ECONOMICS WORKING PAPER 03-07

# Understanding Farm-level Technology Adoption: Lessons Learned from CIMMYT's Micro Surveys in Eastern Africa

CHERYL R. DOSS

CIMMYT MR

E C O N O M I C S

Working Paper 03-07

# Understanding Farm-Level Technology Adoption: Lessons Learned from CIMMYT's Micro Surveys in Eastern Africa

**Cheryl R. Doss***

* International Maize and Wheat Improvement Center (CIMMYT), Apartado Postal 6-641, 06600 Mexico, D.F., Mexico. The views expressed in this paper are the author's and do not necessarily reflect the views of CIMMYT.

CIMMYT® (www.cimmyt.org) is an internationally funded, nonprofit, scientific research and training organization. Headquartered in Mexico, CIMMYT works with agricultural research institutions worldwide to improve the productivity, profitability, and sustainability of maize and wheat systems for poor farmers in developing countries. It is one of 16 food and environmental organizations known as the Future Harvest Centers. Located around the world, the Future Harvest Centers conduct research in partnership with farmers, scientists, and policymakers to help alleviate poverty and increase food security while protecting natural resources. The centers are supported by the Consultative Group on International Agricultural Research (CGIAR) (www.cgiar.org), whose members include nearly 60 countries, private foundations, and regional and international organizations. Financial support for CIMMYT's research agenda also comes from many other sources, including foundations, development banks, and public and private agencies.

FUTURE HARVEST Future Harvest® builds awareness and support for food and environmental research for a world with less poverty, a healthier human family, well-nourished children, and a better environment (www.futureharvest.org).



**Correct citation:** Doss, C.R. 2003. *Understanding Farm Level Technology Adoption: Lessons Learned from CIMMYT's Micro Surveys in Eastern Africa.* CIMMYT Economics Working Paper 03-07. Mexico, D.F.: CIMMYT.

**Abstract:** Drawing on a series of technology adoption studies carried out by the International Maize and Wheat Improvement Center (CIMMYT) in collaboration with national agricultural research systems in Eastern Africa during 1996-98, this paper suggests alternative approaches for designing technology adoption studies to obtain as much useful information as possible. It describes the Eastern African studies and summarizes specific lessons learned, asks what can be learned from farm-level studies in a few communities, explores generic limitations of micro studies and a range of problems and issues faced in carrying out such studies, addresses challenges that arise in trying to put together a set of compatible micro studies, and lists overall conclusions and specific recommendations.

**ISSN:** 0258-8587
**AGROVOC descriptors:**
**AGRIS category codes:**
**Dewey decimal classification:**

Printed in Mexico.

# Contents

**Page**

# Tables

**Page**

## Acknowledgment

The author thanks CIMMYT science writers Satwant Kaur and Mike Listman for their editorial assistance and designer Antonio Luna Avila for his help with layout.

# Understanding Farm-level Technology Adoption: Lessons Learned from CIMMYT's Micro Surveys in Eastern Africa

*Cheryl R. Doss*

## Introduction

Since its earliest days, the Consultative Group on International Agricultural Research (CGIAR) and its member centers have been at the forefront of research concerning the adoption of new agricultural technology by farmers in developing countries. Over the years, the nature of the questions being asked has changed. In the earliest years, policy makers and researchers sought simple descriptive statistics about the use and diffusion of new seed varieties and associated technologies such as fertilizer and irrigation. Concerns arose later about the impact of technology adoption—on commodity production, on poverty and malnutrition, on farm size and input use in agriculture, and on a variety of social issues. Again, CGIAR centers played an important role in developing methodologies for addressing such concerns and researchers at CGIAR centers have carried out innovative surveys and collected enormous amounts of data to describe and document the adoption of new agricultural technologies.

Yet many questions remain. At the simplest level, we still have considerable gaps in our knowledge of which technologies are being adopted, where, and by whom. Bigger questions have also arisen. Scholars and policy makers are asking about the role of policy, institutions, and infrastructure in increasing agricultural productivity. These questions are more complicated to address. Simple descriptive statistics do not offer much insight into the process of technology adoption or productivity growth. As a result, much of the published adoption literature in recent years has focused on methodological issues, trying to model the process of technology adoption and to get empirical measures of the importance of different factors. From an econometric standpoint, this literature has wrestled with deeply embedded problems of simultaneity and endogeneity—problems that were not important in the first generation of descriptive research.

Today, studies of agricultural technology adoption are used widely in four areas of agricultural policy:

- Assessing impacts of agricultural research
- Priority setting for research
- Evaluating distributional impacts of new technology
- Identifying and reducing constraints to adoption

This paper surveys recent studies of technology adoption to ask how they contribute to our understanding in these areas. Too often, studies are not designed well enough to yield useful information. In particular, many studies of technology adoption give disappointingly meager information about the importance of agroecological variables or policy environments. This paper shows why some studies can give little more than descriptive information, and suggests alternative approaches for designing technology adoption studies that provide as much useful information as possible.

The paper is intended to address broad issues about technology adoption, but for illustrative examples, it draws on a series of technology adoption studies carried out by the International Maize and Wheat Improvement Center (CIMMYT) in collaboration with national agricultural research systems in Eastern Africa during 1996-98.[1] The focus on the Eastern Africa studies does not reflect any particular shortcomings and should not be viewed as an implicit criticism. These important studies gathered a wealth of information about maize and wheat farming systems in Eastern Africa. They were designed with care and carried out diligently, and represented standard practice for adoption studies at the time. In addition, they are fairly typical of similar studies carried out by CIMMYT and other research institutes and academics.

The second section of this paper describes the Eastern African adoption studies and summarizes specific lessons learned. The third section asks what can be learned from such farm-level studies conducted in a few communities. The fourth section explores generic limitations of micro studies, however well they are conducted. The fifth section covers a range of problems and issues faced in carrying out individual micro studies. The sixth section addresses challenges that arise in trying to put together a set of compatible micro studies, as was attempted with the CIMMYT/national system Eastern Africa work. The seventh and final section lists overall conclusions and specific recommendations.

## CIMMYT Eastern African Adoption Studies: Background

During 1996-98, CIMMYT collaborated with national agricultural research systems in four countries in Eastern Africa to conduct 22 micro-level studies on the adoption of improved varieties of wheat and maize and of chemical fertilizers. The studies were designed to serve two purposes. The first was institution building: that is, enhancing CIMMYT's working relationships with the local institutions and training local staff in conducting and analyzing such surveys. It is beyond the scope of this paper to examine whether or not the institution building goals were met. The second goal was to increase the information available on technology adoption in Eastern Africa. This paper explores the extent to which the second goal was—and could be—met.

Table 1 provides a brief description of each of the studies.[2] Eight were conducted in Ethiopia: five examined the adoption of improved varieties of wheat, two the adoption of maize, and one the adoption of wheat and maize. Half the Ethiopian studies also examined

---

1 A synthesis of these studies is available through CIMMYT, as is each of the individual study reports.

2 Additional studies were conducted, but they were beyond the scope of the synthesis and this analysis. Appendix 1 lists all research reports from the studies.

**Table 1. Description of CIMMYT studies, Ethiopia, Kenya, Tanzania, Uganda, 1996-98.**

| Country | Region | Year | Crop | Improved Varieties[†] | Fertilizer[†] |
|---|---|---|---|---|---|
| Ethiopia | Bale Highlands | 1997 | Wheat | Yes | Yes |
| | Central Highlands | 1997 | Wheat | Yes | Yes |
| | Chilalo awraja | | Wheat | Yes | No |
| | Enebssie area | 1997 | Wheat | Yes | No |
| | Northwestern | 1999 | Wheat | Yes | Yes |
| | Sidamo and North Omo Zone | 1997 | Maize | Yes | Yes |
| | Western Oromia | 1996 | Maize | Yes | No |
| | Wolmera Woreda | | Wheat | Yes | No |
| Kenya | Kakamega and Vihiga Districts | 1996 | Maize | Yes | Yes |
| | Kiambu District | 1996 | Maize | No | Yes |
| | Narok, Nakuru and Uasin Gishu Districts | 1997 | Wheat | Yes | No |
| | Embu District | 1998 | Maize | Yes | Yes |
| | Coastal Lowlands | 1998 | Maize | Yes | Yes |
| Tanzania | Central | 1995 | Maize | Yes | Yes |
| | Eastern | 1995 | Maize | Yes | Yes |
| | Lake Zone | 1995 | Maize | Yes | Yes |
| | Northern | 1995 | Maize | Yes | Yes |
| | Southern | 1995 | Maize | Yes | Yes |
| | Southern Highlands | 1995 | Maize | Yes | Yes |
| | Western | 1995 | Maize | Yes | Yes |
| | Mbeya Dist. (S. Highlands) | 1997 | Wheat | Yes | Yes |
| Uganda | Iganga District | 1995 | Maize | Yes | No |

[†] Indicates whether the study examined the adoption of this technology

the adoption of fertilizer. In Kenya, four studies examined maize production, of which three examined the adoption of improved varieties of maize and fertilizer, while one examined the use of organic and inorganic fertilizer among maize producers. A fifth study in Kenya examined the adoption of improved wheat varieties and fertilizer. Seven studies in Tanzania examined the adoption of improved maize varieties and fertilizer, while one examined the adoption of improved wheat and fertilizer. Only one study was completed in Uganda. It examined the adoption of improved maize varieties and fertilizer.

Each of the studies dealt with technology adoption in a particular location or set of locations. Study sites were generally in the main wheat- or maize-producing areas. The reports present detailed descriptive data on farmers and farms, with attention to the use of improved technologies and the constraints farmers face.

## What Micro Adoption Studies Can Show

At the outset, one of the main goals of the studies was to generate basic information about the use of modern varieties and fertilizer and to identify constraints to the adoption of such technologies. Micro surveys can provide such information, often at a lower expense than full-fledged agricultural censuses.

In addition to generating descriptive data about technology diffusion, micro studies can provide useful background information about farmers who are currently using a technology and those who are not. For example, very little is known at present about farmers who use modern varieties or fertilizers in much of Eastern Africa. Most national governments in the region do not systematically collect or report such data, in contrast to other parts of the world. Without basic descriptive information on who is adopting and not adopting technologies, it is difficult to know how to formulate policies aimed at improving agricultural productivity. The micro-level studies are an important step toward assembling this information.

Cross-section analysis at the micro-level can answer important questions about technology adoption. At the most basic level, we can find out what crops farmers are actually growing in their fields and how they are growing them. As changes occur in rural areas, it is useful to understand how households and communities make decisions about technology adoption. We can learn about farmer decision-making by asking them what factors were important in their adoption decisions. Cross-section data can also tell us about farmer preferences. We can learn about growing conditions in specific areas and what varietal characteristics are important to farmers. Finally, we can learn about farmers' perceptions of the constraints they face.

Cross-section analysis can also provide information on patterns of adoption and disadoption. Information on whether or not farmers have ever used improved technologies and what they currently use can be collected. Obviously, these patterns can be analyzed more clearly if we have panel data,[3] but it is useful to know whether specific technologies have been tried and discarded by farmers, or whether they are used intermittently or not at all. Farmers are usually able to provide information on why they did not adopt a new technology. Sometimes their answers provide important insights into constraints they face. Other times several constraints are binding, so that removing one would not necessarily result in farmers' adoption of technology.

The profitability of a given technology can sometimes be determined from cross-sectional analysis of micro-level data. Adoption studies typically do not collect data on costs of production, but understanding the conditions under which improved technologies are profitable would add to our understanding of adoption decisions.

[3] Panel data is data collected from the same farmers over time. Analysis of panel data would allow us to understand how farmers' decision change under different circumstances.

Thus, we can obtain a description of farmers' current practices through micro-level studies—what farmers are doing and, possibly, the factors that influence their decisions. Such studies can also inform us about the kinds of technology currently in use and can be used in policy decisions on the allocation of research, extension, and agricultural development projects.

## Limitations of Micro Studies – Generic Issues

Useful as they are, studies such as those conducted by CIMMYT in Eastern Africa do not—and cannot—address certain important research and policy questions. Some shortcomings of micro studies can be dealt with through careful survey design, but others are intrinsic to the studies being based on data collected at a single point in time.

### Lack of Dynamics

One fundamental limitation of micro-level adoption studies is that cross-section data do not permit an analysis of the dynamics of technology adoption. These surveys typically collect cross-section data on adopters and non-adopters. Comparisons between the two groups are interesting, but they cannot tell us as much as studies that look at the same farmers before and after they encounter a new technology.[4] Similarly, cross-section data cannot tell us much about the impact of a new technology on the well-being of farmers or farm communities nor on the distributional effects. For example, researchers might like to know the extent to which new technologies have changed the relative and absolute incomes of farmers. But if we only observe adopters and non-adopters, we do not know whether differences in their income or wealth are causes or effects of technology adoption, or neither.

### The need for Panel Data

Technology adoption decisions are inherently dynamic. Farmers do not simply decide whether or not to permanently adopt an improved variety. Instead they make a series of decisions about whether to try planting an improved variety, how much land to allocate to the improved variety, whether or not to continue to grow it, and whether to try a different improved variety. Their decisions in one period depend critically on decisions made in previous periods. To understand the outcomes, farmers' decisions need to be followed over a period of time. This is best done with panel data sets.

Ideally, we would start to follow farmers before they adopt improved technologies, but panel data studies may be useful even if they are not strictly "before" and "after" studies. Having more than one observation per farmer allows us to control for heterogeneity across households. Since many farmers have already adopted some form of improved technology, we may need to be satisfied with following farmers over time and observing changing

[4] It may be possible to collect some retrospective data from farmers, but any retrospective data should be interpreted differently from data on current practices, since recall and selection biases may be present.

patterns of use of improved technologies. Panel data allow us to look at changes in the use of improved materials, both in terms of varietal replacement and the extent of adoption by individual farmers.

Panel data also help to understand the distributional impacts of new technology. Since many things change within rural communities, both in response to new agricultural technologies and to changes in outside forces, panel data are needed to sort out the effects. With panel data, we can begin to answer questions such as whether the benefits of being an early adopter continue once many farmers have adopted the technology. The sample would need to be large enough and distributed across a wide enough geographical area to capture variation in policies, institutions, infrastructure, and level of economic development.

Because developing panel data sets requires a major commitment of time and resources, we should not dismiss the need for cross-section analyses of individual sites. Yet, to understand the long-term dynamics of adoption, it is necessary to develop panel data for several key locations. Generating the additional information will likely involve considerable expense, but the payoffs could be large in terms of our understanding of technology adoption in Africa and elsewhere.

**Lack of Variation within Samples**

A recurring problem with micro studies is that there may not be much variation across households in a small survey with respect to variables of interest. For example, in a survey of a few villages in close proximity to each other, it will be difficult to get much information about the impact of credit or labor market failures. Use of credit and hired labor often depend on both farmer characteristics and characteristics of the village or region. When all respondents live in the same area, there may not be much variation among farmers with respect to market access. If this is the case, then the variables should not be included in the econometric analysis. However, it may still be useful to collect these data, as will be discussed in the following section.

Similarly, agroecological factors often influence technology adoption. Typically these include location variables for the village or region. Agroecology variables pick up variation in rainfall, soil quality, and production potential. However, these variables may also pick up variation unrelated to agricultural potential, such as infrastructure and availability of markets for inputs and outputs. It would be useful to have a measure of agricultural potential that shows more variation at the local level, even at the farm level, where possible. It might still be important to include a control for agroecological zone, but then this variable would be interpreted differently.

## Challenges in Designing and Implementing Single Studies

Careful analysis of CIMMYT studies, particularly comparisons among the studies, suggests that there are a number of ways to improve micro-level analyses. Most adoption studies, including CIMMYT studies, use a formal analytical model. The basic approach is usually,

$$A=f(X)$$

where $A$ is the measure of adoption and $X$ is the set of explanatory variables. Often the adoption of more than one technology (improved varieties and fertilizer) and, thus, a system of adoption equations are modeled.

Many adoption studies include explanatory variables without clearly describing why particular variables are used or what they are expected to capture. Often the dependent variable is not clearly defined. Careful attention to the variables included (and justification for both those that are included and those that are omitted) will make analyses more useful to policy makers and agricultural researchers. Rather than examine the different econometric approaches to estimating the adoption equation, this paper will discuss the appropriateness of different variables included in the equation. In this section, I focus on some widely used variables, some alternative specifications, and the interpretation of results from econometric estimations.

The general point is that it is rare for social scientists to have variables that exactly measure what we are most interested in: most variables we use are good approximations at best. So it is useful to think about how closely our measures track what we are interested in. Defining and interpreting results obtained from using variables that may be imperfect proxies is key to obtaining useful conclusions from adoption studies at the micro-level.

### Definining an Adopter

One key issue that the CIMMYT studies bring out is the question of what is meant by an "adopter" of a technology. The definition of adopter varied across the CIMMYT studies. What exactly is an adopter? This proves to be a complicated question with no obvious, correct answer.

In defining adoption, the first thing to consider is whether adoption is a discrete state with binary variables (a farmer either is an "adopter" or is not) or whether adoption is a continuous measure. The appropriateness of each approach may depend on the particular context. A number of CIMMYT studies (including Kakamega, Kenya; Enebssie, Ethiopia; Wolmera Woreda,[5] Ethiopia) used a simple dichotomous variable approach. A farmer was defined as being an adopter if he or she was found to be growing any improved materials. Thus, a farmer may be classified as an adopter and still grow some local materials. This approach is most appropriate when farmers typically grow either local varieties or

[5] A Woreda is a District in Ethiopia.

improved varieties. If interesting aspects of adoption are situations where farmers are increasingly planting more land to improved varieties while continuing to grow some local varieties, then a continuous measure of adoption is more appropriate. Many other studies, including all Tanzania studies and several Ethiopia studies (W. Oromia; Sidamo and North Omo; and the Bale Highlands) used measures of the proportion of land allocated to improved varieties as the measure of adoption.

Defining adoption may be further complicated by the complexity of defining the technology being adopted. For the adoption of improved seeds, the CIMMYT studies used several definitions ranging from farmers using a variety that was originally an "improved" hybrid but has been repeatedly recycled (for example, many farmers in the Tanzania samples had recycled hybrid seed for 12 years or more), to farmers following extension service recommendations of using only new certified seed (as in the Kenyan studies). Since the definition of adoption encompasses a wide range of dissimilar practices, the results from these studies are not comparable. Studies should state explicitly how terms are used.

Where the full range of farmer behavior is not known *a priori*, it may make sense to ask farmers for detailed information. The researcher can then create an appropriate adoption measure using this detailed data. The researcher might, for example, collapse detailed survey data into an ordered variable (such as whether farmers are using improved varieties, recycled varieties, or local varieties). This would require the use of multinomial logit or probit estimation, rather than a simple binary model. We may also want to know whether farmers are growing one improved variety or multiple varieties on their farms. Since many farmers grow more than one variety, measures of the proportion of land planted to improved materials are often used; this type of measure does not lend itself easily to more than one definition of "improved materials." Collection of detailed data would also allow the creation of measures of adoption that are comparable across studies.

Finally, in defining an adopter, we may also be interested in farmers' histories of technology use. To develop such histories, we must ask not only whether a farmer is currently using a particular technology, but also whether he or she has ever used it. This helps to distinguish farmers who have never tried a technology from those who have tried it and discarded it. In many studies, both categories are treated as "nonadopters," which may conceal important differences.

Two Ethiopian studies (Chilalo Awruja and Enebssie) analyzed two dependent variables, the awareness of the new technology and its adoption. In this case, they were trying to determine if a lack of information prevented farmers from adopting the technology.

Given the complexity of adoption measures and the potential value of having compatible measures of technology adoption across studies, it would be valuable for CIMMYT—perhaps in conjunction with other institutions—to take a leadership role in developing a scheme for defining adoption that could be used in adoption studies.

**Demographic Variables**

A number of other explanatory variables require similar consideration. One set of commonly used right-hand variables encompasses the demographic characteristics of farmers. "Age" is straightforward, if not always measured accurately. "Farming experience" is a bit more difficult to measure and it is important to define exactly what farming experience entails. Should the survey count all farming experience? Experience farming one's own plot? Experience farming this particular plot? Experience farming this particular crop?

Education is again relatively straightforward. However, simply entering years of education on the right hand side of the equation assumes that there is a linear relationship and that each year of education has a similar effect on the outcome. Since we do not expect the relationship to be linear, it may be better to include dummy variables for primary education and for secondary education. We might, for example, expect a big difference between farmers who are literate and those who are not. The difference between five and six years of education may have much less of an effect on the adoption of improved technologies than the difference between three and four years of education. Depending on the particular context, it may be appropriate to include two or three dummy variables indicating different levels of education. In some contexts, literacy might be a better measure.

**Wealth Measures**

Measures of wealth are often used on the right-hand side of adoption models. Wealth is expected to affect adoption decisions for a number of reasons, including that wealthier farmers have greater access to resources and may be more able to assume risk. The challenge here is to find measures of wealth that do not also contain substantial information about other factors related to adoption. For example, size of landholdings are often used to measure farmers' wealth, but this measure also picks up information about whether there are economies of scale in production using improved technologies. Landholdings may also reflect the social status and prestige associated with owning land, and possibly the ability of a farmer to obtain credit.

Use of an alternative measure of wealth, such as livestock ownership, may be complicated by the fact that oxen provide draft power as well as manure. Farmers with more livestock may be wealthier and thus more likely to adopt fertilizer. But simultaneously, they may have more access to draft power and less need for inorganic fertilizer.

In some places, farmers may own non-agricultural assets that may be good indicators of wealth. These may include a bicycle, TV, radio or other consumer goods. Indicators of housing type (whether the roof is thatched or corrugated metal) may be useful measures. Although it may be important to include land and livestock in the regression analyses, caution should be used in interpreting the results as simple measures of the effect of wealth.

**Access to credit and cash.** Researchers are often interested in whether the farmers have access to cash or credit, because the lack of such access may constrain farmers from adopting technologies that require initial investments, whether those be outlays for seed and fertilizer at the start of the growing season or large cash expenditures for machinery. From a policy standpoint, economists often view lack of access to cash or credit as an indication of market failures that governments or NGOs should help to resolve.

Many adoption studies include a variable that is meant to be a measure of credit availability. The best measure would be whether there is a source of credit available to the farmer. This would mean a source of credit for which the farmer is eligible, at a reasonable cost, both in terms of time and money. However, such a measure is often not available. Instead, many studies ask whether or not the farmer *used* credit. This measure is problematic. Credit use does not distinguish between farmers who chose not to use available credit and farmers who did not have access to credit. Theory tells us that farmers will borrow only if it is profitable to do so, where profitability depends on the price of credit and the potential returns on investment. By contrast, lending institutions will extend credit most readily where they think it is profitable to do so. The distinction between supply and demand for credit is important, if we are trying to determine whether or not credit market failures constitute important constraints to technology adoption.

Some creativity can be used to devise an appropriate credit variable. In the CIMMYT study of Kakamega, Kenya, the measure of access to credit was whether the farmer had ever received credit. Obviously, this measure still has some problems, but it is a better measure of access than the simpler question of whether the farmer used credit in the current period. This measure works better if there have not been major changes in the credit availability in the area during the period covered and if farmers have not changed location or material circumstances. If a credit facility in the area has closed down recently, however, this may be a poor measure of current credit availability, since farmers who had access to credit in the past may no longer have access.

Ownership of land is often thought to be a prerequisite for obtaining credit. For example, in Ethiopia, farmers must have at least 0.5 ha under maize in order to participate in the credit scheme for maize. In Kenya, the Seasonal Credit Scheme requirement that farmers have at least five acres of land. Thus, farmers with smaller amounts of land will not have access to formal credit through these channels. In some circumstances, it may be possible to assume that if any farmer in a village who meets the land requirements obtained credit, then others with similar or greater landholdings also had access to credit.

In a study conducted in Malawi, Diagne and Zeller[6] tried to obtain information about the potential for credit by asking farmers if they *could* borrow money. This seems like a good approach. However, even here, the availability of credit may depend on its proposed use. For example, farmers may be able to borrow for fertilizer, but not for consumer purchases.

---

6 Diagne, Aliou and Manfred Zeller. 2001. Access to Credit and Its Impact on Welfare in Malawi. IFPRI, Washington D.C., Research Report 116.

Similarly, if we are concerned about whether the lack of access to cash is a constraint to the adoption of technology, what we really need to know is whether the farmer has access to a source of cash. Data on local labor markets might provide one indicator. The choice to have a household member engage in wage labor or non-farm, income-generating activities may be made simultaneously with the decision about which agricultural technology to use, so whether someone in the farmer's household actually worked for wages may not be a good measure of access to cash. In addition, farmers may be able to obtain cash by drawing on savings or selling assets. We would need to know whether the farmer had savings or whether the farmer had assets and access to a market in which to sell them. Access to cash, like access to credit, may depend upon the use for which the cash is needed. Access to cash is difficult to measure, so it is important to be careful in interpreting attempts to capture this effect.

**Access to Information**

Another variable of potential interest is access to information. Farmers must have access to information about new technologies before they can consider adopting them. Since extension services are one important means for farmers to gain information on new technologies, access to extension is often used as a measure of access to information. As with measures of credit market functioning, what is usually measured is whether a farmer used the extension service. For example, studies often consider the number of extension visits received by the farmer, whether or not the farmer received any extension visits, or whether the farmer attended a field day. None of these measures captures whether the information was available to the farmer; instead, they indicate whether the farmer took advantage of the resources. More rarely, an effort is made to look at the effectiveness of extension; for example, by measuring whether farmer are aware of the relevant recommendations. This measure actually captures both whether the information resources were effective and whether the farmer took advantage of them. Thus, it may tell us whether farmers who are aware of the technology and understand it are more likely to adopt it, but it is not a measure of access to information.

**Access to Labor Markets**

The final set of variables of interest relate to access to labor. Many researchers suggest that labor market failures discourage farmers from adopting improved varieties and fertilizer. The argument is that, where labor markets do not function effectively, households must supply their own labor for farm activities, so they may choose not to adopt varieties that would require more labor at harvest time than the household can provide. Just as it is hard to measure access to cash or credit, it is difficult to measure a household's access to labor. The measure often used is household size, either measured as "all household members," "adult household members," or "adult equivalents." However, all of these measures are influenced by decisions about agricultural production. Household size, especially when we consider extended households in Africa, may depend at least in part on the productive capabilities of household. If the household does not have sufficient land, some members may migrate to towns in search of employment. Similarly, marriage patterns and the formation of new households depend, in part, on the availability of productive land. It may be useful to have descriptive information on the size of adopting and nonadopting households, but a causal relationship should not be inferred.

We might expect that the availability of labor in local markets would affect technology adoption. When there are local labor markets, farmers can hire labor as needed. Members of farmers' households may also sell labor to obtain cash as necessary. The relationship between the local labor market conditions and technology adoption needs to be explored on a case by case basis. The measures widely used in adoption studies are often not adequate to make policy recommendations about labor markets.

**Other Measures**

Researchers sometimes incorporate explanatory variables in adoption studies, based on what appears to be causal empiricism—and perhaps a desire to boost model goodness of fit—even though these measures may be hard to interpret. For example, one of the CIMMYT/national system studies (Southern Highlands, Tanzania) used as a determinant of adoption a variable indicating whether the farmer used a hand hoe or ox plow for land preparation. This variable may be a measure of wealth. But it may also be a measure of labor availability or even of the relative costs of labor and capital. This is a choice variable for the farmer—clearly not exogenous—and is almost certainly made simultaneously with the decision about whether or not to adopt improved technologies. Again, it may provide useful as descriptive information, but it should not be interpreted as causal.

**Dealing with Endogeneity**

A final issue that arises in using cross-section data from a single study concerns the interpretation of results. Studies that focus on a cross-section of the population and compare adopters to nonadopters cannot be used to analyze the characteristics of farmers at the time of adoption. For example, simply noting that adopters have larger landholdings than nonadopters does not tell us whether those farmers who initially had larger landholdings were more likely to adopt the improved technologies, or the larger landholdings are a result of adopting the technology. We might expect that both would be true, but additional data would be necessary to draw such conclusions. Similarly, comparing farm size of adopters with that of nonadopters does not tell us much about whether new technologies are biased towards large farms. Large farm sizes may be an effect of adoption, not a cause. Extension may be correlated with technology use, but again the causal relationships may not be clear. Extension agents may identify farmers who are innovators and spend more time with them. Thus, being an adopter may result in more extension visits.

These examples suggest that researchers who examine current farmer and farm characteristics as explanatory variables for the current use of improved technologies should be careful interpreting results. The results should be interpreted as a correlation between current technology use and the characteristics. They should not be interpreted as saying that farmers with larger farms or more extension visits are more likely to adopt the technology.

In contrast, other variables are less likely to be endogenous to technology decisions. For example, in many places few adults gain formal access to education after they have begun farming. They may start to attend literacy programs or adult education programs, but the level of education reflected in their formal school attendance will probably reflect that at the time of adoption. In such cases, an education variable may provide some information about the impact of farmer education on adoption.[7]

One thing that clearly does not change based on the decision to adopt is the gender of the farmer. Thus, we can assume that any farmer who is now male was a male when he adopted the technology. However, we should remember that the farmer who is now farming the land may not have been the one who made the initial decision to adopt the improved technology. For example, a *de facto* female household head who was not originally involved in the decision to adopt improved varieties may continue to use practices originally initiated by her husband. In most cases, it should be relatively easy to determine whether this is an issue.

Thus, knowledge of the context and a good understanding of causal relationships is important for interpreting the results of adoption studies. In many previous studies, some of the analyses appear to treat variables as exogenous, when in fact they are clearly endogenous. Where endogeneity is systematic, we need to remember that regression analysis can still provide information about correlations, even if it does not provide evidence of causality. It may be useful to learn that the farmers using a technology are wealthier, use credit, and plow with oxen. However, we should not interpret the results as meaning that farmers who are wealthier, use credit, and plow with oxen are more likely to adopt new technologies.

**Representative Samples**

For micro studies to have broader usefulness, a key issue is to ensure that the samples are appropriately selected. Most of the CIMMYT studies in Eastern Africa focused on areas where adoption levels were known to be high. Although deliberately targeting these areas was useful as a first step to show that some areas did in fact have relatively high levels of adoption, it did not explain why some areas had adopted and others had not.

For the CIMMYT studies in Ethiopia, Kenya, and Uganda, sites were chosen in areas where wheat or maize was particularly important. Within each area, several villages were chosen to represent the range of agroecological conditions in the region. Within these villages, farmers were randomly selected to be interviewed. Thus, the studies used a random sample of farmers in selected locations. A slightly different approach was taken for a survey of maize farmers in Tanzania. In this case, the decision was made to survey one thousand maize farmers. Each region was allocated a specific number of interviews, based on the relative importance of maize in that region. Within the regions, specific survey sites were purposively chosen. Farmers were then randomly chosen.

[7] Of course, farmers' education may be correlated with wealth or other variables that might also affect adoption.

The survey design and sample selection methods used in these studies raise a number of questions. Although it is valuable to know how farmers are adopting new technologies in the main centers of production, surveys of this kind do not generate much information about aggregate impacts. For this, we need samples that can be generalized up to some higher level of aggregation. The Tanzania study is better in this respect than the others, but none of the studies shows how farmers are adopting technology in the more marginal lands. If new varieties are encouraging the spread of maize or wheat production into new areas, we will miss it. Nor can we be confident that the studies are providing representative information even at a more micro level. In fact, several studies specifically acknowledge that the study areas were not representative; for example, when the sites were chosen for ease of access (e.g. Bale Highlands, Ethiopia; Wolmera Woreda, Ethiopia). It seems likely that many of these areas may have relatively high levels of adoption compared with other areas, but there is no way to know this from the data collected.

Ideally, samples should be selected in such a way that generalizations can be made about adoption levels for a country or region or some other aggregate level, such as an administrative district or an agro-ecological zone. Or they should be selected in such a way that generalizations can be made about groups of farmers, such as large-scale farmers, small-scale farmers, commercial farmers, subsistence farmers, male farmers, or female farmers. This may be done through representative samples. In some instances, it may be useful to oversample some areas to obtain enough data on particular regions or farmer categories for results to have statistical significance for the particular group. In these cases, the sampling weights should be made available so that it is possible to generalize to a larger scale. Using a sample that is representative of maize or wheat growing areas is problematic if we are concerned about national-level policies, given that these are likely to change in response to new technologies.

Representative samples will allow the data to be used more readily for impact assessment. There are three major types of impacts that we might be interested in: productivity; poverty and health; and environment. Most micro studies do not in themselves collect enough data for adequate impact assessment. Yet, if the data sets are representative, we may be able to use the data, in conjunction with data from other sources, to perform some kinds of impact assessment.

## Problems of Designing Studies to be Pooled

Even with one-time, cross-section studies, with some care it is possible to collect data in such a way that comparisons are possible across study sites and through time. To keep this possibility open, however, it is important to exercise considerable forethought in the design of the surveys. If concepts are defined in similar ways and data are recorded in a comparable fashion, the data from disparate micro studies can be combined for various types of meta-analysis. This can be particularly useful for analyzing the "big issues" that cannot be addressed within a single micro study. For example, no single micro study can effectively address the impact of government policies or institutions on technology adoption. But a coordinated set of comparable studies might yield information of this kind. If the studies are not designed to be compatible, however, no amount of *ex post* analysis will be able to get at the larger questions. For example, the CIMMYT Eastern Africa studies might have been much more useful for meta-analysis of the effects of agroecology or policy on technology adoption, but the studies were not designed with this goal in mind.

**Compatibility of Definitions and Concepts**

Several key variables were defined differently across the CIMMYT studies, making it difficult to compare features across sites. To keep open the possibility of meta-analysis or synthetic analysis, it is important to pursue some degree of compatibility in definitions and concepts across studies. As noted above, for example, it is important to have comparable definitions of technology adoption, so that outcomes can be effectively compared across study sites. But this issue is not limited to the definition of adoption.

Consider the question of how the agricultural potential of an area affects adoption. The influence of agricultural potential can be assessed to some extent within individual micro-surveys, if information is collected from individual farmers on agricultural potential. A more revealing analysis could come from cross-study comparisons, since there is more variation. To make cross-study comparisons, however, we need comparable measures of potential. To compare across studies, we would need to collect quantitative information on agricultural production, such as rainfall levels and patterns and soil type and fertility. Quantitative measures that can be directly compared are required, rather than simple, qualitative judgments that one study site has a higher potential than the other. In the CIMMYT studies, phrases such as "high potential area" are used to describe villages in different studies, but the definitions of "high potential" are not easily comparable. A high potential maize area in Tanzania may in fact have lower potential than a "moderate potential" site in Kenya.

Next, consider a comparable question about market access. We would expect that areas with higher levels of market access would have greater levels of adoption, since market access is necessary for purchasing inputs and selling outputs. To examine this, we need to collect information on access to markets for inputs and for outputs. Some of the information needs to be at the level of individual farmers: how far do they have to go to the nearest local market? In addition, we need to collect information on the distance to the nearest major market. Distance measures should be in miles (or kilometers), time, and cost.

Information on other institutions related to market access might also be useful. In particular, information on credit availability and local labor markets may be needed. For credit, it might be important to know whether there are formal credit facilities and where they are located. In addition, we need to know what the requirements are for farmers to obtain credit. (If the practice differs significantly from the rules, then both should be noted.) If there are informal sources of credit, including savings and credit associations or moneylenders, this information may also be important. Using this information, it may be possible to gain a sense of whether credit is available to farmers in the area. The extent to which there are functioning, local labor markets will affect the ability of farmers to obtain labor and cash for purchasing other inputs. But these variables must be recorded in some fashion that allows comparison across study sites and, preferably, across moments in time.

Similarly, to address questions about the intensification of agriculture and the adoption of technology, it is useful to have compatible measures of land use and population distribution across study sites. Regional measures of population density do not necessarily tell us about the pressure on agricultural land, since not all of the land may be suitable for agricultural production. It may also be useful to have farmers' perceptions on whether there are shortages of land or whether additional land is available to expand agricultural production.

## Conclusion and Recommendations

Many of the issues that motivate adoption studies are "big issues"—for example, the types of policy and market environments that best support the adoption of improved technologies. These are not easily elucidated via small sample studies carried out in geographically limited areas. But several fairly simple procedural changes can both improve micro-level analyses and make it possible to compile the micro-level studies into broader syntheses that address big questions.

**Representative Sampling**

Organizations carrying out micro-level studies should be careful to pursue sampling approaches that allow the data to be generalized to higher levels of aggregation. With representative sampling, there is more potential to address the questions of interest to policy makers and agricultural researchers.

**Setting Standards and Definitions**

Organizations carrying out adoption studies should strive to adhere to standard formats and definitions. CIMMYT could play an important leadership role by developing guidelines for two aspects of data collection. First, it could design and promote a community survey to collect appropriate data on infrastructure, institutions, and agroecological conditions for each study site in a format that would be standardized across communities and countries so that comparisons could be made. Second, CIMMYT could work with other organizations to establish a typology for defining technology adoption that incorporates several levels of adoption (e.g., for seed: local varieties, recycled improved varieties, new seed for improved varieties) and allows distinction between full adopters, partial adopters, and those who have disadopted improved technologies after trying them. This would allow for a more nuanced understanding of technology adoption, and again allow for cross-country comparison.

**Data Storage and Documentation**
Considering the high cost of primary data collection, it is important that survey data be fully exploited—not only by those who conducted the research, but also by other researchers who may have additional questions and techniques. For this to be possible, it is important to document and store survey data in ways that will facilitate their use by others. This includes making the questionnaires, codebooks, and data available. The questionnaires are not available for the CIMMYT studies. Without documentation, including the specific wording of questions, some of the data are difficult to interpret. For example, one codebook indicates a variable on storage problems, with five possibilities listed. But it is not clear whether farmers were asked to indicate all problems, the most important problems, any problems that they themselves had experienced, or problems facing farmers in the area. Thus, the value of the studies has been limited by the loss of original materials. Moreover, several of the data sets were eventually corrupted and the data are no longer available. Thus, any further analysis must rely on the results reported in the papers, rather than new analysis of the data. Since some reports are vague on important points, such as the definitions of concepts such as "adoption," the results become hard to interpret and compare.

These problems point to the need for all international organizations involved in micro surveys to standardize their procedures for the documentation and storage of data. The data and all documentation should be carefully handled with the intention of making all of it publicly available—preferably on the web—soon after the data are collected and cleaned. Although documenting the data is time consuming, much of the value of the study is lost if explanatory materials are not available for additional analysis. With appropriate documentation, the data can be analyzed later to answer new questions and farmers can be re-surveyed at a later date to obtain additional data.

**Rethinking the Assumptions Underlying Adoption Studies**
Finally, it is important that researchers involved in adoption studies re-think the implicit assumption behind most of these studies—namely, that the "improved technology" is better than existing technologies, so that farmers need to be convinced to use these new and better technologies. There is some recognition that farmers face constraints, such as the lack of credit, but implicitly most adoption studies assume that new technologies are better.

There are three reasons why farmers do not adopt improved technologies. The first is simply that they are not aware of the technologies or the fact that the technologies could provide benefits for them. Farmers may also have misconceptions about the costs and benefits of the technologies. The second reason is that the technologies are not available, or not available at the times that they would be needed. The third reason is that the technologies are not profitable, given the complex sets of decisions that farmers are making about how to allocate their land and labor across agricultural and non-agricultural activities. The technologies may be unprofitable because appropriate varieties for the farmer's agroecological conditions are not available. Alternatively, farmers may prefer characteristics that are found only in local varieties. Institutional factors, such as the policy environment, also affect the availability of inputs and markets for credit and outputs and, thus, the profitability of a technology.

Simply noting that a farmer has not adopted a "recommended" technology does not necessarily imply that the farmer would be better off if he or she did so. As researchers, we need to understand better the challenges that farmers are facing. We need to focus on the broader issue of how to increase agricultural production, realizing that new technologies may be a key component. Rather than asking whether farmers are using improved technologies, we need to be asking them about their levels of production and finding ways to increase it, through improved technologies, improved infrastructure and institutions, and improved policies.

To summarize, micro studies of technology adoption may provide valuable information. There are ways in which micro studies can be improved. Ideally, some can be turned into panel studies or combined with other micro studies to allow for richer cross-section variation. Institutions like CIMMYT can provide leadership in improving the quality of the studies that are carried out and in making sure that their results are sensibly interpreted and useful for developing agricultural policy.

# Appendix 1. CIMMYT Eastern African Adoption Studies

## Ethiopia

A. Tiruneh, T. Tesfaye, W. Mwangi, and H. Verkuijl. 2001. Gender Differentials in Agricultural Production and Decision-Makinga Among Smallholders in Ada, Lume, and Gimbichu Woredas of the Central Highlands of Ethiopia. Mexico, D.F.: International Maize and Wheat Improvement Center (CIMMYT) and Ethiopian Agricultural Research Organisation (EARO). p 62.

Getahun Degu, Wilfred Mwangi, Hugo Verkuijl, and Abdishekur Wondimu. 2000. An Assessment of the Adoption of Seed and Fertilizer Packages and the Role of Credit in Smallholder Maize Production in Sidama and North Omo Zone, Ethiopia. Mexico, D.F.: International Maize and Wheat Improvement Center (CIMMYT) and Ethiopian Agricultural Research Organisation (EARO). p. 24.

Abdissa Gemeda, Girma Aboma, H. Verkuijl, and W. Mwangi. 2001. Farmers' Maize Seed Systems in Western Oromia, Ethiopia. Mexico, D.F.: International Maize and Wheat Improvement Center (CIMMYT) and Ethiopian Agricultural Research Organisation (EARO). p 32.

Tesfaye Zegeye, Girma Taye, D. Tanner, H. Verkuijl, Aklilu Agidie, and W. Mwangi. 2001. Adoption of Improved Bread Wheat Varieties and Inorganic Fertilizer by Small-Scale Farmers in Yelmana Densa and Farta Districts of Northwestern Ethiopia. Mexico, D.F.: International Maize and Wheat Improvement Center (CIMMYT) and Ethiopian Agricultural Research Organisation (EARO). p. 29.

Bekele Hundie Kotu, Hugo Verkuijl, Wilfred Mwangi, and Douglas Tanner. 2000. Adoption of Improved Wheat Technologies in Adaba and Dodola Woredas of the Bale Highlands, Ethiopia. Mexico, D.F.: International Maize and Wheat Improvement Center (CIMMYT) and Ethiopian Agricultural Research Organisation (EARO). p. 26.

Alemu Hailye, H. Verkuijl, W. Mwangi, and Asmare Yalew. 1998. Farmers' wheat seed sources and seed management in Enebssie area, Ethiopia. Mexico, D.F.: Institute of Agricultural Research (IAR now EARO), and International Maize and Wheat Improvement Center (CIMMYT). p. 37.

Hailu Beyene, H. Verkuijl, and W. Mwangi. 1998. Farmers' seed sources and management of bread wheat in Wolmera Woreda, Ethiopia. Mexico, D.F.: Institute of Agricultural Research (IAR now EARO), and International Maize and Wheat Improvement Center (CIMMYT). p.30.

Regassa Ensermu, W. Mwangi, H. Verkuijl, Mohammad Hassena, and Zewdie Alemayehu. 1998. Farmers' wheat seed sources and seed management in Chilalo Awraja, Ethiopia. Mexico, D.F.: Institute of Agricultural Research (IAR now EARO), and International Maize and Wheat Improvement Center (CIMMYT). P 36.

## Kenya

Makokha, S., S. Kimani, W. Mwangi, H. Verkuijl, and F. Musembi. 2001. Determinants of Fertilizer and Manure Use in Maize Production in Kiambu District, Kenya. Mexico, D.F.: International Maize and Wheat Improvement Center (CIMMYT) and Kenya Agricultural Research Institute (KARI). p. 25.

Salasya, B.D.S., W. Mwangi, H. Verkuijl, M.A. Odendo, and J.O. Odenya. 1998. An assessment of adoption of seed and fertilizer packages and the role of credit in smallholder maize production in Kakamega and Vihiga Districts. Mexico, D.F.: Kenya Agricultural Research Institute (KARI) and International Maize and Wheat Improvement Center (CIMMYT). p. 36.

James Ouma, Festus Murithi, Wilfred Mwangi, Hugo Verkuijl, Macharia Gethi, Hugo De Groote. 2001. Adoption of seed and fertiliser technologies in Embu District, Kenya. Mexico, D.F.: Kenya Agricultural Research Institute (KARI) and International Maize and Wheat Improvement Center (CIMMYT).

Paul Gamba, Caroline Ngugi, Hugo Verkuijl, Wilfred Mwangi, and Frank Kiriswa. 2001. Wheat Farmer's Seed Management and Varietal Adoption in Tanzania. Mexico, D.F.: Kenya Agricultural Research Institute (KARI) and International Maize and Wheat Improvement Center (CIMMYT).

Wekesa E., W. Mwangi, H. Verkuijl, K. Danda, H. De Groote. 2002. Adoption of Maize Production Technologies in the Coastal Lowlands of Kenya. Mexico, D.F.: Kenya Agricultural Research Institute (KARI) and International Maize and Wheat Improvement Center (CIMMYT).

## Tanzania

Mussei, A., J. Mwanga, W. Mwangi, H. Verkuijl, R. Mongi, and A. Elanga. 2001. Adoption of Improved Wheat Technologies by Small-Scale Farmers, Southern Highlands, Tanzania. Mexico, D.F.: International Maize and Wheat Improvement Center (CIMMYT) and the United Republic of Tanzania. p. 20.

Kaliba, A.R.M., H. Verkuijl, W. Mwangi, A.J.T. Mwilawa, P. Anandajayasekeram, and A.J. Moshi. 1998. Adoption of maize production technologies in Central Tanzania. Mexico, D.F.: International Maize and Wheat Improvement Center (CIMMYT), The United Republic of Tanzania, and The Southern African Centre for Cooperation in Agricultural Research (SACCAR). p. 29.

Bisanda, S., W. Mwangi, H. Verkuijl, A.J. Moshi, and P. Anadajayasekeram. 1998. Adoption of maize production technologies in Southern Highlands of Tanzania. Mexico, D.F.: International Maize and Wheat Improvement Center (CIMMYT), The United Republic of Tanzania, and The Southern African Centre for Cooperation in Agricultural Research (SACCAR). p. 38.

Katinila, R., H. Verkuijl, W. Mwangi, P. Anadajayasekeram, and A.J. Moshi. 1998. Adoption of maize production technologies in Southern Tanzania. Mexico, D.F.: International Maize and Wheat Improvement Center (CIMMYT), The United Republic of Tanzania, and The Southern African Centre for Cooperation in Agricultural Research (SACCAR). p. 20.

Nkonya, E., P. Xavery, H. Akonaay, W. Mwangi, P. Anandajayasekeram, H. Verkuijl, D. Martella, and A.J. Moshi. 1998. Adoption of maize production technologies in Northern Tanzania. Mexico, D.F.: International Maize and Wheat Improvement Center (CIMMYT), The United Republic of Tanzania, and The Southern African Centre for Cooperation in Agricultural Research (SACCAR). p. 42.

Kaliba, A.R.M., H. Verkuijl, W. Mwangi, D.A. Byamungu, P. Anadajayasekeram, and A.J. Moshi. 1998. Adoption of maize production technologies in Western Tanzania. Mexico, D.F.: International Maize and Wheat Improvement Center (CIMMYT), The United Republic of Tanzania, and The Southern African Centre for Cooperation in Agricultural Research (SACCAR). p. 40.

Kaliba, A.R.M., H. Verkuijl, W. Mwangi, A. Moshi, A. Chilangane, J.S. Kaswende, and P. Anadajayasekeram. 1998. Adoption of maize production technologies in Eastern Tanzania. Mexico, D.F.: International Maize and Wheat Improvement Center (CIMMYT), The United Republic of Tanzania, and The Southern African Centre for Cooperation in Agricultural Research (SACCAR). p. 40.

Mafuru, J., R. Kileo, H. Verkuijl, W. Mwangi, P. Anandajayasekeram, A. J. Moshi. 1999. Adoption of maize production technologies in Lake zone of Tanzania. Mexico. D.F.: International Maize and Wheat Improvement Center (CIMMYT), the United Republic of Tanzania, and the Southern African Center for Cooperation in Agricultural Research (SACCAR). p. 39.

## Uganda

Ntege-Nanyeenya, W.M. Mugisa-Mutetikka, W. Mwangi, and H. Verkuijl. 1997. An assessment of factors affecting adoption of maize production technologies in Iganga District, Uganda. Mexico, D.F.: National Agricultural Research Organization (NARO), and International Maize and Wheat Improvement Center (CIMMYT). p. 30.

ISSN: 0258-8587

CIMMYT MR
INTERNATIONAL MAIZE AND WHEAT IMPROVEMENT CENTER
Apartado Postal 6-641, 06600 México, D.F., México
Worldwide Web site: www.cimmyt.org