kearle, 1976). As Poate & Casley (1985) point out, estimating mean tuber weight and counting the total number of tubers from multiple harvests is "fraught with potential for error." An alternative strategy would be to provide participating households with a standard container, both as a gift for their participation and as a means to enable household members to count the number of times they fill the container in bringing the harvest to the compound (Murphy et al., 1991). This is particularly appropriate when crops are harvested in small quantities over time.

Another solution is to estimate a mean weight per unit for each crop type. This should be done by weighing a sample of five units for each crop. If little variation exists between farmers in the same area, this can be done for just a sample of the area farmers. If the units vary from household to household, which is more likely in subsistence production areas, mean unit weights need to be estimated for each household in the sample.[24] The method for weighing will depend on the equipment available and the units used by the farmers, but should be relatively straightforward.

Input Costs Since Post-Planting Visit

Input costs *since the post-planting visit*, would also be included in the post-harvest survey if "value of agricultural production" is being tracked (see Section 2.2.1 above).

Crop Sales

Crop sales *since the recent harvest* would also be surveyed if value of agricultural production is being tracked. Techniques for analyzing would be the same those for post-planting visits (see Section 2.2.1).

Storage Facilities/Crops in Storage

Monitoring the number and type of storage facilities can take place during post-harvest visits and the information used to derive information on changes in storage losses (i.e. the impact indicator). The approach for measuring storage losses will be to impute losses according to the prevalence of different types of storage facilities based on the different storage loss rates for each type of facility. Therefore, the enumerator will need to verify that farmer storage facilities are comparable not only in type but also in quality to the facilities in the demonstration storage sites.

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24. The weights of the sample units can also be significantly influenced by the moisture content of the crop, which varies over time for each farmer. Murphy et al. (1991), for instance, cites evidence from Zaire indicating that fresh maize loses over 30 percent of its weight after drying. Moisture content can be measured with a hygrometer which may be available at agricultural extension stations. Assuming that measuring moisture content may be impractical, a second-best alternative to limit moisture content biases is to ensure consistency in the timing (relative to harvest dates) of production estimate surveys from year to year.

4 Calculating Indicators

This chapter explains how to calculate the six generic agricultural productivity performance indicators listed in Table 1: crop yields per given area; gap between the actual and the potential crop yields; and yield variability under varying conditions; value of food production per household; months of food stocks; and percent of loss during storage. Some of the key issues raised in Chapter 2 regarding interpreting these indicators will be restated here.

1. Changes in Crop Yields

The general equation for calculating crop yields per area is Y = P/A, where Y is the yield per area of the crop, P is the weight of the crop harvested, and A is the size of the area planted.[25] The values for Y, P, and A will be based on yield-related data collected including farmer estimations of output and mean weights per unit (P) and land areas planted (A). The equation will be as follows:

$$\text{Yield (Y)} = \frac{\text{(Farmer estimate in local units) x (Estimated kgs/local unit)}}{\text{Estimated area}}$$

If the farmer has more than one plot for a particular cropping system (pure stand crops or crop mixtures), the total production and total area for all plots planted under each crop system should be calculated and then the yield for each cropping system determined. Separate yields should *not* be calculated for each plot and then combined.

As noted in Chapter 2, the results of this calculation will not give a convincing picture of the influence of project activities on the yield unless key environmental factors (especially rainfall) are also taken into account (i.e., staff must amalgamate rain data collected monthly from farmers and make a judgment as to how it may have affected production). Although factoring weather into changes in yield trends may require data collected annually over a period of more than five years, a shorter time series may be

25. This equation is the basis for calculating yields whether the crop cutting or farmer estimation method is used. The only difference is that in crop cutting, P and A refer only to the small areas from which the crop cuts are taken, whereas for farmer estimation yield estimates are based on the entire area planted by a farmer.

possible if yields increase while environmental conditions stay the same or become worse from one time to the next.

2. Gaps in Actual vs. Potential Yields

As explained in Chapter 3, this indicator requires two annual measurements: (1) estimates of crop yields of the sample of targeted farmers in the project area based on farmer production estimates and measurements of planted areas; and (2) estimates of yields for the same crops or cropping systems on demonstration plots, based on the complete harvesting method. The calculation is simply the difference between them.

If demonstration plots are pure stand, only farmer plots that are also pure stand should be used for comparison. Likewise, if demonstration plots are intercropped, then the farmer plots used for comparison should be intercropped with the same crop types.

The absolute value of yield gaps between farmer and demonstration plots will be influenced both by real differences in yields and differences resulting from the different measurement methods used. As noted in Chapter 2, Section 2, the complete harvest method is likely to give a higher estimate of yields. Nevertheless, because differences in yield estimates resulting from measurement differences are likely to be fairly constant over time, changes in yield gap estimates from year to year can reasonably be assumed to reflect real changes in yield gaps.

3. Changes in Yields Variability

The simplest measure to assess variability of annual crop yields within a specified time period is the *range*. The range is calculated by subtracting the lowest annual yield during the period from the highest annual yield. This would need to be calculated for each sampled farmer and disaggregated by each crop or cropping system for which the project is trying to reduce variability. Though easy to calculate, the range measure has the disadvantage of being determined only by the extreme values (with no consideration of variability in non-extreme years). In addition, it is very sensitive to *outliers*, i.e., one year of unusually high or unusually low yields greatly increases the value of the range, thus having a disproportionate influence on assessments of variability.

A more commonly used method is the *standard deviation* (SD). Its advantages are that it reflects variability among all years in the period and is less sensitive to outliers. Although its calculation is more complicated, it does not require any additional data collection effort. The standard deviation is defined as the sum of the square of the differences between yields in individual years and the average yield over the period, divided by the number of years in the period. This can be calculated quite easily by basic statistical software. The calculation is based on the following equation (see Figure 4 for an example):

$$SD = \frac{[(Y_1 - Y_m)^2 + (Y_2 - Y_m)^2 + \ .... \ + (Y_N - Y_m)^2]^{1/2}}{N}$$

KEY:

N = the number of years in the period;

$Y_1, Y_2, \ldots Y_N$ = annual yields in years 1 through N; and

Y_m = average annual yield over the period.

Changes in variability of yields can be measured by calculating and comparing the standard deviation of average annual yields between two different periods of time for each sampled farmer. For each crop or cropping system for which reduction of variability is the objective, the standard deviation of annual yields should be calculated for two different time periods (pre-implementation and post-implementation) for each farmer in the sample. Since variability in yields is likely to be strongly affected by variability in rainfall between years, rainfall data should also be collected and the range and/or standard deviations for rainfall be calculated for each period for comparison. To calculate the standard deviations for rainfall, substitute rainfall (R) for yield (Y) in the equation above.

4. Values of Crop Production

This indicator uses farmer production estimates for each crop but multiplies them by crop prices instead of dividing by area planted. The total production will be split into that which is sold and that which is not sold (e.g., crops used for home consumption, seed, feed, in-kind labor payments). The value for the crops sold will come directly from the farmer survey responses. The value of non-sold crops, whatever their use, will be estimated by multiplying the amount of the crop (minus sales and post-harvest losses) by an unweighted average of prices (discounted for inflation) between the time of harvest and the time that stocks are depleted. If post-harvest loss data is not available, another assumption would need to be made regarding the average percent of post-harvest losses for each crop. This yields the *gross* value of production; the calculation will need to be done for each crop produced. The equation for non-sold crops is as follows:

Production value = Crop sales income + (estimated production - sales) x kgs/local unit x average price/kg during period from harvest to stock depletion

To calculate an overall *net* value for household crop production, the total input costs should be subtracted from the total production value (i.e., the sum of the production value for all crops). As was the case for changes in yields and yield variability, measuring and interpreting values of household agricultural production presents many difficulties. To strengthen attribution of causes of changes in crop production values, both changes in practices and in key environmental factors (especially rainfall) should also be reported.

Figure 4: Sample Standard Deviation Calculation

	A	B	C	D	E	F	G	H
1	Year	Yield	Average yield [(B2+B3+B4+B5+B6)/5]	Difference between annual yield and average yield [B-C]	Squared difference [DxD]	Sum of squared difference [D2+D3+D4+D5+D6]	Square root of sum of squared difference	Standard deviation [G2/5]
2	1996	20	26.2	-6.2	38.44	182.80	13.52	2.7
3	1997	23		-3.2	10.24			
4	1998	21		-5.2	27.04			
5	1999	34		7.8	60.84			
6	2000	33		6.8	46.24			

5. Number of Months of Food Stocks

When the food stocks are measured in terms of *grain* self-provisions, this indicator is calculated by counting the months between harvest and household stock depletion. In the case of continuously harvested roots and tubers, the calculation is based on the number of months these are stored in the ground, although this is more difficult to assess than months in storage facilities (see Table 1).

As noted in Chapter 2, this indicator is primarily applicable in highly subsistence-oriented areas where households depend on their own production rather than market purchases for food. It is subject to the same confounding environmental factors as yield and production value.

6. Crop Storage Losses

Storage losses are calculated by multiplying differences in loss rates each month for the improved and traditional facilities/practices in the demonstration sites by the amounts of crops in storage for each facility/practice based on the survey of sampled farmers. As stated in Chapter 3, it is crucial for interpretation that demonstration site practices accurately represent actual farmer practices.

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Appendix 1
Discussion of Alternative Methods for Estimating Crop Yields

Drawing on evidence in the literature, this Appendix discusses the pros and cons of the two most common methods for estimating crop yield — "crop cutting" and "farmer estimation" — and provides a justification for the recommendation in this guide that the latter should be used. In addition, since farmer estimates of crop production need to be combined with estimates of cultivated areas, a brief discussion of the need for using direct area land measurements as opposed to farmer estimates is included.

As described in the text, crop cutting, the more traditional yield measurement method, involves direct physical measurement of area and production in one or more selected (ideally random) subplots within farmers' fields harvested by or in the presence of project staff. Farmer estimation involves surveying farmers to obtain their estimates of how much they harvested, and dividing this by estimates of how much land they planted (ideally obtained by direct land area measurements) to calculate estimated yields. The discussion below addresses the accuracy and the cost-effectiveness of the methods.

Issues regarding Crop Cutting

Accuracy

Crop cutting has been used for measuring crop production in many countries since the 1950s and has been a standard method recommended by organizations such as the Food and Agriculture Organization (FAO) (FAO, 1982; Murphy et al., 1991). For years, it was assumed that farmer estimates were too subjective and unreliable (Verma et al., 1988); when differences appeared between crop cut and farmer production estimates, the assumption was that crop cuts were unbiased and that differences reflected "farmer error" (Murphy et al., 1991). Evidence from research in the 1980s, however, questioned these assumptions. It suggested that crop cutting suffers from serious upward biases and that production data based on farmer estimation method may be just as accurate, at least for estimating total farm *production* (though, as is discussed below, not necessarily for farm yields). (See Casley & Kumar, 1988; Murphy et al., 1991; Poate & Casley, 1985; Rozelle, 1991; Verma et al., 1988).

Meanwhile, Casley & Kumar (1988) cite evidence from studies in Bangladesh, Nigeria and Zimbabwe questioning the validity of crop-cut methods. These studies also indicated that measurements of yield from crop cuts exhibited serious upward biases and had large variances due to heterogeneity of crop conditions within farmer plots. The Bangladesh study found that even in the best of experimental conditions with well-educated (Masters-degree level) enumerators, crop-cut estimates exceeded actual yields by 20 percent, whereas farmer estimates of production were lower. In the Nigerian study, however, results indicated that crop cuts and farmer estimates of yields were both biased, and the biases were of similar magnitude.

Murphy et al. (1991) summarized sources of error in crop-cut estimates of production. These errors primarily relate to biases resulting from non-random location of sub-plots and tendencies to harvest crop-cut plots more thoroughly than farmers would. All these errors result in upward biases. Although the errors may be small individually, the combination of the errors can be significant. Rozelle (1991) further notes that crop-cut techniques are frequently "poorly executed" in developing countries, even by supposedly trained personnel from technical stations. Even under highly supervised conditions with well-educated enumerators, crop-cut-based production estimates have resulted in significant overestimates of yields, as evidenced by Casley & Kumar (1988).

Cost and efficiency

Kearle (1976) pointed out various difficulties in applying crop cutting: "The farmer is requested to notify the enumerator when he plans to harvest the quadrant... so arrangements can be made for the enumerator to be present to weigh the crop(s) taken from the ground. This method of yield sampling is extremely time consuming. It is difficult to schedule the enumerator's time to ensure that he will be present for the harvest, the plot may be harvested over time for family consumption, and the enumerator may not be aware that the quadrant is to be harvested. These difficulties (are) coupled with the statistical problems resulting from the enormous heterogeneity of plots due to the spatial arrangements of crops, tree stumps, logs, termite hills, soil variability, animal damage, etc."

Farmer Estimates

Production

Given the time, cost, and difficulty of crop cuts, interest has turned in recent years to testing the validity of using farmer estimates. Verma et al. (1988) undertook one detailed methodological study that provided strong evidence in favor of farmer estimates for estimating crop *production* (though not necessarily yields). The study was undertaken in five African countries (Benin, Central African Republic, Kenya, Niger, and Zimbabwe). It tested the hypothesis that post-harvest farmer estimates of production were at least as accurate as estimates based on crop cuts on sample subplots.[26] The method involved comparing both farmer and crop-cut estimates with "actual production" figures based on complete harvesting and weighing of crops. Farmer estimates were both closer to "actual production" and had lower variances than crop-cut estimates. Whereas the *average* farmer estimates were fairly accurate, crop cuts gave overestimates that were statistically highly significant. For the five countries, average post-harvest farmer estimates ranged from 8 percent below actual production (Benin) to 7 percent above production (Zimbabwe, Central African Republic). Average crop- cut estimates meanwhile ranged from 14 percent overestimation (Zimbabwe) to 38 percent overestimation (Kenya).

A caveat in interpreting this study is that, although it provides evidence for the accuracy of farmer reports for estimating *total production of crops*, it does not necessarily mean that they are as accurate in estimating *crop yields per hectare*, which is what the Title II generic indicator measures. The reason is that to estimate crop production levels, crop-cut yield estimates must be multiplied by estimates of the area planted, whereas the farmer estimate measures production directly. Thus, crop-cut-based estimates of *production* are subject not only to measurement errors in the crop cut itself but also to errors in area measurement. On the other hand, to estimate *yields* per hectare, crop cutting becomes the direct measure, whereas farmer estimates of production must be divided by area measurements made by the enumerator. Thus the "burden" of area measurement errors (regardless of the method used for measuring areas) shifts from the crop-cutting method (in estimating production) to the farmer estimation method (in estimating yields), resulting in greater errors for farmer estimates. In short, results from Verma et al. do not directly provide evidence of the relative merits of farmer estimation method for estimating yields. What they do suggest, rather, is that, if errors involved in measuring planted areas can be minimized, these results would support the farmer estimation method for estimating yields as well as production. This underlines the need for a high degree of accuracy in area measurements to increase confidence in the validity of using farmer reports to estimate crop yields.

Poate & Casley (1985) also conclude that "under certain circumstances, farmers' estimates of their crop output...will be no more biased than crop cutting on a sample of similar size and can be collected without great expenditure of resources and skills." They observe that in certain well-defined cropping situations, carefully obtained farmer estimates can provide valid indications of the year-to-year changes in production for approximate macro-level overviews. Poate & Casley further observe that crop cutting can produce reasonably accurate results, but only if the field work is "closely supervised," and

26. The study also compared *pre*-harvest farmer estimates (at two different times) but found post-harvest farmer estimates to have both more accurate mean values and lower variance. Two methods of crop cutting were also tested — the "square method" and "row method" — and the square method was found to be more accurate. In this discussion, "farmer estimates" and "crop cuts" refer to the post-harvest and square method variations, respectively.

therefore that crop cutting may be more suitable for a detailed case study approach than for project-wide estimation of crop outputs or yields.

Yields

Rozelle (1991), in a review of six Cornell studies, considered farmers' abilities to make *yield* estimates directly and found that these varied. In study areas in China and Indonesia, farmers easily provided estimates on yields of almost all crops and could even relate differences in yields within the household's own fields to variations in cropping practices and land characteristics. Yield estimates by Filipino and Nepalese farmers were somewhat less reliable, however, and farmers in Malawi had great difficulties in providing yield estimates for most crops. The main reason was errors made by farmers in estimating areas planted, not in amounts produced.

Land Planted

Because farmers often have difficulty in providing accurate estimates of land area *planted*,[27] the general consensus is that in most cases area estimates by farmers in developing countries are highly unreliable.[28] On the other hand, when cultivated areas are measured directly or objectively by enumerators, results are considered relatively accurate and reliable. Even though this approach is more time consuming and requires more training, it is worth the extra time and cost (Belbase, 1991; Casley & Lury, 1981; Kearle, 1976; Poate & Casley, 1985; Verma et al., 1988). It is the approach called for in this guide; and if followed, it would solve the problem mentioned in the preceding paragraph regarding inaccurate farmer estimates of yields.

Given that the farmer estimation method requires less time and money for a given sample size[29] and allows for better sampling efficiency, these findings suggest that farmer estimates offer the potential for

27. It is area *planted*, as opposed to area *harvested* or area *owned*, that is relevant for transforming farmer production estimates to estimated yields. However, for transforming crop-cut yield estimates into production estimates (as would be the case, for instance, if crop cutting was used for measuring the total quantity or value of household production), area *harvested* would be the relevant area measurement.

28. Rozelle (1991) notes an exception in a China study where Chinese farmers in densely populated areas of the Yangtze Delta provided very precise estimates of cultivated area, reporting their plots to the 1/1,500th of a hectare. Conversely, Rozelle concludes from two Malawi studies that "African farmers do not know how much land they are using. As evidence of this, many local languages have no words with which to measure land area."

29. The lower cost and time for farmer estimates vs. crop cutting is presumed. Verma et al. did not actually measure the relative cost and time requirements of the two methods.

both more efficient and more accurate data collection on crop yields. A qualification pointed out by Verma et al. (1988) is that although the evidence shows "that farmers *are able* to state their production in an accurate and useable manner, it does not show that they would necessarily be *willing* to give out this information in all cases." In the Verma et al. study, the farmers were probably more motivated than usual to calculate and report accurate estimates (Murphy et al., 1991). Another caveat is that these studies looked at cereal crops (specifically, maize, millet and rice) and the results may not apply to other crops, particularly roots and tubers. Verma et al. (1988) note that further inter-country methodological studies are still needed to confirm and extend the positive findings and that such studies should include a wider range of crops, cropping patterns, farming systems, socio-economic conditions, and so on.

Conclusion

Despite the various qualifications mentioned above, the World Bank report by Murphy et al. (1991) concludes:

(1) It is not reasonable to assume that farmers do *not* know much they produce.
(2) It is not reasonable to assume that farmers will be biased or evasive in their estimates.
(3) Farmers well-motivated to make their best estimates can do so with impressive results.
(4) Therefore, "farmers' own estimates represent a valid, efficient source of data that should be used more systematically than they have been."

In addition to advantages in time and cost savings involved in the farmer estimation method, because crop-cutting surveys require more effort and must be conducted at the precise time of harvest, they require highly clustered samples. Farmer estimates, however, can be more widely dispersed (i.e., more sample areas with fewer households per sample area) because of the greater scheduling flexibility and the reduced time required. Murphy et al. (1991) calculate with hypothetical figures that the highly clustered design required of crop cuts could necessitate a sample size eight times larger than would be needed for a random sample.

Another important advantage of the farmer estimation method is that the survey of farmers on production can be readily combined with questions on other Title II generic indicators such as adoption of improved practices. Moreover, the interview method is also less intrusive and more convenient for farmers than crop cuts (Murphy et al., 1991).

Appendix 2
List of Generic Title II Indicators

Category	Level	Indicator
Health, nutrition, and MCH	Impact	% stunted children 24-59 months (height/age Z-score)
		% underweight children by age group (weight/age Z-score)
		% infants breastfed w/in 8 hours of birth
		% infants under 6 months breastfed only
		% infants 6-10 months fed complementary foods
		% infants continuously fed during diarrhea
		% infants fed extra food for 2 weeks after diarrhea
	Annual monitoring	% eligible children in growth monitoring/promotion
		% children immunized for measles at 12 months
		% of communities with community health organization
		% children in growth promotion program gaining weight in past 3 months
Water and sanitation	Impact	% infants with diarrhea in last two weeks
		liters of household water use per person
		% population with proper hand washing behavior
		% households with access to adequate sanitation (also annual monitoring)
	Annual monitoring	% households with year-round access to safe water
		% water/sanitation facilities maintained by community
Household food consumption	Impact	% households consuming minimum daily food requirements
		number of meals/snacks eaten per day
		number of different food/food groups eaten
Agricultural productivity	Impact	annual yield of targeted crops
		yield gaps (actual vs. potential)
		yield variability under varying conditions
		value of agricultural production per vulnerable household
		months of household grain provisions
		% of crops lost to pests or environment
	Annual monitoring	annual yield of targeted crops
		number of hectares in which improved practices adopted
		number of storage facilities built and used
Natural resource management	Impact	imputed soil erosion
		imputed soil fertility
		yields or yield variability (also annual monitoring)
	Annual monitoring	number of hectares in which NRM practices used
		seedling/sapling survival rate
FFW/CFW roads	Impact	agriculture input price margins between areas
		availability of key agriculture inputs
		staple food transport costs by seasons
		volume of agriculture produce transported by households to markets
		volume of vehicle traffic by vehicle type
	Annual monitoring	kilometers of farm to market roads rehabilitated
		selected annual measurements of the impact indicators