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Improving the Measurement and Analysis of African Agricultural Productivity: Promoting Complementarities between Micro and Macro Data

by

Valerie Kelly, Jane Hopkins, Thomas Reardon, and Eric Crawford

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EXECUTIVE SUMMARY

A wide variety of multilateral and bilateral agencies, private sector firms, and African governments have a need for high quality, reliable data on agricultural productivity. This paper identifies numerous situations where poor data lead to incorrect estimates of African land and labor productivity. The paper argues that better coordination of macro, meso, and micro data collection, reporting, and analysis efforts can lower costs and improve our ability to monitor trends and to quantify determinants of agricultural productivity.

Seven key points are made in the discussion:

(1) Missing or poorly measured variables used in the numerator (output) or denominator (land and labor, for example) are biasing productivity ratios;

(2) In most cases, these errors underestimate levels of agricultural productivity in Africa and distort trends;

(3) Micro data are an important source of information for identifying the existence and magnitude of these errors in macro and meso data;

(4) Information from micro data can improve estimates of productivity ratios when macro data are not available and too costly to collect;

(5) Detailed micro data sets are the best source of information on the farm-level determinants of agricultural productivity; this information contributes to the development of productivity-enhancing policies and technologies;

(6) Micro data play an important role in identifying the appropriate variables to monitor in macro and meso series;

(7) Only consistently high-quality macro data in unbroken time series can provide adequate information about productivity trends and the contribution of policy and technological change to national agricultural productivity over time.

From these conclusions it becomes evident that improving the data used to monitor and analyze agricultural productivity requires much greater cross-fertilization of detailed micro studies and broad macro-data collection and reporting efforts. As data collection and analysis costs are high, researchers and statistical services need to ensure the maximum complementarity possible among different types of surveys and data. This requires coordination among donors, government agencies, and research institutes that fund, collect, and analyze agricultural data.

Some of the key recommendations for improving agricultural productivity data and analyses are summarized below:

(1) Countries should determine for which variables they can afford to collect data in their macro time-series and insure adequate funding so the data are of a consistently high quality and available in a timely fashion from year to year.

(2) Once a country decides on a macro-survey design that it can competently handle, the institution responsible should ensure that ongoing micro surveys provide information on notable gaps -- particularly labor-use data and output of secondary crops.

(3) Agricultural data bases should be thought of as international public goods which have a value that goes far beyond the value to each individual country. This implies that foreign assistance should be used to (a) improve uniformity of macro data-collection systems and methods across countries, (b) provide supplementary funding when necessary to avoid breaks in time series due to temporary financial constraints, and (c) encourage the collection of the micro data needed to correct and supplement the macro series.

(4) The extent to which macro surveys contain variables permitting data to be separated into different groups considerably enhances the usefulness of the macro data base. To improve analysis of major farm types, for example, one can use micro surveys to identify the most important categories and then include the necessary categorical variables in macro surveys. Advances are possible in meso-level analyses without undertaking entirely new data collection efforts or considerably increasing the costs of current macro surveys.

(5) Efficiency in productivity analyses could be substantially increased if a central clearing house for agricultural data bases were created in each country. This clearing house should publish an index of data and abstracts containing key information such as variables included, time periods covered, sampling procedures and representivity, data format and software used, and a list of contacts for the people or institutions most knowledgeable about the data.

(6) Countries should find ways of using computers, electronic mail, and global positioning technologies to improve data collection and access.

(7) In the long run, the range of variables covered in macro data sets and the time dimension of micro data sets should be expanded. It would also be useful for countries to establish some type of ongoing but affordable survey that covers the entire country using a combination of single- and multi-visit components.

CONTENTS

ACKNOWLEDGMENTS . . . iii

EXECUTIVE SUMMARY . . . v

LIST OF BOXES . . . viii

Section | Page

1. INTRODUCTION . . . 1

2. PRODUCTIVITY INDICATORS . . . 3

2.1 Average productivity indicators . . . 3
2.2 Marginal productivity indicators . . . 3

3. CHARACTERISTICS OF DATA SETS USED IN AFRICAN PRODUCTIVITY ANALYSIS . . . 5

3.1 Macro and meso data . . . 5
3.1.1 Published series . . . 5
3.1.2 Unpublished series . . . 6
3.2 Micro data . . . 7

4. WEAKNESSES IN DATA AND METHODS USED TO MONITOR PRODUCTIVITY . . . 11

4.1 Underestimation of output and yields . . . 11
4.2 Underestimation of agricultural labor productivity . . . 16
4.3 Failure to examine both the physical and value dimensions of productivity . . . 19
4.4 Failure to differentiate policy-relevant groups of producers in data bases . . . 20
4.4.1 Choice of decision-making unit . . . 21
4.4.2 Differentiation across farm types . . . 21
4.4.3 Using geographic location criteria for grouping countries . . . 22
4.5 Inaccurate or missing data for technical and socioeconomic variables . . . 23
4.5.1 Measures of land quality and production externalities . . . 23
4.5.2 Rainfall data . . . 24
4.5.3 Information on the broader set of productivity determinants . . . 24
4.5.4 Price data . . . 25
4.5.5 Labor data by season and activity . . . 26
4.5.6 Capital investment data . . . 27

5. HOW CAN WE DO BETTER? . . . 29

5.1 Strategic planning issues . . . 29
5.1.1 Macro- and meso-level data . . . 29
5.1.2 Micro-level data . . . 32
5.1.3 Reducing cost through technological innovation . . . 36
5.2 Addressing the key data and measurement problems . . . 36
5.2.1 Estimating output and calculating land productivity ratios . . . 36
5.2.2 Correcting estimates of labor productivity . . . 37
5.2.3 Using the most appropriate level of aggregation . . . 37
5.2.4 Broadening the variable base . . . 38
5.3 Summing up . . . 39

References . . . 41

LIST OF BOXES

Boxes Page

1. Lessons on Mixed Cropping from Niger 14
2. Importance of Crop By-Products in Senegal and Niger 15
3. Underestimation of Agricultural Labor Productivity in Senegal 18
4. Increasing the Value Added of Intensive Micro Surveys in Senegal 34
5. Operationalizing Institutional Collaboration in Senegal 35

1. INTRODUCTION

During the last 30 years the physical, cultural, and socioeconomic environment in which cropping activities are carried out has changed in most parts of Africa. Population densities and population growth rates have increased; arable land per capita has declined; soil quality and tree cover have deteriorated; the structure of factor and credit markets has changed; and the relative importance of noncropping income has risen. African governments and donors have devoted much time, effort, and money to identify constraints, develop new technologies, and change the policy environment so that farmers can better cope with their evolving environment, thereby increasing agricultural output and productivity.

As governments implement new agricultural policies and programs, it is imperative that they accurately monitor their impact on productivity. Two types of analyses are needed: trends and determinants. Trends analysis measures changes over time in both aggregate output and the average productivity of key inputs. Determinants analysis gets behind the trends by quantifying the contribution of specific inputs, policies, and technologies to changes in output and productivity. It also examines issues of efficiency.

Poor agricultural data and inappropriate analyses can lead to misallocation of scarce resources and policy formulation that fails to resolve critical development problems. To avoid these pitfalls, statistical services and researchers must correctly measure the variables used to monitor agricultural productivity. In an effort to ensure that donors and policy makers have access to relevant and accurate analyses, we have reviewed recent productivity studies asking the following two questions:

(1) Are we using the most appropriate data and methods to monitor African agricultural productivity trends and determinants?
(2) If not, how can we do better?

The objective of this report is to inform donors and policy makers about the relative strengths and weaknesses of the data and methods used in productivity analysis. We do this by means of an in-depth, critical review of recent studies. It is our hope that this report will lead to a better application of research results and to better design of research and monitoring programs.

The productivity work we reviewed falls into three categories, labelled "macro," "meso," and "micro" studies. Macro studies use time-series data reported at the national level or aggregated to the Africa-regional level, while meso studies use national data disaggregated into a limited number of key farm types, agroclimatic zones, or administrative regions. Micro studies use cross-sectional data, which permit comparisons across different subgroups at a particular point in time, or panel data, which are cross-sectional data collected over time (typically two to five years). Time-series data are most commonly used for calculating productivity ratios (output per unit of land, for example) and tracking trends in output and productivity ratios over time. Cross-sectional or panel data are most commonly used to analyze the determinants of productivity or to calculate productivity ratios for different farm types. We discuss and compare these three broad categories of studies further in Section 3.

Variability in the data quality and analytical methods employed make it difficult for donors and policy makers to interpret, compare, and evaluate the results of productivity studies and, therefore, to monitor the impact of policies and programs. Our understanding of how well African agriculture is doing and why could be substantially improved by:

(1) clarifying the strengths and weaknesses of different types of data analyzed in productivity research, and
(2) making simple changes in how we collect and analyze data when calculating productivity ratios, estimating output and productivity trends, and modeling productivity determinants.

Although a wide range of African productivity studies has been reviewed, we draw most illustrations and recommendations from hands-on experience with recent micro-level analyses for Burkina Faso, Rwanda, Senegal, and Niger.[1] Emphasis is placed on recommendations for improvements that take advantage of complementarities between different types of data.

The most important problems identified by our review are:

(1) Underestimation of output and yields because secondary crops and by-products are not counted;
(2) Underestimation of agricultural labor productivity because the data used represent labor stocks rather than flows;
(3) Failure to use indexing methods that examine multiple dimensions of productivity (both physical and value aspects, for example);
(4) Failure to differentiate in data bases the policy-relevant groups of producers;
(5) Inaccurate or missing data for key technical and socioeconomic determinants of productivity.

These problems are not inherent to any particular type of data; however, the first three are most common in studies using macro and meso data, while the last two are equally common in all types of data. We return to a detailed discussion of each of these problem areas after reviewing definitions of productivity indicators in Section 2 and discussing the relative strengths and weaknesses of macro, meso, and micro data in Section 3. Section 4 elaborates on each of the five problem areas, using examples drawn from recent work to illustrate the points. Section 5 presents suggestions on how we can improve data collection and analyses.

[1] These country studies are reported in Savadogo, Reardon, and Pietola (1994) for Burkina Faso, Clay et al. (1995) for Rwanda, Kelly et al. (1995) for Senegal, Hopkins and Berry (1994) for Niger, and Jayne et al. (1994 and 1995) for Zimbabwe. Full citations are in the list of references at the end of this report.

2. PRODUCTIVITY INDICATORS

In empirical work, one seldom encounters the word "productivity" without a series of modifying adjectives clarifying exactly what aspect of productivity is being measured. Most measures of productivity fall into two broad groups: average and marginal. Average productivity is a simple ratio: output produced divided by the quantity of inputs used. Marginal productivity is a measure of efficiency that provides valuable information about how to increase output and profits.

2.1. Average Productivity Indicators

There are two types of average productivity measures: partial and total. The quantity of output produced divided by the amount of a single input used is a measure of partial factor productivity. Partial productivity measures do not control for the level of other inputs employed. For example, average yields per hectare reported in aggregate national statistics come from fields cultivated with different amounts of labor, fertilizer, and seed.[2] Partial productivity measures are reported in either physical units or value terms.

Total factor productivity measures attempt to control for the full range and intensity of all inputs used.[3] Total factor productivity is the ratio of an index of aggregate output to an index of aggregate input. Indices are based on monetary values; therefore, good price data are a *sine qua non* for good estimates of total factor productivity.

The reliability of average productivity indicators depends on the quality of the data in both the numerator and the denominator, as well as on the appropriateness of the indexing procedures used to aggregate dissimilar outputs and inputs. Thin markets for many inputs (land and labor in particular) and outputs (nontradable cereals such as millet) make it difficult to obtain the price data required to report partial productivity measures in value terms or to create the indices needed for total factor productivity estimates.

2.2. Marginal Productivity Indicators

Average productivity indicators provide little information on how to improve productivity; yet, this is the question that donors and policy makers want answered. Estimation of production, profit, or cost functions permits one to examine the efficiency of resource allocation using marginal physical or value products. A marginal product shows how much more gross output (or value) a producer obtains by adding one more unit of an input if the levels of all other inputs remain constant. By comparing the marginal value product to the unit cost of an input, one can

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[2] Although there are methods to control for levels of other inputs when calculating partial productivity ratios, this is seldom done.

[3] Given gaps in available data (see Section 4.5), it is clearly not possible to control for <u>all</u> inputs.

evaluate allocative efficiency and identify constraints. If the marginal value product exceeds the unit cost of an input, a producer can increase profits (i.e., become more efficient) by increasing use of that input. The challenge is to understand what prevents the producer from employing more of the "constrained" input and to develop policies that will alleviate the constraint.

To fully understand production constraints and predict how farmers will respond to various policies, one needs information on the marginal productivity of key inputs for different types of farms. African agriculture has traditionally been considered land abundant and labor constrained. There is already substantial evidence that these relationships are changing, particularly in the semi-arid tropics and highlands. Given the scenario of rapid population growth (described earlier), monitoring changes in the relative importance of land-versus-labor constraints is crucial for developing policies that will encourage African productivity growth.

3. CHARACTERISTICS OF DATA SETS USED IN AFRICAN PRODUCTIVITY ANALYSIS

In this section we describe the characteristics of existing macro, meso, and micro data sets used for productivity research in Africa, highlighting the relative strengths and weaknesses of each when used for monitoring specific aspects of agricultural productivity. The objective is to explain the general limitations of the data currently being used and lay the foundation for a detailed discussion of the five key data problems presented in Section 4.

3.1. Macro and Meso Data

Ministry of Agriculture surveys are the principal sources for macro and meso data on crop productivity. These surveys enumerate area planted and output per hectare for the principal crops grown by a representative sample of randomly selected farmers. The major strength of macro data is their ability to track changes over time; hence, they are used primarily to examine trends in total and partial factor productivity and occasionally to examine the impact of "macro" determinants (investment in agricultural research, technological change, or major policy changes, for example) on these trends.

We make a distinction between published data series (FAO or UN, for example) and unpublished data series (available directly from Ministries of Agriculture). Although the former are the data series most frequently used in African productivity studies (Timmer 1988 or Block 1993, for example), they contain much less detail than agricultural statistics available from Ministries of Agriculture. In addition, they may suffer from errors made in aggregating national statistics to inappropriate product groups or production periods (see Section 4.1). Because most productivity studies rely on published series, we concentrate on their characteristics, but point out several examples where use of complementary data reported in unpublished macro series could improve analysis.

3.1.1. Published Series

Most macro and meso series begin in the 1960s when many African countries became independent. Over time, these series have improved; they now include a broader range of products, and donor funding has provided technical assistance to improve sampling and reporting techniques.[4] Nevertheless, there remain potentially serious weaknesses in these data series: (1) the data quality is highly sensitive to random events that interrupt or impede data collection, (2) disaggregation of the data into policy-relevant groups of farmers is frequently impossible, and (3) flows of some inputs are poorly represented by stock variables (labor, for

[4] During the last 10 years, the FAO has provided technical assistance to many African Ministries of Agriculture to increase consistency in the methods used throughout the continent and improve data quality.

example) or manufacturing and import statistics (fertilizer, for example). The next several paragraphs illustrate these problems.

Senegal provides a recent example of the sensitivity of macro series to random events. Budgetary problems in 1993 forced the Ministry of Agriculture to eliminate field measurements. Thus, national production estimates were based on informal farm interviews and past trends (Government of Senegal, Ministry of Agriculture 1994). Such "disturbances" in the data series pose serious problems for those monitoring changes in productivity, particularly when there is no documented explanation about the "disturbances."

Similar problems occur when methods are intentionally modified to improve data quality. Using both old and new methods for a number of years could help analysts separate real from apparent changes in productivity, yet resources are seldom adequate to maintain two data series, even for a short time.

Published macro data rarely includes variables permitting disaggregation by agroclimatic region, farm type, or product; data are reported at the country level for commodity aggregates only. Principal crops reported reflect an international rather than an African perspective -- products which are quite important in some parts of Africa are either ignored or combined with other commodities. Cowpea data provide an example; FAO formerly reported cowpeas as an individual crop, but now combines them with other crops in an aggregate "pulse" category.

Published data on variable inputs (fertilizer and pesticides, for example) come from information on imports or manufacturers' sales. These data do not reflect actual farm use (imports, for example, may not be purchased by farmers in the year of import). They also fail to show which types of farms used the fertilizer and on what crops. Capital investments in agriculture are represented by the number of tractors -- not a very useful variable for Africa where animal traction is the most common means of mechanization.

Labor-use data (flows) are totally absent in published series. Instead, census data on the number of people "economically active in agriculture" (stocks) are reported and used as a proxy for labor flows (see Section 4.2).

Published data report "world" prices for key commodities rather than country-specific prices faced by producers. This poses serious problems when analyzing crops such as millet, which are not traded in international markets, or crops subject to government price controls.

3.1.2. Unpublished Series

Unpublished national data series often contain variables permitting disaggregation by administrative region. Although some national statistical services distinguish between farm types, if vastly different production systems exist (smallholders versus commercial farmers in Zimbabwe, for example), this is rare. Cost is a major factor hampering the collection of data on variables permitting disaggregation to the meso level. To obtain broad national coverage, one needs a large and geographically dispersed sample. As large samples are expensive, statistical services contain costs by limiting the range of variables covered.

Unpublished national agricultural statistics usually have better data than published series on domestic prices faced by farmers, on input use, and on capital investments. Price data are available for key crops, but prices reported (particularly prior to the 1980s) often reflect official rather than market prices. These prices often differ markedly.

Senegal provides an example of the types of supplementary input data available from unpublished national sources. Quantities of fertilizer used come from manufacturers' and distributors' reports. They can be disaggregated by the type of fertilizer (which often provides a rough indication of the crop for which the fertilizer was used), type of distributor (private versus public sector), and administrative region where sold. However, these data do not provide information on the types of farmers using the fertilizer, exactly which crops receive treatment, and prevailing application rates. Data on industrially manufactured animal traction units sold are available from the parastatal agencies that provide credit; however, data on purchases of equipment manufactured by local blacksmiths are not available. To the best of our knowledge, no macro or meso data on labor use (flows) is collected.

These examples of the unpublished input data available in Senegal may not be typical of the data available in other countries. The point to note is that there are more macro and meso data available than what is reported in published sources. Macro and meso analyses could be considerably improved if these unpublished sources of data were more readily available and used by analysts.[5]

3.2. Micro Data

This discussion focuses on micro data obtained from surveys using statistical sampling techniques. We treat nonstatistical surveys such as rapid rural appraisals, focus groups, or case studies as an important complement to statistical surveys because they improve our understanding of the dynamics behind observed behavior. As they do not provide the input/output data necessary to quantify productivity trends and determinants, they cannot serve as primary sources of data for productivity analysis.

Productivity researchers in Africa have not used micro survey data as extensively as their Asian counterparts. Several factors make it more difficult to ensure high quality data and more costly to conduct micro surveys in Africa. Education levels of farmers, field staff, and researchers are lower in Africa than Asia. In many African countries, illiteracy is the rule for the current generation of rural household heads, while their Asian counterparts average about 2-3 years of

[5] USAID/Senegal's 1991 agricultural sector analysis is a commendable step in this direction. It includes extensive data annexes that make a substantial amount of unpublished production and input data available at both the macro and meso levels. The next logical step is to make it available on diskette.

primary school.[6] Higher literacy rates for farmers can contribute substantially to data quality, as literate farmers can keep notes about details that are difficult to recall and even fill in questionnaires. The typical level of education for African field staff conducting farm interviews is six to nine years of formal schooling; our review of Asian literature suggests that interviewers there have completed high school and, in some cases, attended university. Compounding these problems is the paucity of African agricultural researchers, both absolutely and relative to the agricultural population.[7]

African survey costs are higher than elsewhere due to lower population densities, higher transportation costs, and higher salary costs for field staff and researchers.[8] Due to high costs, sampling frames in Africa usually combine purposive selection of zones or villages with random selection of households within the zones or villages (the Rwanda survey is a notable exception, as it is a micro study that covers the entire country). Although the statistical justification for generalizing the results of a purposive sample beyond the immediate zones or villages is weak, supplementary reconnaissance surveys can provide guidance on how representative the selected villages and zones are of others in the country (see Diagana et al. 1993). In addition, judicious use of complementary nonstatistical surveys can have a high payoff and substantially increase the value of the data obtained in the statistical sample (see section 5.1.2 and Box 4 for further discussion).

Micro surveys can be divided into two types: single or multiple interview surveys. Single interview productivity studies use long recalls to obtain household-level input and production data or information on farmers' knowledge, attitudes, and practices (known as KAP surveys). The strength of single-visit-surveys is that they can be rapidly analyzed. The loss of accuracy in input and output data collected using long recalls, however, often outweighs the benefits of rapid analysis and reporting. Norman et al. (1995) point out that the distinction between "single points registered" and "continuous non-registered" data is a useful one to keep in mind when designing surveys and determining appropriate recall periods. Complementing single visits on certain variables with multiple-visit data for others could reduce the overall cost of micro surveys. In choosing a single or multiple visit survey, one must consider the nature of the research question and how accurate the data need to be to answer that question.

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[6] Only 6 of approximately 250 household heads in the IFPRI/ISRA study in Senegal had any type of literacy training in either French or one of the local languages (Kelly et al. 1993). By contrast, the average level of schooling was 2 years in a study of Indian farmers' attitudes about risk (Binswanger 1980).

[7] Pinstrup-Andersen and Pandya-Lorch note that sub-Saharan Africa has only 42 agricultural researchers for each one million persons reporting agriculture as their principal economic activity; the comparable number for industrialized countries is 2,458.

[8] In many cases, the higher salary costs are related to overvalued exchange rates which make African salaries higher when converted to US dollars; one cannot conclude, therefore, that the real incomes of African researchers and field staff are higher. Evenson (1987) and McIntire (1983) both discuss the higher costs for micro surveys conducted in Africa.

If, for example, an analyst seeks rough estimates of output and is not concerned about relating quantities of output to precise amounts of land and labor used, a single interview at the end of the cropping season may suffice. On the other hand, if a researcher is investigating the hypothesis that labor is a more important constraint than land, or wants to estimate potential increases in productivity if a labor constraint is eliminated, detailed and accurate labor and land data wil be necessary. Only a multi-visit survey can provide the detail and accuracy required for such a study. Teklu (1993) reviewed some of the alternative survey methods used in recent IFPRI time- and labor-use surveys suggesting that more work is needed to fine-tune these methods and reduce costs of collecting labor data.

It is also important to consider the relative costs of different data collection methods and frequencies. Using cost data for six ICRISAT and CIMMYT surveys reflecting different data collection intensities, McIntire (1984) found that the overall cost per sampling unit differed little between the intensive and extensive methods.[9] However, he notes that if the costs of internationally recruited staff are excluded, extensive methods would be less costly.

Scherr and Vosti (1993) present a detailed discussion of cost/benefit tradeoffs in survey work. They make the point that when assessing the optimal level and type of investment in data collection, one must consider the cost of <u>not</u> collecting relevant data. If, for example, data are collected for policy analysis, the cost of omitted variables is the lost value of improvements in policy design that would result from the data.

Multiple interview surveys consist of field- or household-level observations collected at specified intervals. Examples encountered in our review ranged from as frequently as two times per week to as seldom as once every season. Multiple visit surveys can generally be <u>dis</u>aggregated by agroclimatic zones, producer characteristics (farm size or type of technology, for example), or field characteristics (soil type or gender of producer, for example). This disaggregation makes it possible to study the characteristics of farms with high or low productivity, and use this information to design and target productivity-enhancing programs. It also allows studies of equity and distributional issues that cannot be addressed by aggregate national statistics.

Most multiple-visit farm surveys fully enumerate quantities of agricultural inputs and outputs by field or household. Price information is obtained by enumerating input purchases and output sales; these "transaction-derived" prices may be supplemented by market surveys. If information about noncropping activities is also enumerated (food consumption patterns, household consumption expenditures, income from livestock and nonfarm activities, and so forth), the data set permits one to look at interactions among the full range of household activities. Multi-visit micro data lend themselves to a variety of narrow productivity analyses (estimation of crop and whole-farm production functions, crop budget calculations, and linear programming models) as well as to broader analyses of household consumption and supply

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[9] Intensive surveys are multi-visit surveys that collect detailed input-output data at the household level. Extensive surveys are more qualitative, using rapid reconnaissance techniques combined with a limited number of in-depth surveys to confirm the reconnaissance results (McIntire, pages 71-72).

behavior. Analyses using micro data provide answers to questions regarding the underlying determinants of agricultural productivity that simply cannot be answered by tracking trends with macro and meso data.

Given the short duration of most farm surveys (typically 1 to 5 years), they are seldom a source of information on trends and can rarely be used alone to evaluate the long-run impact of research investments, technology, or macro-economic policies.[10] If repeated once a decade, as was done in North Arcot, India, micro surveys can provide valuable, detailed snapshots of a region over time (Hazell and Ramasamy 1991). The short duration of most micro surveys also makes them vulnerable to random events or atypical producer behavior. For example, we were unable to analyze the productivity of fertilizer in Senegal because use declined so much in the late 1980s that sample farmers applied no fertilizer to principal crops during the survey period. In addition, farmers boycotted cotton production, making it impossible to study cotton in one of the survey zones and severely limiting the number of observations in another (Kelly et al. 1993). Despite these shortcomings, multi-visit micro surveys remain the only source of data for analyzing the combined impact of technical and socioeconomic variables on agricultural productivity. Without farm survey data, our understanding of agricultural productivity will be limited to what happens in agronomic trials, where technical variables are set at prescribed levels and socioeconomic factors do not interact with technical variables.

[10] A notable exception to this general rule is Rwanda, was in its ninth year of a multi-visit survey when civil disturbances brought it to a halt.

4. WEAKNESSES IN DATA AND METHODS USED TO MONITOR PRODUCTIVITY

In this section we expand on the five most important weaknesses in data and analysis methods identified by our review of recent productivity work. We describe situations where these problems are most likely to occur and present examples from recent MSU and IFPRI micro studies, conducted in collaboration with African research centers, to illustrate the magnitude of potential biases.

4.1. Underestimation of Output and Yields

As explained in Section 2, productivity indicators are ratios of output divided by inputs. If output is underestimated, total and partial factor productivity are underestimated. If any input is overestimated, the partial productivity of that input is underestimated. Micro data available suggest that underestimation of output can reach 50 percent in areas where:

(1) mixed cropping[11] is common,
(2) crop by-products are not enumerated,
(3) crops are home consumed or used as inputs to other household production activities, or
(4) farmers have diversified strongly into new products that are poorly enumerated in national surveys.

The issue of mixed cropping is not new in African production analysis. In the 1970s, researchers identified as many as eight different products grown in mixtures in the middle belt of Nigeria (Norman, Simmons, and Hays 1982). Dommen (1988) provides an excellent review of mixed-cropping research. Much of this early work focused on the motivations for planting mixed-rather than single-cropped fields -- risk aversion, labor constraints, or higher profits (Norman 1973a, Abalu and D'Silva 1979, Just 1981, Just and Candler 1985, for example). The potential for underestimating national production by not fully enumerating mixed fields did not receive much attention in earlier work.

Recent research suggests, however, that the danger of underestimating national output and yields due to mixed cropping can be high (Hopkins and Berry 1994). Bias is introduced into national or FAO statistics if:

(1) output and yields are based on data from only single-cropped fields,
(2) only the principal crop on a mixed field is enumerated,

[11] We use the term "mixed cropping" in a general sense to cover all the various situations where more than one crop is grown on the same field (intercropping, sequential cropping, relay cropping, and so forth).

(3) the outputs of two or more crops grown on the same field are enumerated using the entire field size for the denominator in the yield calculations for each crop,[12] or

(4) methods of aggregating data into annual observations do not properly account for either sequential cropping or growing cycles that exceed a single calendar year.

Recent micro studies in Rwanda, Burkina Faso, Senegal, and Niger reported mixed cropping in each country. In Senegal, it was relatively rare in the survey zones and thus was not analyzed. The rarity is probably related to the extensive use of animal traction for seeding, weeding, and harvesting; animal traction could not be used as effectively, particularly for seeding and weeding, if mixed cropping were common.

In Burkina Faso, where mixed cropping is common, Savadogo, Reardon, and Pietola et al. (1994) aggregated the output of intercropped fields into cereals (the principal crop) and pulses (the secondary crop). They found that the value of the "secondary" pulse crop rarely exceeded 2 to 3 percent of the total value of output per hectare. As there is no active market for peanut hay in the survey zones, and cowpeas are grown primarily for the seeds, the authors believe that valuation of this hay would not substantially change the relative importance of cereals in the crop mixture.[13] Although enumerating only cereals on intercropped fields in Burkina Faso captures about 97 percent of the value, ignoring the pulses means that a crop grown by virtually all households is absent from aggregate statistics.

In Niger, intercropping is the dominant agricultural practice. Intercropped fields in the IFPRI/INRAN data set have up to six crops per field. Hopkins and Berry (1994) report that cereal (millet or maize/sorghum) is the principal crop for 64 percent, and pulse (peanuts or bambara nuts) for 36 percent of the intercropped fields. If just the principal crop is enumerated on an intercropped field, the value of output captured represents only 74 percent of the total value produced per hectare and only 72 percent of the total value produced per labor day. Enumerating both the principal and secondary crops, however, captures 90 percent of the output value per hectare and per labor unit.[14] These findings illustrate the importance of accounting for more than the principal crop on intercropped fields, and suggest that the magnitude of underestimation bias could be significantly reduced by enumerating at least the two principal crops. Box 1 provides more detail on the Niger intercropping analysis and results.

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[12] The 1993 FAO *Production Yearbook*, for example, acknowledges in the introductory notes that this is a problem with their yield estimates for dry beans: "In certain countries where a considerable amount of dry beans is grown mixed with other crops, area data are clearly overestimated and yields per hectare consequently appear rather low" (FAO 1994, page *x*).

[13] Comments are based on personal communication from Savadogo. He notes that the per-kilogram-value of cowpea seed is substantially greater than that of millet. The high producer price for grain provides the primary incentive for planting cowpea; the fodder production, which is largely home consumed, is a secondary incentive.

[14] Note that the definition of "secondary" crop for the Niger study differs from the Burkina Faso study. Each cereal crop was considered a separate crop by Hopkins and Berry; therefore, both the principal and the secondary crops are frequently cereals in Niger.

In Rwanda sequential cropping (one crop following another during the same year on a given plot of land) and intercropping (several crops planted at the same time on the same plot) are common. Although the potential for underestimating output is high because mixed and sequential cropping are common, surveys to collect national production data enumerate all crops and use measures of relative crop densities to determine how much land is occupied by each crop. The "density method" is not without its problems (particularly when there is a random rather than a systematic distribution of crops within the mix), measuring crop densities has the advantage of providing product-specific yields.

Data collection and analysis methods used in Niger do not permit the disaggregation of crops within mixtures. For example, there is no way to say what the yield per hectare is for millet grown in a mixture versus millet grown in a pure stand because there is no estimate of millet's share of land in the mixed field. Although progress has been made in developing methods for assessing crop densities and yields for both systematic and random crop mixtures, researchers and statistical services need to consider the research question at hand, as well as the cost and feasibility of getting accurate density estimates, before adopting these procedures (Norman et al. 1995).

Another source of downward bias in aggregate production statistics is the failure to account for crop by-products. There is a tendency for agricultural statistics services to ignore by-products used for construction (millet stalks) or animal feed (hay). Even micro surveys do not often fully account for these by-products because they are difficult to quantify and value. During the last decade, commercial marketing of by-products has increased considerably in countries such as Senegal (peanut and cowpea hay) and Niger (cowpea hay), making it easier to value them. Crop budgets presented in Martin (1991) show that peanut hay accounts for 39 to 47 percent of the gross value of output from peanut fields in Senegal's central Peanut Basin. Micro-survey data for Niger show that cowpea hay accounts for 35 to 59 percent of the gross value of cowpea output when cowpeas are produced as part of a mixed-cropping enterprise (see Box 2 for more details). Given current concerns about loss of organic matter in African soils, monitoring the production, disposition and value of crop by-products will become increasingly important over time.

Another problem is the failure to enumerate crops that serve as inputs to other production processes (fodder crops consumed by dairy cattle, manure), or farm production that is not marketed (milk products, produce from kitchen gardens, some cereals). Failure to enumerate these products underestimates agricultural production at the macro level. At the micro level, a failure to examine the full range of farm activities and their complementarities can lead to incorrect conclusions about profitability and the rationality of farmers' production choices.

A final source of downward bias in aggregate statistics on agricultural output is the failure to fully enumerate new crops when farmers begin to diversify into products such as fruits and

Box 1

box 2

vegetables. So far, the evidence suggests that the production of fruits and vegetables in rural areas accounts for a relatively small share of household income and total value of crop production (with the exception of a few zones that specialize in horticulture). Nevertheless, fruit and vegetable production is being encouraged in many drought-prone areas as a way of reducing risk and smoothing annual income streams. As this type of production grows in importance, aggregate estimates of agricultural output will have to pay more attention to it.

4.2. Underestimation of Agricultural Labor Productivity

Agricultural labor productivity ratios should be estimated as the quantity of output (the numerator) per unit of labor used (the denominator). The key point is that the denominator should represent flows (labor used) rather than stocks (labor available). To compute labor productivity at the macro level, an estimate from the FAO *Production Yearbook* of "all economically active persons engaged principally in agriculture, forestry, hunting or fishing" from the FAO *Production Yearbook* is used in the denominator.[15] This denominator is a poor proxy for the labor actually used because:

(1) in most studies of agricultural productivity, the numerator includes crop production only, while the FAO denominator includes persons working in livestock, hunting, fishing, and forestry;
(2) those in the denominator may work anywhere from 3 to 12 months of the year in cropping activities, with 6 months or less being typical in much of Africa;
(3) those in the denominator may devote substantial time during both the cropping and noncropping season to noncropping activities;[16]
(4) procedures used to account for female labor may not adequately or consistently account for the time devoted to housekeeping versus agriculture;
(5) children's labor is not included in the denominator.

The following examples illustrate problems created by using stock data, and suggest simple ways of adjusting the data so that they better represent flows.

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[15] FAO does not tell us exactly how one determines if a person is "economically active in agriculture," but our understanding is that these numbers come from national census data where the interviewer asks what the respondent's principal occupation is. Our experience has shown that rural households declare agriculture as their principal activity even when survey data reveal that 50 percent or more of the household's income comes from noncropping activities (see, for example, Diagana et al. 1993).

[16] The focus of this paper is on agricultural productivity, thus we concentrate on how use of FAO data overestimates the denominator, causing underestimation of agricultural labor productivity. An alternative approach would be to look at rural labor productivity in general. In this case, one would need to (1) adjust the numerator so that it included output of all rural farm and nonfarm activities, and (2) broaden the denominator so that it included all economically active rural persons. Even with these adjustments, the ratio would only provide a rough approximation of "labor productivity" because the denominator would still be a "stock" rather than a "flow" variable.

When estimates of agricultural labor productivity use only crop production in the numerator, but include individuals (who are full- or part-time herders or fishermen) in the denominator, productivity of cropping labor will be underestimated.

In areas with irrigation, sequential cropping, or perennial crops, farm households, may engage in cropping activities most of the year. By contrast, in areas of the Sahel, the cropping season is only three to four months. In both situations, all farmers receive equal weight in the FAO enumeration of persons "economically active in agriculture," without adjustment for the labor time actually devoted to agriculture during the year. A more correct comparison of agricultural labor productivity across such different zones would deflate the denominator for the Sahelian zone by 66 to 75 percent simply to account for differences in the length of the cropping seasons.

To more fully adjust the FAO denominator, one would need to account for all time during the agricultural season that "economically active" persons did not work in cropping because of other income-generating activities or leisure. Information to make these adjustments may be available in countries with multi-visit micro data; informal surveys may also provide rough estimates of the time devoted to cropping versus other activities.

In Rwanda, where cropping is a year-round activity, micro data show that noncropping income accounts for 20 percent of total income. This suggests that both cropping and noncropping labor are included in FAO stock variables, resulting in underestimation of cropping labor productivity. Unfortunately, labor data are not available for Rwanda to estimate the degree of bias introduced. However, micro data for Senegal can be used to correct for both a short growing season and substantial noncropping activity (see Box 3). Our calculations suggest that adjusting for these two factors can increase labor productivity estimates by two to seven times those obtained with FAO methods.

Although using FAO "economically active" stock data is most problematic in calculating levels of labor productivity, trend analyses are also affected when using these data if the share of labor used in cropping and noncropping activities has changed over time. Although no data on changes in the relative share of household labor allocated to cropping and noncropping activities is available, there is evidence that the share of income derived from noncropping activities is increasing. Earlier studies generally reported noncropping income shares in the 25 to 30 percent range (Matlon 1979, Haggblade et al. 1989). A review of more recent studies by Reardon et al. (1994a) reports shares from 31 to as much as 83 percent. The implication is that the share of labor devoted to cropping is declining as more attention is given to noncropping activities. These changes are not captured by FAO labor stock data.

There is an extensive literature on the role of African women in agricultural production and issues of correctly measuring and weighting labor time for different gender and age groups (Dixon-Mueller 1985, for example). Much of that literature goes well beyond the scope of this paper. The point that needs to be made here is that women's roles in African agricultural production is not uniform across the continent, nor within individual countries. In some cases, women

box 3

provide most of the agricultural labor (parts of Zambia and South Africa, for example), while in others, they provide no more than half (parts of Senegal and Niger, for example). In each society, some women are able to devote most of their working hours to cropping activities because they have limited domestic responsibilities, while others spend most of their time cooking and caring for children. There is an urgent need to reduce the rhetoric about "the" role of women in African agriculture, and collect data that permits us to better understand the diversity that does exist and how it affects cropping productivity.

FAO data sets do not even differentiate at present between labor supplied by men and by women, so suggesting that they tackle the issue of differentiating among different types of women is asking a great deal. Nevertheless, it appears to us that uniformly counting all female farmers is more problematic than uniformly counting all male farmers. For example, most rural women in Senegal consider themselves farmers, and would thus fall into the groups "persons economically active in agriculture"; yet factors such as ethnic group, polygamous versus monogamous marriages, number of children, caste, and degree of participation in noncropping activities can substantially influence the amount of time actually spent in farming activities. Some women may devote only a few hours per week to cropping, while others are in the field from sunrise to sunset. It is not clear to what extent the census data used by FAO differentiates between female "farmers" who are primarily housewives and those who are primarily farmers. To the extent that this distinction is not made, African labor productivity for cropping activities will be underestimated.

4.3. Failure to Examine Both the Physical and Value Dimensions of Productivity

Individual farms and nations produce a variety of products using a number of different inputs. To evaluate the overall productivity of a farm or nation, one needs aggregate measures of both inputs and outputs. A variety of indexing methods are used to accomplish this (Capalbo and Antle 1988).

The implications of using different indexing methods are not always well-understood. Of four recent studies examining trends in total and partial factor productivity at the national and Africa-regional level, three (Antle 1983; Timmer 1988; and Craig, Pardey, and Roseboom 1991) found that productivity generally declined from 1960 through the 1980s (although there was some positive growth during the early 1960s and again in the 1970s). The fourth study (Block 1993) found that total factor productivity increased in the 1960s, dropped during the 1970s and early 1980s, then rose again from 1983 through 1988. In the next few paragraphs we explain why the studies produce conflicting results and discuss the implications.

The choice of a price-based index versus one measuring output in physical units strongly influences a study's results.[17] The three studies showing declining productivity through the end

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[17] Trend analyses of total factor productivity are also strongly influenced by (1) the choice of beginning and ending years for the time period analyzed, and (2) the methods used to account for climatic effects. The latter issue is discussed in Section 4.5.

of the 1980s used price-based procedures to index the output of more than 40 commodities so they could be added together in one measure of total output-per-country-per-year. Price-based indices are extremely sensitive to overvalued exchange rates or changes in exchange rate policy. If a devaluation takes place, for example, the export value (reported in local currency) of output for a crop such as coffee increases, even though the physical output (measured in kilos) may remain the same. Price-based indexing cannot separate increases in the value of output from increases in the quantity produced.

The fourth study (Block 1993) converted all output to physical "wheat equivalents," thereby removing the effect of prices and exchange rate policies to obtain a "pure" physical productivity effect. Block's results suggest that the agricultural sector is now responding to many of the recent structural adjustment initiatives because both land and labor productivity are generally increasing.

It appears prudent to consider results based on "physical" indexing methods as complements to, rather than replacements for, results using price-based indices. We recommend this for two reasons: (1) there is continued debate in the literature about the theoretical foundations of the "wheat units" approach, and (2) ignoring changes in "agricultural productivity" due to prices and exchange rates can be an important omission, particularly if farmers respond more to changes in value than changes in physical productivity.[18]

4.4. Failure to Differentiate Policy-Relevant Groups of Producers in Data Bases

All analyses require some level of aggregation over units of observation. Examples are averaging over time (years), over crops (cereals, pulses), over space (agroclimatic regions, countries), or over decision-making units (individual farmers, households, firms). Decisions concerning the appropriate level of aggregation to use when collecting and analyzing data need to be consistent with the technical or policy question being addressed. For example, trends analysis showing changes in agricultural productivity growth rates for Africa may help financial institutions and donors evaluate regional programs, but it does not provide the Minister of Agriculture with useful information about how well Niger is doing or how productivity can be improved. At the farm level, estimating crop-specific rather than whole-farm production functions can provide valuable information about household resource allocation and how the productivity of inputs differs across crops (examples are found in Massell and Johnson 1968, Tench 1975, or Wolgin 1975).

There is a clear tradeoff between the level of aggregation and costs. If, however, productivity analyses are to provide policy-relevant information, they must be based on data that represent (1) the relevant decision-making unit, and (2) a homogeneous group of the relevant decision-making units.

[18] Getting into a discussion of the debate concerning the theoretical foundations of the wheat units approach is beyond the scope of this paper. Block (1993) presents an overview of the debate, and details of the critique are reported in Rao, Sharma, and Shepherd (1991).

4.4.1. Choice of Decision-Making Unit

Production functions for Senegal estimated with household level observations suggest that household heads could increase productivity by switching some labor from peanuts to cereals. The implicit assumption when using the household as the unit of observation is that it acts as a single decision-making unit, allocating resources to maximize total household income. In fact, many crop production decisions (particularly labor use and the purchase of variable inputs such as seed and fertilizer) are made by individual members of the household trying to maximize income from their personal fields, rather than total household income. Decisions about labor allocation in the Senegalese example are part of a multi-layered process which cannot be fully captured in a single household production function, yet modeling the decision-making process for each individual field or category of producer within the household is also not a feasible solution.

Our conclusion is that results from household-level analyses need to be considered in a broader (generally more qualitative) framework that provides information about factors influencing resource allocation within the household -- the kind of information that is lacking in macro and meso studies but can be obtained from multi-visit micro studies or KAP surveys of farmers' knowledge, attitudes, and practices.

4.4.2. Differentiation Across Farm Types

Many policies, extension messages, and marketing initiatives are more cost-effective when they can be fine-tuned and targeted to particular segments of the population. To improve our ability to target policies and messages, we need to know more about the productivity of different types of farms.

Recent work in Zimbabwe provides an illustration of the problems posed when meso-level data do not include the variables that would permit differentiation of the major farm types (Jayne et al. 1995). Although the distinction is made between smallholders and commercial farmers in Zimbabwe's meso data series, there is no effort to further subdivide the commercial sector into ranchers and crop farmers. Given the important differences in how these groups use land, labor and capital, the aggregate input/output data (and marginal products estimated from them) represent a strange amalgam that is neither rancher nor cropping specialist. Had it been possible to disaggregate the input/output data into the farms specializing in ranching or cropping, constraints specific to each group could have been identified. This information is needed to focus technology development efforts and design effective policies to boost productivity.

One must also exercise caution in using highly aggregated data to study efficiency and to identify the determinants of productivity in countries that appear to have more homogeneous farming systems than Zimbabwe. Earlier work by Shapiro (1973) and Mijindadi (1980) showed that different groups of farmers often operate on different production functions. Our Burkina Faso analysis, which differentiates between farms using and not using animal traction, shows that the animal traction group realizes higher returns to both land and labor (Savadogo, Reardon, and Pietola 1994). Our Senegal analysis, which estimated separate production functions for high- and low-yield farms, shows that high-yield farmers could increase their productivity considerably by using more fungicide, while low-yield farmers could benefit more from additional peanut seed (Kelly et al. 1995).

4.4.3. Using Geographic Location Criteria for Grouping Countries

The problem of interpreting results that aggregate dissimilar farming units has a counterpart when one does Africa-regional analyses that group several African countries. There is a tendency to group countries by geographic location (West Africa, East Africa, etc.) when studying agricultural productivity. As noted earlier, grouping large numbers of countries gives us a picture of "average" performance, but hides important information about which countries are doing well and which ones are not. Another problem is that grouping countries by geographic area can produce misleading results if key socioeconomic variables that differ across countries in the same geographic area are not included in the analysis.

A comparison of results reported in Block (1993) and Block (1994) illustrates the problem. In both cases, Block wanted to quantify the impact of research investments on agricultural productivity. In analyzing countries that had been grouped by geographic area (with no control for different exchange rate policies). Block (1993) found that investments in research explained only a very small share of the productivity growth in all regions but Eastern Africa. Block (1994) found, however, that research investments and exchange rate policies accounted for two-thirds of the total factor productivity growth. He believes that the 1994 analysis, which eliminated the geographic groupings (each country was entered as a separate observation) and controlled for differences in exchange rate policies, was better able to evaluate the contribution of research to productivity.

The message is that many factors other than geographic location influence a nation's agricultural productivity; care must be exercised to include these other factors in analyses to avoid incorrect conclusions about the influence of geographic location.

4.5. Inaccurate or Missing Data for Technical and Socioeconomic Variables

Many productivity analyses produce incomplete or incorrect results because key technical or socioeconomic variables are missing that influence trends or act as determinants of productivity. Data for some of the key missing variables are already being collected, but simply not in a "user-friendly" form available to researchers and analysts (rainfall, policy changes, and prices, for example). In other cases, greater effort needs to be made to develop cost-effective ways of collecting the data (labor flows, for example), including the development of new methods for measuring some of the more difficult variables (nonfarm labor allocation and costs associated with production externalities, for example).

4.5.1. Measures of Land Quality and Production Externalities

Designing policies to encourage the development and adoption of agricultural technologies that improve yields without degrading fragile African soils is extremely important, given growing evidence that land constraints are increasing. Lack of data on soil characteristics, however, limits our ability to (1) control for soil quality when measuring the productivity of different technologies, (2) monitor changes in soil quality over time, and (3) quantify the negative externalities of policies or technologies that lead to soil and general environmental degradation.

In Rwanda, data on plot characteristics permitted Clay et al. (1995) to quantify the impact that soil erosion has on yield and aggregate output. In Senegal, information on farmers' perceptions of their soil quality relative to that of their neighbors eliminated some false hypotheses that we had about poor soil quality pushing farmers into nonfarm activities (Kelly et al. 1995).

There is a need to develop a set of soil quality indicators that can be collected at a reasonable cost so that soil degradation and its effect on output can be quantified and monitored. The conventional wisdom of the past has been that collecting data on soil quality is a luxury that Africa cannot afford. Failure to monitor this precious resource, however, may have a higher price tag in terms of lost productivity than the foregone studies required to develop base line data and monitoring indicators.

There are numerous examples of production externalities in Africa that are detrimental to the environment. Failure to leave crop residues on a field or removal of trees to facilitate use of animal traction are practices which encourage wind erosion. Cutbacks in fertilizer credit and subsidies reduce farmers' ability to intensify thereby encouraging expansion to marginal lands. Although the use of fertilizers and pesticides is relatively low in Africa, the potential for pollution from the increased use of these products is also an issue that merits attention. A great deal needs to be done to quantify the indirect costs and benefits of such policies and cropping practices; collecting data on soil characteristics is a first step. A failure to examine these externalities could lead to the promotion of agricultural practices that are not sustainable in the long run. The comment by Scherr and Vosti mentioned earlier about the necessity of considering the costs of not collecting certain data is particularly relevant in this case.

4.5.2. Rainfall Data

In an environment where output is highly dependent on rainfall, it is difficult to draw any conclusions about causality in either cross-section or time-series analyses without first controlling for rainfall. Unfortunately, methods for doing this remain rudimentary. Block (1993) uses five-year averages rather than annual observations to estimate total factor productivity. This reduces (but does not eliminate) the influence of inter-annual rainfall variation on his overall results. Gersovitz (1987) discusses difficulties encountered when modeling the effect of rainfall on aggregate production in Senegal. Other African studies simply ignore the issue (Masters 1994, for example).

More progress has been made in modeling the relationship between climatic risk and agricultural productivity in India, where both detailed rainfall data and unusually long panel data sets (10 years or more) are available (Herdt 1972 or Rosenzweig and Binswanger 1993, for example). The utility of these types of analyses should be considered when evaluating the costs and benefits of multi-year household surveys in Africa.

While it is clear that there is a need to improve our ability to use rainfall data, there is also a need to improve data. Many countries collect rainfall data that can be disaggregated by region. The data available include total millimeters of rainfall per year and sometimes information on the distribution of rain during the season (number of 10-day periods without rain, for example). The major constraint on the data side appears to be the lack of a systematic approach to centralizing the data from various regions and making it available in its disaggregated form (i.e., by collection point and day), so that analysts can develop indicators of both rainfall levels and distribution.[19]

Until rainfall data are generally available and researchers have developed adequate methods of analysis to control for rainfall, debates about the relative impact of technological innovation, nonfarm income, and policy-change-versus-climate will continue to dominate African productivity literature without resolution.

4.5.3. Information on the Broader Set of Productivity Determinants

A wide range of factors going well beyond technical inputs influence productivity outcomes. Reardon et al. (1994b) provides numerous examples of how factors such as transportation and market infrastructure, marketing rules and regulations, political stability, price and exchange rate policies, research and technological innovation, and local and export demand for crops directly or indirectly affect productivity. Failure to control for changes in these factors over time can lead to erroneous interpretations about what is driving productivity trends.

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[19] A notable exception to the dearth of rainfall data is Le Borgne (1988) which presents detailed tables disaggregated by collection point and year from 1935 through 1987 for Senegal and The Gambia.

Howard (1994) found that it was not maize research *per se* that improved Zambian maize productivity but an aggressive program to make complementary inputs (fertilizer, for example) available with the new varieties. Similar results were found in Zimbabwe, where new maize varieties had been "on the shelf" for years but not adopted by smallholder farmers until input and marketing policy reforms were implemented to encourage their adoption (Jayne et al. 1994).

Kelly et al. (1995) shows that failure to account for changes in peanut seed distribution and credit policies fostered the erroneous conclusion that Senegalese farmers increased their cereal production in the mid-1980s because of concern over cereal self-sufficiency rather than a peanut seed constraint.

Recent data on fertilizer use in Senegal provided another example of how aggregate statistics can be misinterpreted if information is not available on the broader range of factors influencing the producers' input decisions. A trend analysis showed that fertilizer consumption increased at a rate of 5 percent per year between 1986 and 1991, offering some hope that farmers were at last adjusting to the era of structural adjustment and gradually returning to earlier levels of fertilizer consumption.[20] One's optimism was tempered, however, by the knowledge that most of the increase came during the last year when the eligibility requirements for obtaining fertilizer credits exhibited a strong pre-structural adjustment flavor. A 10,000-ton fertilizer gift from the Japanese encouraged the government to reduce down payments for fertilizer credit, making it more accessible to the average farmer (Government of Senegal 1992).

To incorporate the extent to which changes in agricultural input distribution and output marketing policies affect productivity, analysts must have access to information on the nature and timing of major policy changes. This lack of information is a greater problem in aggregate analyses that cover several countries. In the absence of a "time series" on policies that might have influenced production behavior, external analysts are left to their own devices to explain the patterns found in the data.

4.5.4. Price Data

Poor data on both input and output prices hamper productivity analysis. When these prices are either missing or poorly reflect real scarcity values, analysts cannot correctly measure efficiency, identify constraints, or aggregate inputs and outputs using price-based indices. The common problem with existing price series is that they often contain "official" rather than "market" prices, and they fail to report dates when official price changes were announced and implemented. The fact that "official" prices have rarely been "effective" prices makes it difficult to examine the farm-level profitability of production. Poor information about the dates that price changes were announced makes it difficult to analyze supply response.

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[20] Farm-level use ranged from 50-70,000 metric tons during the 1970s and early 1980s, but was only 20 to 32,000 tons from 1986 through 1991.

With market liberalization and the withdrawal of parastatals from marketing activities, many governments have developed good price information services for key crops. As there is no way to retroactively correct existing series that contain "official" prices for the 1960s and 1970s, analysts frequently use world prices for similar products as a proxy. This is not an ideal solution for products such as millet which are not traded on world markets and whose scarcity value in Africa is poorly reflected by world prices for products such as sorghum.

The price problem on the input side is more difficult to deal with; it is not a simple matter of collecting price data in household-level surveys, since the markets can be extremely thin (agricultural labor, for example) or even missing (land, for example). The existence of missing or thin markets suggests a need for research directly focused on gaining a better understanding of why the markets do not function well and what can be done to improve the situation. When prices for key inputs are not available, it is impossible to compare marginal value products and marginal input prices, which comparison is at the heart of economic efficiency analysis.

4.5.5. Labor Data by Season and Activity

Poor labor data can lead to an underestimation of agricultural labor productivity (Section 4.2). Poor labor data also hampers our ability to analyze the (1) labor supply, (2) potential for adoption of labor-intensive agricultural technologies, and (3) efficiency of labor allocation across different activities (both farm and nonfarm).

The ability to disaggregate labor by laborer category (family versus hired, or by age and gender, for example) can improve our ability to understand labor supply and sociocultural factors that influence labor use (Mbithi 1977, Young 1977, and Copans 1972 provide examples of such analyses).

Given the evidence that nonfarm activities provide a growing share of income in rural Africa, looking at household labor allocation across farm and nonfarm activities becomes increasingly important. Using time-series data, Minford and Ohs (1976) found a significant negative correlation between the amount of labor used in cropping and labor's returns to nonfarm employment activities in Malawi. Norman (1973b) found that nonfarm activities compete for labor in off-season cropping in northern Nigeria. These earlier results show that farm and nonfarm activities compete for household labor throughout the year. Many natural resource management practices demand large amounts of labor during the noncropping season. Composting and building bunds are two examples. Without good data on returns to labor for noncropping activities that compete for household labor time, we have no way of evaluating the probability that these labor-intensive techniques will be adopted, or of evaluating policies that might make them more competitive.

Hopkins and Berry (1994) illustrate that analyses of labor efficiency by cropping activity provide valuable information on seasonal labor constraints in Niger. It is common to use a single variable to represent both family and hired labor during the entire cropping season when estimating agricultural production functions (Savadogo, Reardon, and Pietola 1994; Kelly et al.

1995). While the marginal value products of labor estimated from these variables provide useful information about "average" marginal returns to labor across all cropping activities, they fail to provide useful information about labor constraints that occur at selected periods during the cropping season. Hopkins and Berry divided cropping labor inputs into two variables: peak season (weeding) and slack season (all other periods). Their results show that the ratio of the marginal value product to the seasonally adjusted wage rate is approximately 1 for all non-peak labor periods (suggesting efficient labor use) and 2 for the peak period (suggesting that more labor used during this time would increase profits).[21] When the authors used only one variable for all household labor during the entire cropping season (as done by Savadogo, Reardon, and Pietola 1994, and Kelly et al. 1995), the ratio was only .42, suggesting that more than the economically efficient amount of household labor was used.

The implication of the peak season result is that researchers should be looking for labor-saving weeding technologies or opportunities to spread labor inputs more smoothly (intercropping, for example). The implication of the .42 "average" ratio for household labor during the entire season is that there is slack labor that could be used at various times during the cropping season if noncropping employment options were available locally. The implication for data collection and productivity analysis is that we need to pay more attention to collecting labor data at different levels of aggregation and to improving modeling techniques. Finally, the implication for policy makers is that marginal value products of cropping labor have different interpretations which depend on the way that the labor data are aggregated.

4.5.6. Capital Investment Data

In analyses of productivity using country-level FAO data, the only variable available to control for differences in the amounts of capital invested in fixed production assets is the number of tractors -- a capital investment rarely found in Africa. Most cultivation in Africa is done manually or with animal-drawn plows, hoes, and seeders. For some countries, data on the units of different types of animal traction equipment sold via government-controlled distribution networks are available in national statistics, but often for only short periods of time when government programs were encouraging the adoption of animal traction. As the parastatal systems decline in importance and equipment replacements are increasingly supplied by local blacksmiths (the current situation in Senegal), national statistics are less likely to reflect the full extent of such investments or capital inventories.

Clearly there is a need to differentiate farms, regions, and countries that are using mostly hand cultivation from those using animal traction; yet, neither the FAO nor most national statistics services have good information on animal traction use and investments.

Investments in land improvements such as trees, bunds, and terracing can also have positive effects on cropping productivity, but there are no data series on these investments. Investment in livestock holdings is another factor which can explain differences in cropping productivity

[21] Both household and hired labor were combined in this analysis.

across farms or regions. More animals often mean better liquidity for input purchases and easier access to manure. These are investments that are now being encouraged in many parts of Africa, yet little is being done to monitor the resulting levels of investment or their impact on productivity.

5. HOW CAN WE DO BETTER?

Seven key points emerge from the discussion in Sections 1 - 4 :

(1) Missing or poorly measured variables used in the numerator (output) or denominator (land and labor, for example) are biasing productivity ratios;
(2) In most cases, these errors underestimate levels of agricultural productivity in Africa and distort trends;
(3) Micro data are an important source of information for identifying the existence and magnitude of these errors in macro and meso data;
(4) Information from micro data can improve estimates of productivity ratios when macro data are not available and too costly to collect;
(5) Detailed micro data sets are the best source of information on the farm-level determinants of agricultural productivity; this information contributes to the development of productivity enhancing policies and technologies;
(6) Micro data play an important role in identifying the appropriate variables to monitor in macro and meso series;
(7) Only consistently high-quality macro data in unbroken time-series can provide adequate information about productivity trends and the contribution of policy and technological change to national agricultural productivity over time.

From these conclusions it becomes evident that improving the data used to monitor and analyze agricultural productivity requires much greater cross-fertilization of detailed micro studies and broad macro-data collection and reporting efforts. At present, there is little cross-fertilization in the planning, implementation, or analyses stages of agricultural monitoring and research efforts. As data collection and analysis costs are high, we need to ensure the maximum complementarity possible among different types of surveys and data. This requires coordination among donors, government agencies, and research institutes that fund, collect, and analyze agricultural data.

Most of the issues raised in Section 4 represent errors in productivity measurement that require immediate attention. Given limited budgets, the discussion of "how we can do better" makes recommendations for setting priorities: incrementally broadening the agricultural data base without jeopardizing quality, and keeping costs down by exploiting the complementarities among different types of data. The discussion is divided into two parts: (1) strategic issues in planning and funding agricultural data collection, and (2) solutions to specific problems raised in Section 4.

5.1. Strategic Planning Issues

5.1.1. Macro- and Meso-Level Data

Errors in measurement of output for mixed cropping systems and agricultural labor use can cause serious underestimation of productivity ratios. Yet, it is not feasible for African governments to include labor-use data in macro-level agricultural statistics or to do field cuttings for all the crops on heavily intercropped fields. Rather than ignoring these problems, governments could develop strategic plans for collecting data from different surveys that are designed to be complementary from the start.

We recommend that each country (1) determine which variables they can afford to collect for their macro time-series data, and (2) ensure adequate funding so that the data are of a consistently high quality and available in a timely fashion from year to year. Given the important role that micro data can play in identifying and correcting macro measurement errors and contributing to our knowledge of factors which influence production at the farm level, the financial commitment to a quality macro data base must allow for the funding of complementary micro studies.

Given the quality/quantity/cost tradeoffs, it is important that governments not over-commit themselves in designing their macro surveys -- consistent, accurate data are required to diminish the current skepticism about the quality of African data. We list, in order of priority, the types of basic macro data that should be collected:

(1) Area planted in key commodities
(2) Quantities of key commodities produced
(3) Yields per hectare for each commodity (calculated from 1 and 2 above)
(4) Consumer and producer prices for key commodities
(5) Capital equipment stocks per hectare cultivated (animal traction and tractors)
(6) Average fertilizer use per hectare by crop[22]

Prices should be collected from a representative sample of urban and rural markets, while other data should be from a random sample of farmers. Items 1-4 are essential. Items 1-3 should be collected and reported in a manner consistent with international reporting procedures (FAO *Production Yearbook*, for example), thereby improving the quality of the data used in cross-country productivity analyses. The benefits of conforming to international standards may not be apparent at the national level, but the knowledge that donors, international financial institutions, and multi-national companies -- i.e., the principal sources of investment capital -- use FAO and UN data bases when examining investment alternatives should provide ample incentives. Furthermore, countries that do not follow international standards will find it difficult to evaluate their progress in agricultural productivity vis-a-vis other countries in Africa and elsewhere.

To ensure consistent, high-quality data, we recommend limiting the commodities covered in the short-run and expanding them over time. Decisions about expanding the commodity base, dealing with mixed cropping and crop by-products, and adding data on capital stocks or fertilizer should be based on judgments about the relative importance of each variable to the measurement of a country's agricultural productivity and the feasibility of collecting the information at the

[22] It could be argued that in the African context, enumerating applications of organic matter would be more appropriate; as this is not what is typically done in macro data series, we prefer reporting fertilizer in macro series but using micro data to follow the use of organic matter.

time that crop cuttings or field measurements are made for macro-surveys.[23] Prior micro studies may provide guidance in these areas. If no micro studies exist, we recommend that appropriate studies be designed at the same time as the macro-data collection effort is planned. The availability, representivity, and quality of alternative sources of information for capital stocks and fertilizer use should also be considered (manufacturers' or distributors' sales information or cooperative records, for example).

Although we stress the importance of governments designing affordable programs, donors and international financial institutions have a vested interest in ensuring that each country maintains at least the minimum series on yields and output of key commodities. Agricultural data bases (both macro and micro) should be thought of as international public goods which have a value that goes far beyond the value to each individual country. The World Bank, the IMF, and bilateral donors regularly evaluate the success of their programs using macro-level data. Many industrialized countries doing international commodity and trade analyses also rely heavily on UN and FAO production data. Given the importance of good agricultural production data to the entire international community, we believe that donor assistance is justified and should be used to (1) improve the uniformity of macro data-collection systems and methods across countries, (2) provide supplementary funding when necessary to avoid breaks in the time-series due to temporary financial constraints,[24] and (3) encourage the collection of micro data needed to correct and supplement the macro series.

At the meso-level, the key is to stratify macro-surveys by the variable of interest, or at a minimum, enumerate the variable so that the data can be later regrouped. Stratification variables of most interest are: (1) agroclimatic zone, and (2) farm type. The sampling frames used in most macro-data collection efforts are based on administrative regions rather than more agroclimatically-relevant spatial or farm-type categories. Improving our ability to disaggregate data to agroclimatic zones would permit us to compare similar agroclimatic zones across countries rather than comparing entire countries in the aggregate.[25] A first step toward better analysis of major farm types is to identify the most important categories (using micro surveys if available) and to include the necessary variables in macro surveys. In brief, advances are possible in meso-level analyses without undertaking entirely new data collection efforts or considerably increasing the costs of current macro surveys.

A final point concerning the design of macro and meso data series is the need to centralize the administrative responsibility for archiving and distributing the data so that users need to contact

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[23] The long-run objective for Africa as a region is to develop good macro data series on animal traction and fertilizer use because failure to incorporate these key variables in macro analyses severely limits their usefulness. On the other hand, countries where fertilizer and animal traction are not important should not be burdened in the short-run with collecting these data if enumerating labor use or nonfarm income responds better to their situation.

[24] The loss of an entire year of data in Senegal (see section 3.1), for example, may well prove more costly in terms of our ability to evaluate productivity change than the amount of supplementary funding that would have been required to carry out the standard set of field measurements and crop cuttings.

[25] Martin (1988) provides an example of how this was done in Senegal.

only one institution. This does not mean, however, that one meta service should be established to conduct the various data collection activities. For example, price data may be best collected by market information services in the Ministry of Agriculture, while rainfall data would be better collected by the national weather services or agricultural research institutes. We recommend a central *clearing house* for these various data bases. The clearing house would develop an index of the data bases available and perhaps publish abstracts containing key information such as variables included, time periods covered, sampling procedures and representivity, data format and software used, and a list of key people (institutions, addresses) most knowledgeable about the data. Ultimately, the key variables from the different surveys (particularly prices and output data) could be combined into single data bases using the same format and software. Although this recommendation may appear to be adding a costly new level of bureaucracy, it could well lead to reductions in overall costs if each researcher or analyst no longer had to spend inordinate amounts of time tracking down data from a myriad of institutions and data bases.

5.1.2. Micro-Level Data

As indicated in Section 3, macro- and meso-level data do not provide adequate answers to questions of economic efficiency, equity, and farm-level response to policies and technologies -- micro data are often needed to supplement or adjust macro data. Unfortunately, micro surveys are usually designed and conducted by institutions that are not involved in collecting and reporting macro series, making it difficult to recognize some of the complementarities. We are <u>not</u> suggesting that the same institutions that conduct macro surveys also need the micro surveys. What *is* important is that once a government has decided on a macro-survey design that it can competently handle, the responsible institution should consult with donors, other government agencies, and research institutions to ensure that ongoing micro surveys provide some information on notable gaps -- particularly labor-use data and output of secondary crops.

In the long run, we would like to see African countries establish some type of ongoing, but affordable, survey that covers the entire country, using a combination of single- and multi-visit components. The single-visit component could be conducted annually. Identical questions on input/output levels and demographics could be repeated every year, while questions on knowledge, attitudes and practices might change, permitting analysis of the impact of policies or technologies that have been introduced since the previous survey. The multi-visit survey could provide detailed input/output and household expenditure data for a subsample of zones at a frequency that would ensure coverage of each zone once every five years or so. This would permit more detailed analysis of productivity determinants and more systematic coverage of changes in crop production behavior and technology over time. These types of surveys should be designed, implemented, and analyzed by African nations in response to their perceived needs. Outside funding, when used, should contribute to building national capacity and improving the chances that programs will continue over time. This has not been a strong point of most donor-funded micro-survey efforts in the past.

We have not identified many examples of ongoing surveys that link micro and macro data as well as formal and informal methods. The Rwanda data set referred to in this paper is, however, a good example. This Ministry of Agriculture data set is based on a combination of ongoing micro data collection for a national sample, plus a stream of informal and formal add-on studies (Clay et al. 1995). Recent experience with adding informal, qualitative components to detailed quantitative household surveys in Senegal suggests that with very little additional cost, the value of the quantitative data can be considerably enhanced (see Box 4).

Identifying the most appropriate institutions for conducting micro surveys needs to be resolved on a case-by-case basis. Most national agricultural research institutes have the capacity to do micro surveys in conjunction with farming systems research in specific agroclimatic zones, but are unlikely to have the resources necessary to conduct national surveys. Statistical services in the Ministries of Finance and Planning are increasingly involved in national surveys that collect household-level data, but they tend to do a poor job of collecting agricultural variables. More collaboration between the agricultural research institutes and national statistical services in sampling, survey design, and interviewer training could increase the usefulness of the survey work done by both types of institutions. Costs of inter-institutional collaboration can be high, particularly if unnecessary bureaucracies are created or turf battles ensue. It is our experience that considerable progress can be made by simply increasing opportunities for informal contacts among researchers and field staff at survey design workshops or training seminars (see Box 5).

Although the idea of an ongoing micro-survey program may seem too costly at first glance, it could prove to be much more effective and less costly in the long run. The ad hoc methods of doing micro studies now mean that data and results from different surveys are rarely complementary and there is often no time dimension in micro work. Furthermore, the biggest survey expenses are often related to picking the sample, collecting basic household demographic information, and recruiting and training temporary staff. An ongoing micro-survey, with periodic replacement of the households sampled would considerably reduce these costs, increase the quality of the data, and improve our ability to report in a timely fashion on farm-level response to major policy changes.[26]

[26] Some important but sensitive data (livestock holdings or income, for example) can rarely be collected in a single interview survey. Maintaining contact with the same households over a number of years can considerably increase respondent confidence and, therefore, the quality of the data. Having an ongoing sample in place would considerably speed up the turnaround time in surveys that look at farmers' short-run responses to policy changes.

box 4

box 5

5.1.3. Reducing Costs Through Technological Innovation

Although most African statistical services have entered the computer age, there is a growing potential to use new satellite and communication technologies to reduce the costs of collecting, storing, and disseminating agricultural data. This is a topic that warrants a separate paper, so we will simply mention a few of the promising technologies that African governments should be considering:

(1) Use of satellites and global positioning systems to increase the accuracy of, and reduce the time required for, field measurements;
(2) Use of remote sensing, aerial photography, and geographic information systems to monitor natural resource bases;
(3) Use of electronic media for recording data and making it available to the public;
(4) Use of electronic mail systems to transfer data from regional to national bureaus.

In sum, strategic planning for the collection, recording, and dissemination of agricultural data is necessary if a cost-effective system combining macro, meso, and micro data is to be developed that will meet the needs of donors, national policy makers, agricultural scientists, and, ultimately, the African and international business community.

5.2. Addressing the Key Data and Measurement Problems

5.2.1. Estimating Outputs and Calculating Land Productivity Ratios

We showed in Section 4.1 that failure to account for mixed croppings, crop by-products, and crop diversification can lead to serious underestimation of output and yields. When micro data are available on crop by-products or secondary crops in mixed enterprises, agricultural statistics services can use these data to adjust their estimates of total outputs and the area planted. When this is done, however, it is imperative that both published and unpublished series contain information on (1) how the original measurements were made, and (2) the assumptions used in making these adjustments.

If one suspects that the types of underestimation described in this report exist, but micro data are not available for confirmation, some exploratory micro work should be done such as low-cost, single-visit surveys. In cases where no recent micro work is available, it may be necessary to conduct more costly but detailed multiple-visit surveys that provide information on outputs as well as other missing or poorly measured variables not easily collected in single-visit surveys. If the micro data confirm that current procedures have led to significant errors in estimating outputs or land-use per crop, analysts can use this data to adjust the current estimates. Documentation of the procedures used is essential.

The above are short-run solutions that have the potential for immediate improvements in the quality of agricultural data at the macro level. When underestimation of output is severe, or a failure to report the production of individual mixed crops with their respective land use hinders analysis of key policy issues, it may be necessary to revise the procedures used for macro-data collection. The key is to judiciously assess the degree of error caused by current practices and aim for substantially improved (not perfect) results.

5.2.2. Correcting Estimates of Labor Productivity

It was shown in Section 4.2 that basing calculations of agricultural labor productivity on persons "economically active in agriculture" (a stock variable), rather than labor-use data (a flow variable), can result in significant underestimation of labor productivity. Although individual countries can use existing micro-survey data on cropping labor to adjust their estimates of labor productivity, this will not resolve the major problem, which is macro, cross-country analyses of labor productivity that are based on the FAO labor stock variables. FAO (1994) notes that the numbers reported in 1994 were simple projections from an ILO study of economic activity and employment conducted in 1986. The fact that the survey is nearly ten years old suggests that it may be time for an update. We strongly recommend that any effort to update these data addresses the following questions:

(1) How long is the cropping season?

(2) During the peak period of the cropping season, what share of working hours available to the household is spent in crop production? in leisure? in noncropping activities?

(3) During the nonpeak period of the cropping season, what share of working hours available to the household is spent in cropping? in leisure? in noncropping activities?

(4) During the noncropping season, what share of total working hours available to the household is spent in leisure? in noncropping activities? in cropping activities (building bunds, for example)?

(5) Have these shares changed considerably during the last five years? last ten years? If so, in what direction?

If answers to these questions come from a representative national survey, analysts could adjust the FAO labor stock variable to better reflect the labor actually used in cropping activities, thereby improving comparisons of agricultural labor productivity across countries and time. This is only a first step in the move from stock to flow data. Ultimately, data will be needed on labor allocated to specific cropping and noncropping activities.

5.2.3. Using the Most Appropriate Level of Aggregation

Section 4.4 showed that the ability to examine productivity at more disaggregated levels can substantially improve our understanding of production behavior. The extent to which macro surveys contain the variables which permit the data to be separated into these different groups considerably enhances the usefulness of the macro data base. In most cases the additional cost of adding these variables is surpassed by the value of additional, policy-relevant analyses that can be done.

The issue of selecting the appropriate units for analyzing resource allocation decisions is not easily resolved. Despite the fact that crop production in African households is usually carried out by a number of relatively independent decision makers within the household, we believe that the household should remain the basic unit of analysis for studying farm-level resource allocation and efficiency. Nevertheless, it is important to collect data so that it can be disaggregated to examine the behavior of individual decision makers within the household. We also recommend collecting supplementary information on sociocultural factors that affect how household labor and capital stocks are allocated to different members of the household. Knowledge, attitude, and practices surveys (KAPs) providing this type of information can enhance analysts' ability to interpret socioeconomic information such as marginal value products.

5.2.4. Broadening the Variable Base

We noted in Section 4.5 that inadequate data series on technical and socioeconomic variables such as soil characteristics, rainfall, prices, historical events (particularly policy changes), and labor use, hamper our ability to fully understand the determinants of agricultural productivity. As discussed in Section 5.1, the short-run objective for improving agricultural data is to develop reliable macro series, with only those variables that can be adequately enumerated in a consistent fashion from year to year, using micro surveys to obtain complementary information on a wider range of variables. In the long run, we would like to see both the range of variables covered in macro data sets and the time dimension of micro surveys expanded. In the meantime, there are a number of relatively inexpensive ways for governments to considerably enhance their existing data bases.

Both rainfall and price data often exist, but are seldom available in a "user friendly" form. The Ministries of Agriculture also produce annual reports which mention key changes in policies or other events that influence access to credit, input distribution, or producer incentives. All too often these data and information are not centralized (located at regional offices), not made available in either printed or electronic form (hand-documented ledgers or files), or not available from regional offices in a timely manner. We recommend that governments investigate ways of using computers and electronic mail to centralize these data and make them available to both national and international analysts on electronic media. Substantial investments are already being made to collect these data, yet few benefits are realized because the data are not generally available. We believe that with some additional investments, the returns to these data collection efforts could increase exponentially because of the increase in the quality of the productivity analyses in general.

The first step in this process is to improve the availability of rainfall and price data, and information on major events influencing production behavior for individual countries. For example, in cases where official prices are still used, the exact dates when changes are announced would improve the ability to evaluate farmers' price response. Once individual countries master such variables, FAO might consider adding them to their *Production Yearbook*.

The lack of data on soil quality, production externalities, and labor use for individual cropping and noncropping activities is a serious constraint to productivity analyses. Poor price data for land and labor due to missing or thin markets is also a major problem. Micro-surveys are the only means of collecting these types of information; yet, existing survey methods are either extremely costly, methodologically weak, or both. Although these are not problems that can be resolved in the short-run, they are issues that national and international agricultural research centers need to add in an incremental fashion so that eventually these factors can also be incorporated into productivity analyses. In the meantime, it is important that policy makers understand the implications of omitting these variables from productivity analyses: (1) analysts are unable to evaluate the extent to which soil quality is declining over time, (2) productivity of environmentally damaging technologies may be overestimated, (3) important knowledge about peak season labor constraints may be missing, and (4) important knowledge about the relative profitability of cropping and noncropping activities is not available.

5.3. Summing Up

A wide variety of multilateral and bilateral agencies, private sector firms, and African governments need high quality, reliable data on agricultural productivity. We have identified numerous cases where poor data lead to serious underestimation of African land and labor productivity. We have also shown that better coordination of macro, meso and micro data collection, reporting, and analysis efforts can lower costs and improve our ability to monitor trends and quantify determinants of agricultural productivity. This type of monitoring and analysis is essential if we are to identify constraints and improve productivity. What has not been apparent in the past is the extent to which the data can be improved and costs contained by exploiting the complementarities of macro, meso, and micro data sets. The present review of recent productivity studies identifies numerous ways that information from micro surveys can be used to identify and correct errors in the macro data used to monitor trends and calculate productivity ratios. We also show that by using strategic planning to coordinate macro, meso, and micro data collection efforts, we can considerably enhance the time dimension of micro surveys.

If we are to progress in our understanding of what is needed to increase African agricultural productivity, we need complementary sets of accurate and timely macro, meso, and micro data on key trends and determinants. Each type of data has its place and role in the overall picture; none is a luxury. As the utility of these data bases goes far beyond the borders of each African country, regional and international assistance to ensure the accuracy and timeliness of a minimum set of macro variables, supplemented and corroborated by micro surveys, appears justified.

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Box 1: Lessons on Mixed Cropping from Niger

Hopkins and Berry (1994) found that a failure to account for all the crops produced on a field in Niger can significantly underestimate productivity and income. Using a sample of 135 households in five different zones, a set of 216 distinct crop enterprises were identified for 716 fields with up to 6 crops in a given field. The combinations were identified by ranking the crops within each field in terms of their relative importance as determined by the producer at planting time. To generate enough observations for meaningful statistical analyses (descriptive or econometric), crop enterprises were aggregated first to ten major categories: (a) millet/cereal, (b) millet/pulse, (c) sorghum, (d) maize/sorghum, (e) maize/rice, (f) maize, (g) rice, (h) fonio, (i) peanut, and (j) bambara nut. These categories were further aggregated for final analysis to millet (a-b), maize/sorghum (c-f), and peanut/bambara nut (i-j).

These aggregated "crop enterprise" categories are defined by the principal crop in the field (millet, sorghum/maize, peanut/bambara nut). For millet enterprises, all output is expressed in terms of millet-equivalent kilograms (i.e., all intercropped output is converted to millet-equivalent kilograms by dividing the total value of the intercrops by the average annual price of millet). For sorghum/maize, output is expressed in maize equivalents, and for peanut/bambara nut fields in peanut equivalents. The analysis focuses on rainy season crops (90 percent of the total value of production in the study areas).

Numbers summarized below show that the output of the principal crop accounts for only 70 to 80 percent of the net returns to land and 65-70 percent of the net returns to labor. Part of the bias comes from not reporting the value of secondary crops produced, while the other part comes from accounting for land, labor, and other indivisible inputs that are erroneously charged entirely to the principal crop. These results strongly suggest that productivity is being substantially under-reported in data series that enumerate only the principal crops produced in a field.

The influence of intercropping on net returns to land and labor in Niger

		Sudano-Sahelian		**Sudano-Guinean**		
	Overall Sample	Northern Boboye	Southern Boboye	Dallol Maouri	Gaya Plateau	Gaya River
NET RETURNS TO LAND (FCFA/HA)						
Principal crop	13378	8674	11978	10622	13145	21531
Principal and secondary crop	16400	10507	13612	11640	16972	27899
Whole field	18071	12429	15250	13962	16893	30484
Share accounted for by principal crop	0.74	0.70	0.79	0.76	0.78	0.71
NET RETURNS TO HOUSEHOLD LABOR (FCFA/DAY)						
Principal crop	359	314	342	282	347	495
Principal and secondary crop	446	375	433	308	443	648
Whole field	496	439	523	364	449	689
Share accounted for by principal crop	0.72	0.72	0.65	0.77	0.77	0.72

Source: Hopkins and Berry 1994.

Box 3: Underestimation of Agricultural Labor Productivity in Senegal

Using micro-survey data for Senegal, we find that failure to correct FAO labor stock data for the length of the growing season and the use of labor in noncropping activities overestimates the denominator (quantity of labor used) in labor productivity estimates by a factor of 6 in the drought-prone north and by a factor of 2 to 4 in zones with better rainfall.

The rainy season in the Senegalese Peanut Basin ranges from only 3 months in the northern Sahelian zone to about 6 months in the southern zones. The average share of noncropping income in total income is relatively high in the north (74 percent), and ranges from 30 to 45 percent in the central and southern zones, suggesting that substantial amounts of household labor are used in noncropping activities (Kelly et al. 1995). The number of persons per household who would be considered "economically active in agriculture" by FAO (and, therefore, included in the FAO labor stock data) ranges from 4.2 to 6.7 across the zones. The implicit assumption when using FAO data is that each of these "economically active" persons is principally engaged in agriculture throughout the year. Assuming a standard workweek of 5 days and 8 hours per day, each "economically active person" represents 2000 hours of available labor time per year. In the table below, we compare the available labor stock data with the hours of labor actually used (household plus hired) in cropping activities during the 1989/90 cropping season. As 1989/90 was a year of relatively good rainfall and harvests, the labor used may be somewhat greater than that employed in an average year.

Crop labor use as a share of agricultural labor stocks based on the number of persons "economically active in agriculture"

North	Center-West	Center	Southwest	Southeast
10,300	8,440	11,180	10,880	13,360
1,522	2,275	2,616	2,608	5,895
15 %	27 %	23 %	25 %	44 %

Source: IFPRI/ISRA survey data

These results show that labor used in cropping is only 15 to 44 percent of the labor implicitly included in the denominator when based on the FAO labor stock data. In the extreme case of the northern zone, where very little available labor is used in cropping, estimating labor productivity with labor-use rather than labor-stock data increases "productivity" seven-fold (because labor use is about one-seventh of the labor stock). In summary, the FAO data do not provide true measures of labor productivity, but are, rather, indicators of output per capita. If we want true measures of labor productivity at the macro level, more effort needs to be devoted to developing data series that permit one to determine the share of available labor time that is actually being used in cropping activities.

Box 2: Importance of Crop By-Products in Senegal and Niger

Pulses such as peanuts and cowpeas produce hay that provides very high quality animal feed, which is used for traction animals and fattening small ruminants.

Estimates of the value of hay, relative to the value of peanut or cowpea seed, for different zones of the Senegalese Peanut Basin suggest that failing to count hay underestimates the value of output by almost 50 percent in some cases.

Peanut and cowpea hay as a percent of the crop's total value: Senegal

Zone/Crop	Good Rainfall	Average Rainfall	Poor Rainfall
Northern Peanut Basin (cowpeas)	48	40	36
Central Peanut Basin (peanuts)	39	44	47
Southeastern Peanut Basin (peanuts)	29	34	41

Source: Martin 1991.

Household survey data for the Dosso Department of Niger show that the value of cowpea hay can be more than 50 percent of the total value of production.

Cowpea hay as a percent of the crop's total value: Niger

Zone	1989	1990
Sudano-Sahelian zone	35	37
Sudano-Guinean zone	46	59

Source: IFPRI/INRAN survey data.

In the case of cowpeas, the percentage of value attributed to hay increases as rain increases. This can be seen in the differences between the lower-rainfall Sudano-Sahelian zone and the higher-rainfall Sudano-Guinean zone in Niger. The same pattern is observed when comparing production of years with different amounts of rainfall in the northern Peanut Basin.

Rainfall has the opposite effect on the ratio of hay to seed in peanut production, so peanut farmers earn relatively more from their hay in years of poor rainfall or in zones with lower rainfall.

Box 5: Operationalizing Institutional Collaboration in Senegal

Recent activities in Senegal provide two illustrations of how different national and international institutions have collaborated in an effort to improve agricultural data bases.

In the early 1980s the Senegalese Agricultural Research Institute (ISRA) began a marketing research program to monitor cereal prices in rural markets and collect data on cereal marketing costs at various levels of the marketing system. The program was funded by USAID and technical assistance was provided by Michigan State University. After several years of work, ISRA had developed an effective system of collecting, analyzing, and publishing producer and consumer cereal prices and volumes traded . The data were used to monitor the impact of cereal market liberalization policies that were implemented in the mid-1980s.

Recognizing that it was not the role of the national agricultural research service to become a permanent price information service, ISRA worked with the Senegalese Food Security Commission -- which up until that time had been responsible for food aid and security stocks -- to develop their capacity as a price information service. With initial funding from German technical assistance, the Food Security Commission set up a program of weekly market surveys for cereals. Prices are published weekly in national newspapers and announced on the radio. The Food Security Commission continues to report cereal prices and now includes prices of other key agricultural products (peanuts and cowpeas, in particular).

In the early 1990s the National Statistical Service in the Ministry of Planning and Finance was charged with implementing two World Bank-funded national surveys to examine living standards (a "priority" study) and a living standards measurement survey. The surveys called for collecting much more detailed socioeconomic data than the national statistical service had previously collected, and their staff had little experience with this type of data collection, particularly in rural areas. ISRA and IFPRI researchers who had conducted a very intensive multi-visit household survey in rural Senegal from 1988 through 1990 collaborated with personnel from the National Statistical Service during the survey design and interviewer training process in an effort to share what they had learned from their own field experiences, and to explore the potential for complementarities between the various data bases. To date, there have been no joint analyses of the various data bases or comparative studies, but discussions continue in an effort to find ways of making these data intensive studies (that are, in large part, donor driven) more complementary and useful to national policy makers.

Box 4: Increasing the Value Added of Intensive Micro Surveys in Senegal

Common criticisms of intensive micro surveys are that they are slow to produce policy-relevant results, often fail to fully answer some of the specific questions they were designed to address because the policy environment does not stand still and wait for the results to be produced, and are difficult to apply to questions broader than the initial research questions because critical variables are missing.

Given the expense involved in collecting intensive micro data, it behooves donors and governments to examine ways of increasing the value of these data sets by encouraging continued analysis and complementary follow-up surveys. A number of initiatives have been taken to increase returns to the initial investment in the IFPRI/ISRA data set for Senegal. We list a few of these efforts as illustrations of steps in the right direction:

(1) USAID/Senegal provided supplementary funding to permit thorough documentation of the base data files.

(2) IFPRI and ISRA have made the data available to students doing masters and Ph.D dissertations on agricultural policy issues in Senegal. Researchers at MSU and ISRA have been funded to work with these students to ensure that they understand the data sets and that any supplementary data files they create, or data they collect, are added to the data base.

(3) Although the initial project ended in August 1993, collaborative work between ISRA and expatriate researchers associated with the original project has been able to continue because of USAID funding through projects in Senegal and support to land grant institutions in the US. This funding has covered international travel, follow-up surveys, and doctoral level training for Senegalese researchers.*

(4) The data set has been used to examine a number of issues for which it was not initially intended. In several cases, questions came up that could not be answered from the quantitative data but required follow-up interviews to better understand the decision-making logic behind certain behaviors. For example, several analyses suggested that high shares of nonfarm income might have been associated with households that had unusually poor quality soil because they were realizing lower yields than other households. Soil quality data were not available, but a follow-up survey found that the households concerned did not consider their soil to be any different than their neighbors. Another example concerned evidence that some farmers were using much higher peanut seeding densities than others. The data were not adequate to determine if seeding densities were a function of how much seed one was able to obtain or predetermined by individual preferences or soil quality. A follow-up survey clarified that seeding density was related to soil quality but not to the quantity of seed available.

Because ISRA researchers involved in the original study were involved in the supplementary research raising these questions, they designed and conducted follow-up interviews. These interviews were conducted rapidly (about two months from conception to final report) at an extremely low cost relative to the initial intensive survey.

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* It is worth noting that most of the supplementary work on the data base has been funded through the Michigan State University Cooperative Agreement with USAID. This is an excellent example of how core funding of general research themes can be administered in a way that complements prior or ongoing research of African institutions and USAID missions.