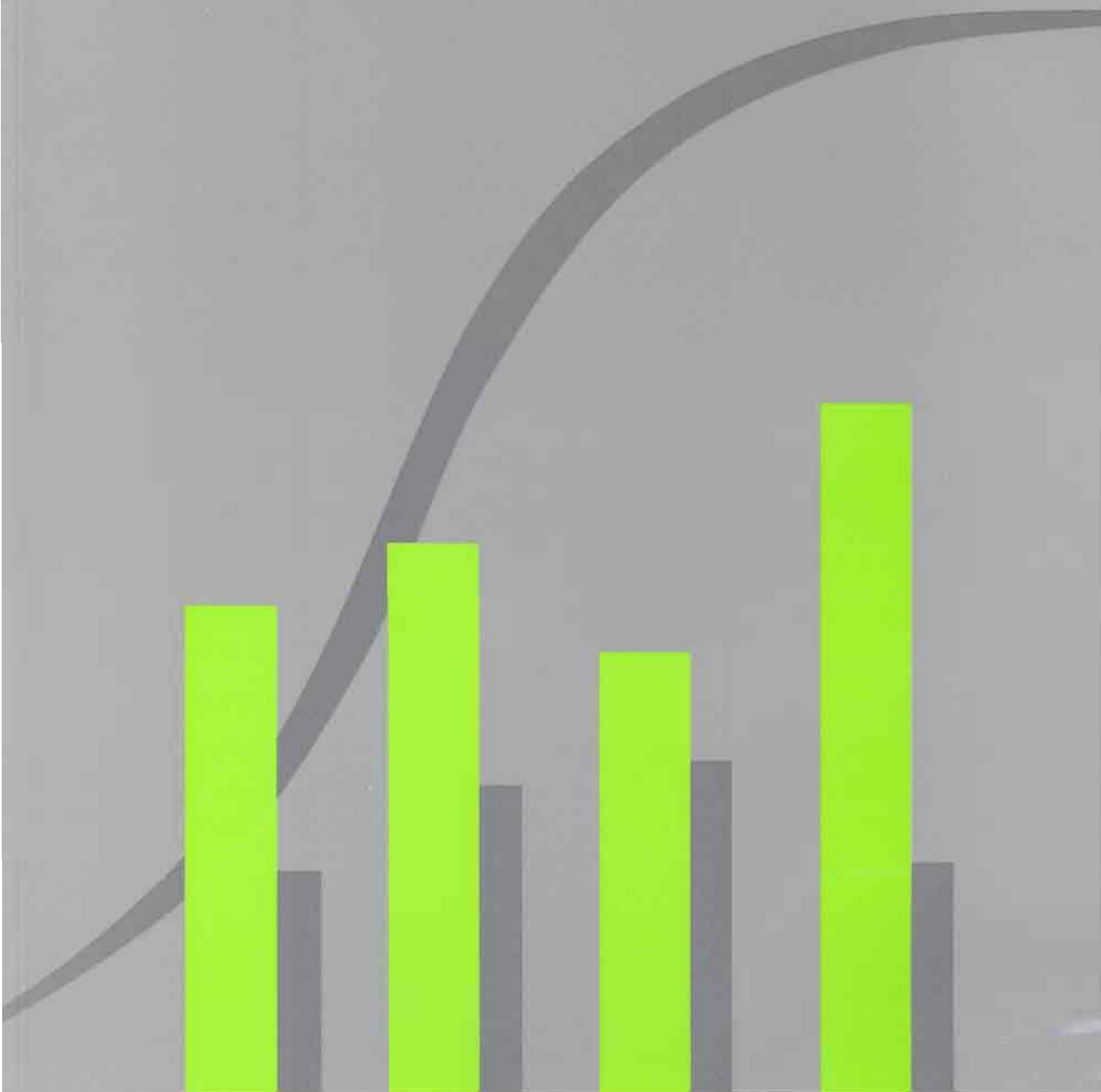
CIMMYT

The Adoption of Agricultural Technology:

A Guide for Survey Design



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The Adoption of Agricultural Technology:

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CIMMYT Economics Program

CIMMYT is an internationally funded, nonprofit scientific research and training organization. Headquartered in Mexico, the Center is engaged in a research program for maize, wheat, and triticale, with emphasis on improving the productivity of agricultural resources in developing countries. It is one of 17 nonprofit international agricultural research and training centers supported by the Consultative Group on International Agricultural Research (CGIAR), which is sponsored by the Food and Agriculture Organization (FAO) of the United Nations, the International Bank for Reconstruction and Development (World Bank), and the United Nations Development Programme (UNDP). The CGIAR consists of some 40 donor countries, international and regional organizations, and private foundations.

CIMMYT receives core support through the CGIAR from a number of sources, including the international aid agencies of Australia, Austria, Belgium, Brazil, Canada, China, Denmark, Finland, France, India, Germany, Italy, Japan, Mexico, the Netherlands, Norway, the Philippines, Spain, Switzerland, the United Kingdom, and the USA, and from the European Economic Commission, Ford Foundation, Inter-American Development Bank, OPEC Fund for International Development, UNDP, and World Bank. CIMMYT also receives non-CGIAR extra-core support from the International Development Research Centre (IDRC) of Canada, the Rockefeller Foundation, and many of the core donors listed above.

Correct citation: CIMMYT Economics Program. 1993. T*he Adoption of Agricultural Technology: A Guide for Survey Design*. Mexico, D.F.: CIMMYT.

ISBN: 968-6127-77-1
AGROVOC descriptors: Innovation adoption, agricultural development, farmers, technical progress, farming systems
AGRIS category codes: E14, E10
Dewey decimal classification: 338.064
Editing: Kelly Cassaday
Design: Miguel Mellado E.
Layout: Eliot Sánchez P. and Miguel Mellado E.
Printed in Singapore.

Contents

Abstract

This manual presents methods for designing formal surveys that measure and analyze the adoption of agricultural technology. First it discusses the rationale for undertaking an adoption study and the issues involved in determining the study's audience and scope. The manual then reviews factors that influence adoption patterns and should be considered in designing the survey: farm resources (e.g., farm size) and farmer characteristics (e.g., age, gender, education), the farming systems, post-harvest utilization and markets, and farmers' sources of information about new technology. Next, the organization of adoption surveys is discussed, giving attention to sampling issues and the timing of the survey as well as to overall survey design and implementation. The final section describes several analytical techniques that are useful for interpreting the results of adoption studies. Numerous examples from adoption studies conducted in Asia, Africa, and Latin America illustrate the main points.

Preface

This document is the latest in a series of manuals on research methods produced by the CIMMYT Economics Program. Our previous manuals have addressed themes of on-farm research planning and analysis, whereas this manual is concerned with methods for monitoring and evaluating the results of agricultural technology generation and transfer programs.

The manual focuses on the design of surveys that assess and analyze the adoption of agricultural technology. We are convinced that not enough effort has gone into carrying out and utilizing formal adoption studies. We have found that although there are a number of good sources on survey design and analysis, there is little available that could help researchers organize and plan a survey whose purpose is the measurement and analysis of technology adoption patterns.

As more attention is paid to the evaluation of agricultural research, and as research budgets come under more scrutiny, it is imperative that researchers have the capacity to measure the outcomes of their work and to use this information to refine their strategies and to document impact. We believe the methods described in this manual will be useful not only for agricultural researchers, but also for technology transfer agencies, rural development programs, and non-governmental organizations, all of whom need to be able to monitor and assess the progress of their work.

The first draft of the manual was written by Robert Tripp, who also managed the review process. Paul Heisey collaborated on subsequent drafts, which also benefited from contributions by Daniel Buckles, Michael Morris, Martien van Nieuwkoop, Larry Harrington, Miguel López-Pereira, Wilfred Mwangi, and Gustavo Sain. In addition, Louise Sperling (of the Centro Internacional de Agricultura Tropical, CIAT) and Willem Janssen (formerly of CIAT) provided thorough reviews and suggestions for improving the document.

We hope the manual will prove useful for helping to understand the adoption process. We welcome suggestions and comments from those who use it.

Derek Byerlee
Director
CIMMYT Economics Program

Chapter 1

Adoption Studies

Why Study Adoption?

There is no more distinctive feature of agriculture than its dynamism. Farming practices change continually. Farmers build on their own experience and that of their neighbors to refine the way they manage their crops. Changes in natural conditions, resource availability, and market development also present challenges and opportunities to which farmers respond. In addition, farmers learn about new technologies from various organizations, programs, and projects dedicated to research, extension, or rural development. These organizations develop and promote new varieties, inputs, and management practices. It is essential that such organizations be able to follow the results of their efforts and understand how the technologies they promote fit into the complex pattern of agricultural change in which all farmers participate.

This manual is focused on one method for studying agricultural change. It describes the design and management of farm surveys used to document and explain farmers' adoption of agricultural technology. Too little attention has been paid to this aspect of the process of agricultural technology development. The aim of this manual is to help strengthen institutional capacity to carry out such adoption studies. This capacity is important for agricultural research organizations that develop innovations for farmers, extension institutions that promote new technology, various types of rural development projects that introduce changes in agricultural technology, and a range of non-governmental organizations (NGOs) and community level efforts that are working to improve farming practices.

There are several reasons to invest in studying the adoption of agricultural technology. These include improving the efficiency of technology generation, assessing the effectiveness of technology transfer, understanding the role of policy in the adoption of new technology, and demonstrating the impact of investing in technology generation. Each of these is now discussed in more detail.

Monitoring and feedback in technology generation

Any program that attempts to develop and promote improved farming practices should be able to assess progress and use that information to make future actions more effective. One of the principal incentives behind the development of adaptive research methods such as farming systems research (FSR) or on-farm research (OFR) was the criticism that much agricultural research was being done on experiment stations, isolated from the fields, problems, and perspectives of client farmers. Many national agricultural research programs have now established location-specific adaptive research capacity that includes diagnostic surveys and on-farm experimentation. But few of these organizations regularly monitor technology adoption to improve the efficiency of adaptive research. It is not uncommon to find that a well-conceived program of agricultural research and extension has been carried out for a number of years in a given area but that none of the personnel involved can give any more than anecdotal evidence of changes that have taken place in farmers' practices, let alone the reasons for these changes. In many cases, the adaptive research is in danger of straying far from farmers' needs unless researchers have a way of monitoring farmers' experience with the new technologies being generated. For example, a new variety may have been tested on farmers' fields and promoted by extension. But unless some sort of monitoring is carried out, researchers will not know the degree to which the variety is actually being used. In addition, it will be very helpful to know what farmers see as the advantages of the new variety and what they perceive as its drawbacks, in order to provide feedback to plant breeders for refining their selection criteria.

The effectiveness of technology transfer

Most extension services are actively engaged in promoting new technologies with farmers. Resources are invested in various extension activities, such as field days or demonstrations, and the extension service may undergo considerable reorganization, such as with the training and visit (T&V) system (Benor and Harrison 1977). But only infrequently are resources reserved for monitoring the outcome of these extension efforts and using the analysis to understand why some recommendations or extension techniques are more successful than others. For example, if the extension service is recommending a green manure crop, it will be very useful to know what proportion of farmers are using the new practice. For those farmers who have not adopted, do they find disadvantages with the new practice, is the practice too far removed from farmers' knowledge base, or has the extension methodology not been effective in acquainting these farmers with the new technique?

Governments or donor agencies sponsor rural development projects in which the introduction of new agricultural technology plays an important role. Although these projects may represent a large investment of funds, the capacity to monitor progress is rarely a focus of project design. For instance, a development project may operate under certain assumptions about the possibility of improving tillage operations, and the effects this will have on yields and income. It is important to follow the degree to which project participants are actually changing their tillage practices and identifying any problems that have occurred.

It is often difficult to draw a line between technology generation and technology transfer. An effective adaptive research effort should involve both researchers and extension agents, for instance. There is growing emphasis on participatory research as well, in which farmers assume more responsibility for the identification and dissemination of new technologies. One good example is the efforts of NGOs to improve agricultural practices at the community level.

Many of these projects are effective at identifying the priorities of farmers and enlisting widespread participation of community members to investigate and promote innovations. But these projects rarely go to the trouble of documenting their results and assessing their progress to make future actions more effective. A project may generate considerable enthusiasm about the importance of improved crop storage, for instance, and several options may be available for farmers to try. But it is important to follow up on the actual number of farmers who make a change, to analyze which of the storage options they find most attractive, and to understand farmers' choices.

Thus there is a widespread need to place additional emphasis on monitoring the results of technology transfer and eliciting farmers' feedback. Organizations responsible for developing new technology need to know if the transfer process is functioning. Organizations responsible for promoting technology need to know if their message is being heard. And community or regional development efforts need to judge to what extent technological change is contributing to their goals.

The role of policy in technology adoption

Monitoring progress is necessary not only to improve the internal efficiency of research and extension efforts, but also to improve the effectiveness of interactions with other institutions, particularly those responsible for policy. Very often a research or extension effort falls well short of its goals because of lack of coordination between institutions. Adoption studies may show the potential for technology diffusion by demonstrating progress in areas where institutional coordination is good, or may analyze the problems in areas where technology diffusion has been slow.

Adoption studies are also useful for illustrating the degree to which acceptance of new technologies is limited by insufficient inputs, credit, or marketing infrastructure. If it appears that farmers are unable to take advantage of a new technology because they lack inputs, this information can be presented to policymakers who have responsibility for the agricultural inputs that are available and the way they are distributed. If an adoption study shows that access to credit significantly influences the type of technology that farmers use, then this information may be presented to those responsible for designing and funding credit programs. Similarly, adoption studies may be used to highlight marketing bottlenecks that limit the acceptability of new technologies.

Effective communication between researchers and policymakers is not very common. It will take more than a few adoption studies to establish good links among researchers, extension personnel, national policymakers, and public interest groups. But the information from a well-conceived and effectively presented adoption study can be very useful for improving this type of communication.

Measuring the impact of technology generation and transfer

Another important use of the information from adoption studies is to assess the impact of agricultural research and extension and to measure the returns to investments in these activities. Research and extension institutions are often engaged in a battle to maintain their budgets, and this implies the necessity for demonstrating results. Adoption studies are an important tool for measuring and assessing impact. They also provide data that can be used to estimate the returns to investment in research or extension. Such an analysis may be used to justify further investment in these sectors or to help identify the most productive opportunities for investment within research or extension.

An important question on the minds of policymakers is who benefits from new technology. Adoption studies may be designed to document what kinds of farmers and what areas of the country have profited most from the development of a particular technology.

The evaluation of impact and returns to investment is also a common feature of rural development projects, but these evaluations are often done without access to solid data on adoption. Even NGO projects need to spend more time documenting progress and analyzing the effectiveness of their investments. As more donor attention is directed to the option of NGO contributions to agricultural change, these organizations will come under increasing pressure to present well-documented evidence of their accomplishments.

Contributing to the literature on adoption

There is a very large body of literature on the adoption of agricultural innovations (Rogers 1983; Feder, Just, and Zilberman 1985). The methods described in this manual can add to that literature, although their principal purpose is to serve institutions involved in promoting agricultural change rather than to contribute to the theory of adoption. Many academic studies on adoption assume that the technology is appropriate and tend to concentrate on identifying the characteristics of farmers who are likely to adopt. The kind of study described in this manual faces the more difficult challenge of not only describing patterns of adoption but also understanding whether or not the technology and its institutional environment are adequate to the needs and resources of farmers. This type of adoption study must be done with an open mind; its purpose is not to promote a particular technology but rather to help research and extension be more effective in responding to farmers' needs.

The following chapters are concerned with adoption studies that help describe, evaluate, and understand the process of technological change. It is assumed that the principal audience for the studies will be staff of research and extension institutions (public or private), and of other institutions at the national level that are responsible for assessing or setting policies and allocating funds that determine the scope and direction of agricultural development.

Ways of Studying Adoption

The process of agricultural research

Although this manual focuses on the design and analysis of formal adoption surveys, it would be misleading to think of adoption as something that is the subject of a single study conducted at the end of a research effort. Monitoring changes in farming practices and assessing the adoption of new technology should be important elements of the entire research process.

When a program of research or extension is being planned, it is essential to get a clear idea of what type of changes or technologies would be acceptable to farmers. Diagnostic surveys provide information on farmers' current practices and concerns (Byerlee, Collinson, et al. 1980). To the extent that these surveys assess the distribution and rationale for farmers' present use of technology, they can be thought of as "adoption studies" for previous technology generation efforts. Information from such surveys and from other sources needs to be carefully considered in planning a research agenda (Tripp and Woolley 1989), and a growing number of techniques are available for improving farmer and community participation in the planning process (Farrington and Martin 1988).

As research is carried out, and especially as experiments are planted in farmers' fields, it is essential to obtain continuous feedback from farmers. It is a waste of resources to conduct several years of research on a technology only to discover that farmers find it unacceptable. There are several ways of monitoring on-farm experiments. One basic strategy is simply to make sure that farmers are consulted when researchers or extension agents visit field sites and that farmers' opinions are recorded and analyzed (Tripp 1982). Other techniques are available for ensuring that farmers participate in the evaluation of technologies being tested. Guidelines have been designed to help elicit and utilize farmers' reactions to experimental treatments (Ashby 1990) (see Box 1 at the end of this chapter). Farmer groups have also been helpful in planning and monitoring on-farm experiments (Norman et al. 1988).

Methods for assessing adoption

Although constant monitoring of farmers' opinions and experience is essential during the design and testing of agricultural technology, it is also necessary to carry out some sort of assessment after a new technology has been recommended or introduced. The type and the timing of the assessment will depend on the purposes of the study.

This manual describes the design and analysis of formal survey instruments for assessing the adoption of agricultural technology. A formal survey of technology adoption is one of several kinds of studies that can be done to assess adoption (Box 2). As mentioned in the previous section, it is important to have a continual interchange between farmers and researchers as technology is being developed and tested, and this interaction provides the first indication of whether or not a new technology is acceptable. Another way of assessing a technology's acceptability is by following up on what farmers who have hosted experiments do the following year.

Once a technology has been released or an extension program has been initiated, it is possible to study a random sample of farmers to analyze the degree of adoption. An informal survey (similar to the informal diagnostic surveys used to help set priorities for a research program) is very useful for providing researchers with preliminary feedback about the acceptability of a technology. It can also provide information about policy-related problems that may impede the spread of a technology. An informal survey may be sufficient for analyzing adoption patterns, but more often the type of formal survey described in this manual is necessary. Formal surveys generate quantitative information that is useful to decision makers and are better able to explore some of the complex issues in understanding variability in adoption among farmers. But it is assumed that such a survey will be carried out as part of a research or extension effort that has been well planned and executed and has included various opportunities for assessing farmers' opinions and practices along the way. It is also assumed that the design of the questionnaire is preceded by a good informal survey that helps researchers identify key issues to be pursued in the questionnaire.

The results of a formal adoption study can be combined with other data on changes in farm production, farm incomes, or consumer gains to develop a more complete impact study. There are also other ways of studying the spread of a new technology. Data from an agricultural census may provide some idea of the degree to which farmers use a particular technology. If a new technology involves purchased inputs, for instance, surveys of input merchants may be useful for assessing the spread of the technology.

Summary

All institutions that are involved in generating agricultural technology should have the capacity to carry out studies that document the degree of adoption and help explain the rationale for farmers' decisions. Adoption studies can be useful for several purposes, and a decision about the audience for the study must be taken before the study is designed.

The information from an adoption study can be used to:

1) provide feedback from farmers that is helpful in refining the technology generation effort;

2) assess the effectiveness of a technology transfer strategy;

3) improve the flow of information between research and extension, on the one hand, and policymakers, on the other; and

4) document the impact of a technology generation or extension effort.

This manual describes the design of formal surveys for studying adoption. A formal survey is a particularly useful method, but it must be seen as part of a wider range of activities that are used to make technology generation as efficient and as responsive to farmers' needs as possible.

After defining the audience for an adoption study, the next step is to carefully define what changes are going to be measured. The following chapter describes various factors related to measuring adoption.

Box 1. Interview Form for Farmer Evaluation of Experimental Treatments

Cassava Varieties Open Evaluation

Variety G-1786 **Farmer** LUIS BETANCOURT

Farmer's Comments

HAS HIGH STARCH, NOT "WATER", "DRY", IS "FLOURY". THE "SKIN" IS WHITE, AND FLESH "CREAMY", A DISADVANTAGE BECAUSE PINK SKIN IS GETTING A BETTER MARKET PRICE,

THIS PLANT IS "MEDIUM" IN HEIGHT

"I LIKE THIS BECAUSE VERY TALL PLANTS ARE DIFFICULT TO HARVEST. BUT IT BRANCHES VERY CLOSE TO THE GROUND. THIS MAKES WEEDING DIFFICULT. THIS WILL HAVE TO PLANTED FURTHER APART TO MAKE WEEDING EASIER, SO THE PRODUCTION WILL BE LOWER. "THIS HAS A GOOD NUMBER OF ROOTS - THE YIELD WILL BE GOOD."
"IT IS DIFFICULT TO HARVEST. LOOK AT THE BROKEN ROOTS".

DISLIKED: (CAUSES STORAGE LOSSES DUE TO ROT WHEN ROOT IS DAMAGED)

"I WILL NOT PLANT THIS AGAIN BECAUSE YIELD WILL BE LOW AND THERE WILL HARVEST LOSSES"

Code for Comments:

Criteria	Positive aspects	Negative aspects
(a) Yield		
(b) Plant height	"MEDIUM"	
(c) Height of branching		LOW - DIFFICULT TO WEED
(d) Resistance (disease/pest)		
(e) Period(s) for harvest		
(f) Root appearance		
(g) Root rot		
(h) Starch content	DRY, FLOURY	
(i) Color of epidermis		WHITE
(j) Color of flesh (pulp)		CREAMY
(k) Root position on stem		NO PEDUNCULE - ATTACHED TO STEM
(l) No. of roots	ASSOCIATED WITH HIGH YIELD	
General evaluation		DISLIKED - LOW BRANCHING (YIELD)

Source: Ashby (1990).

Box 2. Studies Used to Assess Different Aspects of Adoption

Type of study	Timing	Sample size[a]	Purpose
Monitoring farmers' opinions of technology; farmer participation in experimental design	During experimental program	10-20	Refine research objectives to meet needs and conditions of farmers
Follow-up on acceptability with farmers who have participated in experiments (individual or group interviews)	1-2 years after experimental program	10-20	See if farmers keep using technology. Identify whether there are problems with its continued use.
Informal survey of technology adoption	2-4 years after release of technology and/or initiation of extension program	20-40	Provide feedback to researchers on feasibility of technology and feedback to policymakers on accessibility of technology. The study is a necessary step for designing a formal survey.
Formal survey of technology adoption	**2-4 years after release of technology and/or initiation of extension program**	**60-120**	**Provide feedback to researchers, information for policymakers. Contribute to impact assessment.**
Impact study	2-5 years after release of technology and/or initiation of extension program	60-120	Combine data on adoption from formal survey with estimates of yield/income gains and estimates of research and/or extension program costs.
Studies of technology use based on secondary data (e.g., agricultural censuses)	2-4 years after release of technology and/or initiation of extension program	n.a.	Use secondary data (such as agricultural census) to assess spread of new technology.
Interviews with input suppliers (e.g., seed sales agents)	2-4 years after release of technology and/or initiation of extension program	5-20	Estimate demand for technology. Detect bottlenecks in input supply system.

Source: This table borrows from a similar one developed by W. Janssen for training courses at CIAT.

[a] These sample sizes are only suggestive and may vary outside the ranges listed here, depending on the purpose of the survey and the proposed analysis.

n.a. = not applicable.

Defining Adoption

One of the most important issues in designing an adoption study is the definition of criteria for adoption. If we are interested in the diffusion of a new variety, for instance, what constitutes adoption? Are farmers who plant even a few rows of the new variety considered adopters, or do they have to plant a certain minimum proportion of their fields with the new variety? If we are interested in the adoption of crop management practices, how closely does the farmer have to follow a recommendation before being considered an adopter? Is any fertilizer use to be counted as adoption, for instance, or does the rate and timing of application have to fall within certain limits?

Although these may seem to be definitions that can be decided after the survey is completed, they need to be discussed beforehand because they can influence the sorts of questions asked to the farmer. An example of definitions of adoption for a survey that examined changes in weed control, planting practices, and tillage is shown in Box 3 at the end of this chapter.

In defining the criteria for adoption, it is also important to remember that although recommendations may be presented to farmers as a package of several practices, some components of the package may be adopted first, others may be adopted later, and some may never find widespread acceptance. The adoption study should therefore ask specifically about each component of the package, bearing in mind that individual components may be adopted at different times or under different conditions.

In many cases a survey will examine technological change in circumstances where farmers have several options from which to choose. For instance, the objective of an extension program may be to acquaint farmers with the principles of erosion control. Farmers may be able to take advantage of several appropriate crop management practices, and the survey should explore which ones farmers are using and the rationale for their choices. Similarly, farmers may make their own modifications to a new technology (such as a storage technique or a piece of machinery), and an adoption study needs to pay careful attention to this type of farmer innovation.

The adoption of a new technology may have implications for the rest of the farming system, and these attendant changes may be examined in an adoption study. Researchers will be pleased to see the widespread adoption of a new variety, for instance, but what effects does this change have on the use of other varieties and the genetic diversity in farmers' fields? In other cases the adoption of a new variety may bring about significant changes in other management practices. An example is shown in Box 4.

Another issue in measuring adoption is the fact that farmers often have several fields that may be subject to different management practices. Researchers need to decide whether to assess adoption on all fields or only the largest field, or on fields that have characteristics relevant to the new technology (e.g., examining soil conservation practices only on sloping fields). The answer to this question depends in part on whether it is necessary to estimate the total area where a particular technology is in use. If, for instance, researchers wish to estimate the proportion of crop area in a given region planted to improved varieties, then either all fields should be included in the survey, or fields rather than farmers should be randomly sampled. Asking farmers to estimate total area planted to different varieties is usually not difficult, but if the practice under investigation is more complex, such as the rate and timing of fertilizer application, then estimating the range and average for these practices will be more time consuming. If the average rate of input application is reported in the survey analysis, it should be clearly stated if the rates are only for those farmers who use the input, or are the average across users and non-users.

Investigating practices by individual field also has other advantages. One of the important ways of explaining differences in adoption behavior between farmers is to look at related aspects of crop management. It may be hypothesized that a particular weed control practice is used only in intercropped fields, for instance. This hypothesis on adoption can be tested only with field-specific information.

Sometimes there is more than one agricultural season per year. In this case, adoption may be assessed for only the most important season or for all seasons (Box 5).

In summary, the adoption of a new technology can be defined in several ways. In all cases, the definition of "adoption" needs to be agreed upon. Sometimes it may be sufficient simply to report on the proportion of farmers using the technology (at some defined level). In other cases, the actual proportion of fields or crop area under the new technology will need to be estimated. An example of several ways of reporting these results is shown in Box 6.

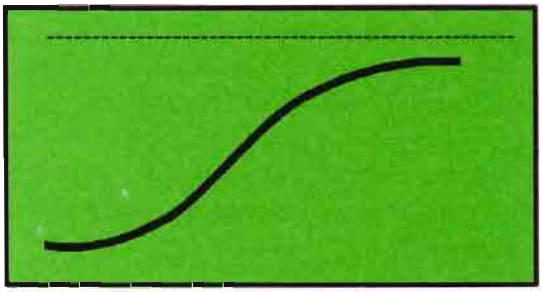
Describing Adoption: The Logistic Curve

Many adoption studies go beyond an analysis of current practices and attempt to document adoption history. Information about past seasons requires more time to obtain, but can be very useful. Ideally, information on past practices and adoption history would come from baseline surveys, but such information is often not available.

Not all adoption studies will want to analyze historical change, but such analysis can be useful for several purposes. It may help project future demand for inputs, determine whether extension needs to be strengthened, or quantify the change in the number of technology users over time to assess impact.

It is useful to distinguish between adoption, which is measured at one point in time, and diffusion, which is the spread of a new technology across a population over time (Thirtle and Ruttan 1987). Much of the literature on diffusion assumes that the cumulative proportion of adoption follows an S-shaped curve in which there is slow initial growth in the use of the new technology, followed by a more rapid increase and then a slowing down as the cumulative proportion of adoption approaches its maximum (which may be well below 100% of the farmers).

The most common function used to portray the curve is the logistic function. For technology adoption, the y-axis represents the proportion of farmers or area adopting a technology and the x-axis represents time.



This curve can be described mathematically:

$$Y_t = K / (1 + e^{-a-bt}),$$

where:

Y_t = the cumulative percentage of adopters or area at a time t;

K = the upper bound of adoption;

b = a constant, related to the rate of adoption; and

a = a constant, related to the time when adoption begins.

If we have sufficient observations on Y_t, we can estimate the three unknown parameters K, a, and b with a non-linear regression. For practical purposes, however, this very difficult technique can be replaced with an ordinary least squares regression if we have at least three observations on

Y_t and we can estimate K (the maximum adoption expected) independently. In this case, we note that the equation of the logistic curve can be transformed to:

$$\ln \left(\frac{Y_t}{K - Y_t}\right) = a + bt .$$

Simple ordinary least squares regression of the transformed variable $\ln [Y_t / (K - Y_t)]$ on a constant and time will then yield estimates of a and b (Griliches 1957). This kind of calculation is easy to do with many spreadsheet packages. One could also fit a curve *without* regression with only two observations, although the information from only a few observations is likely to be limited (see below).

There are several methods of estimating K. The first is simply to plot the data and to choose the level that appears to be the upper bound of adoption. A second method is to run the regression using different values of K and choose the one that maximizes R^2. (This is also readily accomplished with most spreadsheets. It should be noted that in general, R^2 and t-statistics from these regressions have no statistical meaning. This technique only helps to choose K to get a fairly close fit to the data.) To reduce the time spent selecting K, a combination of simple plotting and experimental regressions might be used.

Although the logistic curve is the most common way of representing technology diffusion, it is well to remember that it is based on certain assumptions about diffusion, and that the fixed parameters estimated for the curve imply that the relevant price ratios, infrastructure, and the technology itself have remained constant over the period when the curve is fitted. An example of a logistic curve is shown in Box 7.

Time Frame

It is also important to remember that not only is the diffusion of a new practice among farmers a gradual process, but that individual farmer testing of technology may follow the same type of curve. If possible, a farmer will test a new technology on a small part of the farm, and if the results are positive will gradually increase the use of the technology. Box 8 shows this process for a new variety.

If an adoption study examines a number of different practices, whether or not they have been presented to farmers as a technological package, it is important to consider the relationships among the adoption patterns. In some cases, different elements may be adopted independently, while in other cases there may be a sequential adoption pattern, as shown in the example in Box 7. Sometimes certain elements will likely be adopted together, either because of biological complementarities between them or because farmers are provided incentives (e.g., a credit package).

Although it is important to remember that actual diffusion patterns may not follow the smooth theoretical curves, historical data on adoption provide valuable information about trends and prospects for a new technology. These data allow one to see when adoption began and to judge the degree to which research or extension programs were in fact responsible for the introduction or spread of the technology. This information also allows for an estimate of the rate of adoption and predictions about future progress.

One problem with these estimates, however, is that they assume cumulative adoption — that is, once a farmer begins using the technology, he or she will keep using it. In some cases this is not correct, and many farmers may have one or more years of experience with the technology only to have subsequently abandoned it. One way of investigating this phenomenon is to compare current use with past use (Box 9). It may be that a significant proportion of farmers has experience with the technology but very few currently use it. If this is the case, it is worth trying to get information on why farmers have stopped using the technology. This comparison between past and current use is relatively straightforward. More detailed information on historical patterns of adoption, use, and disadoption requires questioning on year-by-year use of a technology, which is often quite difficult.

Besides looking at past patterns of adoption, it is sometimes tempting to try to assess future trends by asking farmers their plans for using a technology the following year. Although it is often valuable to obtain farmers' opinions about the feasibility of using a technology and identifying what its attractions and drawbacks might be, this information cannot be used to assess adoption. Statements about what a farmer would like to do, is interested in, or hopes to do, are not substitutes for data on actual technology adoption.

The adoption literature also refers to differences between early and late adopters (Rogers 1983). In the case of technologies that depend on purchased inputs, for instance, the first farmers to adopt a new technology may be larger-scale farmers or those with more resources or capacity to experiment with new practices. In some cases a technology may be appropriate only for this type of farmer and does not diffuse any further. In other cases farmers who have fewer resources also adopt the technology, or it may be that the technology is in fact more appropriate for these farmers. In any case, it may be important to draw a distinction between earliness of adoption and the current degree of adoption (Box 10).

Measuring Impact

Earlier sections discussed ways of estimating the degree of adoption of a new technology. These included measures of the proportion of farmers, cropped area, or harvest. If the adoption study has been done to help provide some measure of the impact or importance of the research or extension effort, it will be helpful to convert these figures so that the actual amount or value of the increased production (or other benefits) resulting from adoption can be estimated. This may require some additional questions on the survey, as well as complementary information.

If the benefits of the new technology are largely expressed as increased yield, the first step is to estimate yield changes due to adoption. There are several ways of doing this. The adoption survey itself may be a source of yield data. Farmers may be asked to estimate their yields from particular fields, or crop cuts may be taken as part of the survey. Reliable yield estimates, either by farmers' reports or by crop cuts, are not particularly easy to obtain, however, and the reader is referred to Poate and Casley (1985) for advice on appropriate methods. Even if good yield estimates are obtained from the survey, it will be difficult to find farmers who manage comparable fields in which the only difference is the adoption of the technology under study, or to find comparable farmers who use and do not use the technology, to provide firm estimates of yield differences that can be attributed to adoption. Year-to-year variations caused by climatic factors make it very difficult to use data from the same farmer across several years to estimate yield changes due to technological change.

A better way of obtaining data on yield differences that have occurred because of the new technology is through experimental data. If the recommendations have been derived from on-farm experiments, then yield estimates should be available comparing farmers' practice with the new practice. Caution must be exercised in using experimental data, however, to ensure that the yield estimates for the new technology were obtained under typical farmers' management, rather than researchers' management. Comparisons between new and traditional technology under researchers' management often give misleading results.

Once the yield difference has been estimated, it is possible to assign a value to the increased yield and calculate the total value of increased production resulting from adoption in the study area. The simplest approach is to assume that widespread adoption has not affected prices, but when this is not the case, price effects must be accounted for. If a diffusion curve has been calculated, this can be used to estimate the stream of benefits over time. This figure will provide some idea of the value of the product of the research effort. It may also be important to obtain an estimate of the increased income for farmers who have adopted the new technology. Such an estimate will require good data on the variable costs of the technology. Estimates of the benefits of a new technology should be balanced against possible costs implied by changes in other parts of the farming system (for example, if a new technology leads to a change from intercropping to monocropping). The long-term sustainability of a new practice may also need to be examined when considering costs and benefits.

If the research program has been planned carefully, with due attention to developing technologies appropriate for specific groups of farmers ("recommendation domains"), then the adoption study may hold few surprises regarding the distribution of the technology. But often unexpected or unexplored factors influence the actual distribution of a new technology or of its benefits. Although the "average" impact in terms of yield or income gains may be impressive, which farmers are able to take advantage of the change? Are many excluded from using the new technology? Answers to these questions may be sought by ensuring that the adoption survey covers a wide range of farmers, placing special emphasis on the resources available to farmers. Thus the survey should seek to assess the experiences of larger- and smaller-scale farmers, those who have access to credit and those who do not, and so forth. These factors are discussed in more detail in Chapter 3.

More complex questions may also be asked about the distributional impacts of a new technology. Not only is it important to understand how a new technology is used by different types of farmers, it is also important to see how the benefits of the technology are distributed among various sectors of the population. Is it farmers or consumers who gain most? In the farming sector, how is the extra income divided among landowners, tenants, and laborers? Do male farmers gain at the expense of female farmers? Does the technology increase or decrease the demand for labor, and how does that affect the incomes of the poorest sectors of the population? An example of this kind of analysis is shown in Box 11. The answers to most of these questions go beyond the basic adoption study described in this manual, but such adoption studies are a necessary part of research on the distributional impacts of technological change. Further discussion of these issues can be found in Barker, Herdt, and Rose (1985, Chapter 10) and Lipton with Longhurst (1989).

The Role of Adoption Studies in Assessing the Returns to Research and Extension

One of the reasons for doing an adoption study is to provide evidence of the returns to a research or extension effort. This analysis is done by comparing the investment in the technology development effort to the value of the results, measured in terms of yield or income gains. Although this manual does not pretend to provide guidance for this complex type of study, it should be obvious that the results of a good adoption study are an essential element for a benefit-cost analysis of an agricultural technology generation program.

If the adoption study is to be used for this purpose, it is quite likely that additional information, beyond the degree and distribution of adoption, will be needed. In particular, the survey will need to collect evidence that allows the change in technology to be attributed clearly to the research or extension program under examination. The information required includes evidence of the similarity between the farmers' new practice and the recommended technology, assurance that farmer adoption took place after the recommendations became available, and evidence that the information utilized by farmers had its origin in the research or extension program. If the only change being examined is the adoption of a new crop variety, then it is usually easy to collect this information and attribute the change to a particular research program. But obtaining similar information for crop management practices may be considerably more difficult (Box 12).

In some cases it will be necessary to distinguish between returns to research and returns to extension. If a study is to estimate the returns to one or the other of these activities, particular care must be taken in separating the two, and in examining to what extent research and extension are substitutes or complements. Assessing the returns to extension programs is quite challenging; a review of recent literature and advice on the organization of such studies can be found in Birkhaeuser, Evenson, and Feder (1991).

Once the extent and value of the technological change has been documented and it is possible to attribute a definite proportion of this change to the research or extension program, the benefits of this change are compared to the costs of that program. A standard reference for benefit-cost analysis is Gittinger (1982), and a review of methods for evaluating the returns to agricultural research is presented by Norton and Davis (1981).

Summary

In designing an adoption study, care must be taken to define precisely what technologies are being considered. It is likely that changes in farmers' practices will represent a combination of farmer adaptations to new technology, farmer innovation, as well as other changes external to the technology generation effort.

Decisions must also be taken regarding how to measure adoption. Is the objective to see if farmers are using a practice on any part of their farms, or is it necessary to quantify the area planted or to measure the proportion of yield produced with the new practice?

What time frame is of interest? Is the objective to assess adoption in the current year, to try to establish a history of first use, to explore the diffusion process, or to examine patterns of continued use or abandonment of technology?

If the objective is to help assess impact, the study needs to be able to demonstrate a connection between changes in farmers' practices and the research, extension, or community development effort. The survey should develop information that establishes a causal link. The survey may also need to provide evidence regarding the adoption of the technology among different classes of farmers, in order to further analyze impact. The survey may also provide an opportunity to develop some of the additional information necessary for assessing impact, such as yield or income changes, as well as evidence of other changes attendant on the new technology, such as changes in labor patterns or land use.

Besides clearly defining and documenting the degree to which farmers have changed their practices, an adoption study is also useful for understanding the rationale behind these changes. The following chapter examines some of the factors that help us to understand adoption patterns.

Box 3. Variables and Criteria Used for an Adoption Study on Weed Control, Planting Practices, and Tillage

For each of three technological alternatives in a maize on-farm research program in Panama, a series of acceptance criteria were defined. These criteria allow for a range of definitions of adoption (e.g., it is possible to distinguish those farmers that have adopted the herbicide only from those that use the herbicide at the recommended time and rate).

Technological alternative	Discriminant variables	Acceptance criteria
Chemical weed control	1. Chemical weed control	1. If the farmer uses chemical weed control
	2. Type of product	2. If the farmer uses Gesaprim or Gramoxone
	3. Application time	3. i) Gesaprim: 0-5 days after planting ii) Gramoxone: 0-35 days after planting
	4. Application rate	4. i) Gesaprim 1-3 kg/ha ii) Gramoxone 1-3 lt/ha
Spacing arrangement and density	1. Planting arrangement	1. If planting is done in rows
	2. Density	2. 45,000 - 60,000 plants/ha
Zero tillage	1. Tillage system	1. If the farmer does not use mechanical tillage
	2. Application of herbicides	2. If the farmer applies herbicides prior to planting

Source: Martínez and Sain (1983).

Box 4. Describing Changes Related to Adoption

In some cases, the adoption of a new technology leads to other changes in the farming system. If these changes are of interest to researchers, they can be analyzed in an adoption study. The example below shows that many farmers in Peru who adopted a new bean variety also changed some of their management practices because of the new variety's characteristics.

Percentage of farmers who changed their crop management after adopting the bean variety "Gloriabamba," Peru

Management change	Percent of farmers (by province)		
	Cajabamba	Chota	Santa Cruz
Plant seed less deeply	24	0	30
Reduce planting distance	16	0	0
Increase fungicide use	2	6	24
Increase fertilizer use	7	6	24
Change from broadcast to row planting	1	36	18
Plant beans closer to maize in intercrop	6	36	0
Change to monocrop beans	0	3	6

Source: Adapted from Table 15, Ruiz de Londoño and Janssen (1990).

Box 5. Adoption in Different Seasons

Farmers in Bumbogo, Rwanda grow beans during two seasons. Researchers were interested in assessing the degree to which farmers had switched from bush beans to climbing beans. The data below show that the relative importance of improved climbing beans is considerably higher in the long rainy season, where they account for one-quarter of the bean area and half of the bean production.

Adoption of different bean types in the short and long rainy seasons, Rwanda

Bean type	Short rainy season				Long rainy season			
	(ha/ household)	(%)	(kg/ household)	(%)	(ha/ household)	(%)	(kg/ household)	(%)
Local bush beans	.28	(74)	166	(56)	.07	(54)	23	(27)
Improved climbing beans	.05	(13)	77	(26)	.03	(25)	42	(49)
Local climbing beans	.05	(14)	52	(18)	.03	(21)	21	(25)
Total	.38	(100)	295	(100)	.13	(100)	86	(100)

Source: Sperling et al. (1992).

Box 6. Alternative Ways of Presenting Adoption Data

A survey in three regions of Malawi examined the adoption of hybrid maize. Questions were asked about varietal use on each field that the farmer managed.

It was possible to calculate several estimates of hybrid adoption. Not only does adoption vary by region, but the different estimates provide a complex picture of hybrid adoption. Only 12% of total maize area is in hybrids, although 27% of farmers grow some hybrid maize. But despite these relatively low figures, 35% of total maize production comes from hybrid maize.

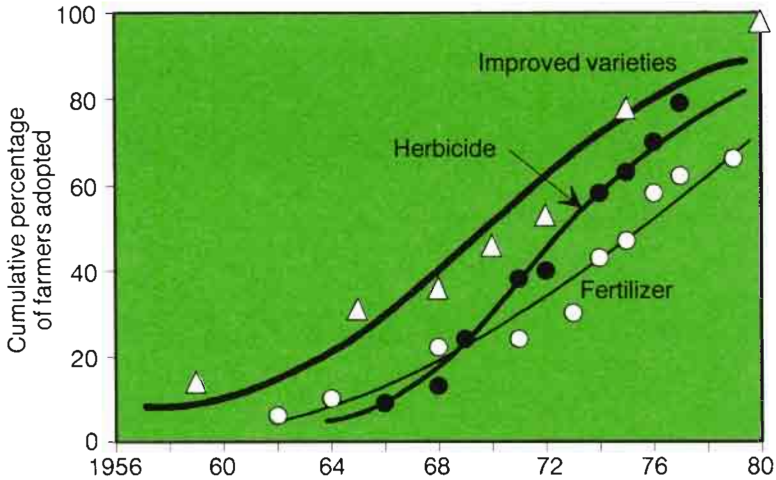
Adoption of different maize types by farmers in three areas of Malawi

Characteristic	Area			All areas
	Blantyre	Kasungu	Mzuzu	
Percent farmers growing				
Local maize	97	99	97	98
Hybrid maize	14	33	38	27
Other maize	8	11	14	10
Percent aggregate maize area				
Local maize	91	84	74	85
Hybrid maize	6	13	22	12
Other maize	2	3	4	3
Percent aggregate maize output				
Hybrid maize	18	44	47	35

Source: Smale et al. (1991).

Box 7. Logistic Curves

The following graph shows the actual adoption history and fitted logistic curves for three technologies (variety, fertilizer, and weed control) that were presented to barley farmers in Mexico as a package but had independent adoption patterns. Farmers tended to adopt the variety first, then improved weed control, and finally fertilizer.



Logistic curves for the adoption of three technological components in the wet zone, Central Mexico.
Source: Byerlee and Hesse de Polanco (1986).

Box 8. Farmers' Testing of New Technology

A survey in Peru that examined the adoption of a new bean variety asked farmers how much of their farms they planted to the new variety in the first year that they used it and in subsequent years. The results show a gradual increase in the use of the variety as farmers gain confidence.

Use of bean variety Gloriabamba, by province, Peru

Experience	Area planted (ha), by farm		
	Cajabamba	Chota	Santa Cruz
First season	0.11	0.28	0.13
Second season	0.24	0.40	0.40
Third season	0.43	0.57	0.50
Fourth season	0.43	1.06	0.83

Source: Ruiz de Londoño and Janssen (1990).

Box 9. Comparing Current Use with Past Use

One valuable contribution to assessing adoption patterns is to compare the proportion of farmers who have ever used a technology with the proportion currently using it. If the latter is much lower than the former, there is an indication that although farmers have tried the technology they have encountered difficulties with it.

The following example comes from Nepal and shows that different types of farmers have very different experiences with respect to improved maize varieties. The majority of large commercial farmers have tried these varieties and continue to use them. Almost half of small commercial farmers have also tried these varieties, but only a small proportion continue to use them. Some part-time and subsistence farmers have also tried the varieties, but almost none currently use them.

Current and past use of improved maize varieties by type of farm, Nepal

Farm type	Percent of farmers planting improved maize	
	Currently	Ever
Large commercial	54	60
Small commercial	13	45
Part time	4	21
Subsistence	3	26

Source: Ashby (1982).

Box 10. The Difference between Early Adoption and Current Adoption

The farmers who adopt a technology first are not always the ones who find it most useful. The following example from Nepal shows that although larger farmers were the first to adopt improved (high yielding) varieties (HYVs) of rice, it is the smaller farmers who have the highest current usage.

Adoption of improved rice varieties (HYVs) by farm type, Nepal

Farm type	Average years since first use of HYV rice	Percent of rice land sown to HYV rice
Large commercial	8.3	31
Small commercial	7.6	60
Part-time	5.1	72
Subsistence	5.8	66

Source: Ashby (1982).

Box 11. Assessing the Distributional Impact of Technology Adoption

A study of mechanical wheat harvesting in Pakistan examined the advantages of the new harvesting method for farm owners in terms of time saved, ability to plant the following crop earlier, and yields. Although mechanical harvesting was not a practice recommended by the research service, it was spreading, and researchers wished to study the implications. The following figures show substantial advantages for farmers.

Farmers' estimates of differences in supervision time, harvest duration, and yields for harvesting by hand and with a combine, Pakistan[a]

Item	Unit	Wheat harvesting method	
		Hand	Combine
Supervision (mean)	h/day	10.4	2.7
Harvest duration (mean)	days	23.0	2.4
Time available to prepare for next crop (mean)	days	9.1	29.4
Yield (grain recovery) (mean)	t/acre	2.5	2.8

Source: Smale (1987).
a Holding input levels, variety, and harvested area constant.

However, an accompanying study showed the importance of the wheat harvest as a source of income for landless laborers. The following data show how a shift to mechanical harvesting could affect the incomes of the poor.

Percentage distribution of laborers by most important income source, *rabi* and *kharif* seasons, Pakistan, 1986-87

Most important income source	Percent of laborers	
	Rabi[a]	*Kharif*[b]
Wheat harvesting	82.7	..
Rice harvesting	..	62.7
Rice transplanting	..	2.7
Farming	1.3	6.7
Livestock rearing	2.7	4.0
All agricultural income	86.7	76.0
All non-agricultural income	13.3	24.0
Total	100.0	100.0

Source: Smale (1987).
a *Rabi* is the period from wheat sowing to wheat harvesting.
b *Kharif* is the period after wheat harvesting through rice harvesting.

These contrasting sets of data are valuable to research leaders and policymakers as they decide on guidelines for research and the possible promotion of mechanical harvesting.

Box 12. Attributing Changes in Farmers' Practices to a Research and Extension Program

The following data come from a study of wheat technology adoption in northern Mexico (Traxler and Byerlee 1992). Surveys were carried out in several different years (results from 1981 and 1989 only are shown here). There is evidence of change in several crop management practices. An analysis was also done on changes in recommendations and evidence of causality between the recommendations and farmers' new practices. It can be seen that although there is evidence of change in four practices, only two of those changes can be attributed to research and extension.

Evidence of causality between changes in recommendations and farmers' practices, northern Mexico

Practice	Measure	Survey results		Change in farmers' practice	Change in recommendation	Causality between change in recommendation and change in farmers' practice
		1981	1989			
Land preparation	Percent farmers subsoiling	32	23	No	Minor	..
Planting date	Median date	5 Dec.	6 Dec.	No	Minor	..
Nitrogen	Kg/ha	176	230 *	Yes	Minor	No
Phosphorus	Percent farmers applying	59	78 *	Yes	Significant	No
Planting method	Percent farmers ridging	8	33 *	Yes	Significant	Yes
Insect control	Percent farmers applying insecticide	82	56 *	Yes	Significant	Yes

Source: Traxler and Byerlee (1992).
* = difference significant at 1%.

The recommendations for nitrogen use changed only slightly between 1981 and 1989, but farmers significantly increased the amount of nitrogen they applied, mostly in response to economic factors. The proportion of farmers using phosphorus increased significantly as well, but there is little evidence that they responded to a recommendation for soil testing for phosphorus. On the other hand, ridge planting was developed by the research service and the survey showed that adopting farmers learned of the technique through demonstrations and field days. Similarly, the survey showed that the farmers who no longer use insecticide now take advantage of the information provided by an integrated pest management program developed by local research and extension personnel. It is these latter changes whose contribution to increased wheat yields needs to be examined in an investigation of returns to research investment. The costs of the entire investment in crop management research over the period, including research in components not adopted by farmers, must be compared to the benefits of those elements that have actually been adopted.

Chapter 3

Understanding Adoption

The Factors That Influence Farmers' Decisions

Besides documenting the degree and scope of adoption of a technology, many adoption studies also try to understand the patterns of adoption that are observed. Chapter 1 emphasized that this type of analysis can be useful for helping to refine the objectives of a technology generation program, as well as for improving interactions between technology generation and various aspects of national agricultural policy. Our task in analyzing adoption patterns is to see what is acceptable and useful to farmers, identify what is not, and suggest ways for improving the situation.

The introduction mentioned that there is a large literature of technology adoption studies, many of which pay little attention to the technology itself but rather concentrate on characteristics of the farmer. In some cases it is the attitude or personality of the farmer that is analyzed, with adopters being considered more "progressive" or "modern." In other cases, socioeconomic characteristics, such as wealth, landholding, or education, are used to explain the differences between those who adopt and those who do not.

Although such approaches may be interesting, the type of analysis proposed in this manual requires a more careful examination of the interaction between the characteristics of the technology and the characteristics of the farmers and farming systems that might accommodate the technology. This analysis of adoption patterns should be a logical continuation of the research planning process. When technologies are being planned and tested, priorities are set on the basis of potential benefits for farmers (including a consideration of profitability and risks) and the ease with which farmers may be able to adopt the technology (including compatibility with their farming system, the possibility that they can test the new technology themselves, and the availability of institutional support) (Tripp and Woolley 1989).

An adoption study can be seen as another phase of the technology generation process and an opportunity to look in more detail at how researchers help adapt technology to farmers' needs, and how farmers adapt their practices and conditions to take advantage of new technology. This chapter will examine several sets of factors that influence adoption patterns, including: the degree to which the technology is appropriate for farmers' conditions; the compatibility of the technology with the local farming system; how the technology is supported by markets; and how it is presented by extension and other information systems.

The list of factors that may influence adoption is long. Researchers will want to review this list before planning an adoption study and decide which factors should be included in their analysis. Researchers will use their knowledge of the types of farmers potentially affected, a comparison of the characteristics of the new technology with farmers' traditional practices, and an understanding of the technology diffusion process, to decide which factors deserve attention in a particular adoption study.

Farm Resource and Farmer Characteristics

The first set of factors that we will explore are those characteristics of the farmer and farm resources that can be used as explanatory variables in understanding adoption patterns. These include factors such as education or wealth that may predispose a farmer to take an interest in a new technology, and resources such as amount of land or access to credit that may make it easier or more profitable for a farmer to change practices.

Such farmer and farm resource characteristics occupy a major part of the literature on adoption. Analysis of this kind of factor can be directed at either of two audiences. It can be used for an assessment of the impact and distributional consequences of adoption; is the new technology restricted to certain sectors of the farming population? As well, an analysis of farm and farmer characteristics may provide feedback to research itself for refining the technology; is it only appropriate for farmers with certain resource or skill levels, and what can be done to make the technology more widely available?

Characteristics of the farmer

Much of the literature on adoption assumes that new technology is necessarily "good" and concentrates on analyzing those characteristics of individual farmers that make them more receptive to these innovations. For the purposes of a technology generation program, however, it is much better to examine the correspondence between the recommendation and farmers' conditions, without assuming that the technology is perfectly appropriate or that those farmers who adopt ought to be called "progressive." Our purpose is rather to identify specific conditions that make a technology more, or less, acceptable to farmers and that can be addressed through research, extension, or agricultural policy to make technology generation more efficient.

Education. Many adoption studies examine the relation between a farmer's formal education and adoption behavior. Education may make a farmer more receptive to advice from an extension agency or more able to deal with technical recommendations that require a certain level of numeracy or literacy. These skills are of course not necessarily perfectly correlated with years of schooling, and some adoption studies go so far as to include a small test of farmers' skills (for example, of the mathematics necessary to calculate a dosage of herbicide). Informal education may be important as well, and in certain cases adoption studies enquire about such things as attendance at short courses organized by the extension service (see the section on "Information," p. 41). It may also be interesting to ask about the farmer's own history of innovation and of trying new ideas.

Many (but certainly not all) adoption studies show some relationship between technology adoption and the educational level of the farmer. The more complex the technology, the more likely it is that education will play a role. Thus the diffusion of a new variety among farmers may not depend at all on their education level, while the diffusion of a chemical input may be more rapid among farmers who have at least some minimum amount of schooling. The important point is that if such a relation is demonstrated, we must then ask how strong that relationship is and what the practical implications might be. If a particular technology finds its way predominantly to farmers with a certain level of education, then several options should be considered. One is to try to simplify the technology (or develop alternatives) so that it is more accessible. Another option is to concentrate extension resources on farmers with less education and to train them in the use of the new practice. And a third option is to use this result in making a case for more investment in extension services, training, or rural schools to accelerate the use of agricultural technology—which is becoming ever more complex.

Age. Another farmer characteristic that is often examined in adoption studies is age. A farmer's age may influence adoption in one of several ways. Older farmers may have more experience, resources, or authority that would allow them more possibilities for trying a new technology. Experience in a particular farming area or with a given crop may not be strictly correlated with age, however, and it may be worth asking more specifically about experience. On the other hand, it may be that younger farmers are more likely to adopt a new technology, because they have had more schooling than the older generation or perhaps have been exposed to new ideas as migrant laborers.

In either case, it is unlikely that the demonstration of a relation between age and adoption *per se* will be of immediate utility. It is more important to see if the relationship is due to farmers' experience or education or if the association with age is more a reflection of characteristics of the farm household, including the distribution of authority, labor availability, or sources of income. An example of this type of analysis is shown in Box 13 at the end of this chapter.

Gender. Women farmers are often forgotten in official agricultural statistics. Because women play a key role in most agricultural systems, it is important that adoption studies consider the degree to which a new technology reaches women farmers. This requires careful planning of the survey. In the first place, researchers should have a good idea of the crops, cropping systems, or farm operations that are important for women farmers and should make sure that the survey is designed to obtain the relevant information. Perhaps more important, the survey sampling and interviewing strategies should be planned so that women are interviewed where they are the decision makers or have considerable knowledge about a particular subject.

If the survey results show a significant difference in adoption rates between men and women farmers, there are at least two hypotheses to be explored. The first relates to the type of farming system managed by women. It may be that the recommendations being examined are less appropriate for the crops grown or crop management practiced by women, and decisions would have to be taken regarding a reorientation of the research program. The second hypothesis related to differential adoption between men and women farmers is that women farmers are less likely to command the resources (such as land, credit, or information) to take full advantage of the technology. In such cases the conclusion might be to place more emphasis on technology development that is appropriate to the resources available to women, or to address policy changes that might make services such as credit or extension more available to women farmers. Box 14 provides a few examples of how gender analysis may contribute to an adoption study.

Ethnic, religious, and community factors. In many cases a technology is introduced to an area that includes farmers of different customs and traditions. These differences may be most notable between communities or between members of several groups living in the same community. It will not be surprising to find that adoption patterns may differ among these groups. Although these differences may be easy to demonstrate, again we need to ask whether this information can be used to make the research or extension program more effective. In many cases, differences among groups arise from differences in the resources they manage (for example, one group may have access to more or better land than another) or to differences in farming systems or practices among the groups. In these cases, it is a question of tailoring the recommendations for the conditions of the different groups. Another possible explanation for such differences is that one group may have better access to government services. If this is the case, the conclusion may be one of reorienting government policy.

Wealth. Wealthier farmers may be the first to try a new technology, especially if it involves purchased inputs. This may be because wealthier farmers are more able to take risks or have better access to extension information or to credit, or they may be able to use their own cash resources to experiment with a new technique. Whether or not this pattern persists, and wealthier farmers are the ones that are the major adopters and users of a new technology, may be an important issue for an adoption survey. The targeting and organization of the original research is also an important factor, especially the degree to which the research was aimed at resource-poor farmers.

A survey might use any of several methods for estimating a farmer's wealth, and the method chosen will depend primarily on the hypotheses that researchers wish to explore. Many times it is farmers with more resources (land, labor, capital) who are able to take advantage of a new technology. These factors are discussed in the following section. In other cases a farmer's wealth may be a proxy for education (discussed above) or connections with extension (discussed below in the section on "Information," p. 40). Or in some cases farmers with a more commercial orientation, who sell a large proportion of their harvest, are the ones who adopt particular technologies (see "Post-Harvest Utilization and Markets," p. 38). Wealth *per se* is a difficult parameter to measure on a survey, although it is sometimes a useful concept in explaining adoption. A method of "wealth ranking," in which knowledgeable members of a community are asked to divide households into groups according to locally recognized wealth standards, is described in Grandin (1988).

Farm resources

Farm size. Farm size is a common variable examined in adoption studies and is often a good proxy for wealth. It is often assumed that larger-scale farmers will be more likely to adopt a technology, especially if the innovation requires an extra cash investment. It may be that a certain threshold farm size is necessary before the investment in a technology is worthwhile. Or it may be that on larger farms different management practices (e.g., mechanization) are used, making a recommendation more appropriate for them. On the other hand, certain technologies are more appropriate for the intensive management characteristic of smaller farms (or at least of farms with a higher ratio of labor to land). Finally, farm size may be related to access to information or credit that would facilitate the adoption of a recommendation. The distribution of a new technology among smaller and larger farms is valuable information for assessing impact, but in order to refine a technology and ensure that it is appropriate for a range of farm sizes, more specific information about the relation of farm size to farm management is usually required (Box 15).

Labor. Technologies have different labor characteristics; some reduce the amount of labor required for growing a crop, while others significantly increase it. In planning an adoption study, researchers need to identify the labor implications of each technology being examined. Are changes in labor required, and if so, how great are they, and at what time of the crop season do they occur? How does the technology change the division of labor between men and women? If the new technology requires a significant amount of extra labor, it may be necessary to develop a rough labor profile for the farm household (see the next section, "The Farming System"). How many laborers are available? When are the peak labor periods during the year? Do some household members work off of the farm and, if so, during what periods? In addition, the survey may need to obtain information on the availability of hired labor during the period relevant to the recommended technology. An example of how labor availability affects technology adoption is shown in Box 16.

Credit. Credit may be an important factor in determining adoption. If a recommendation implies a significant cash investment for farmers, its adoption may be facilitated by an efficient credit program. If the majority of adopters use credit to acquire the technology, this is of course a strong indication of credit's role in diffusing the technology. Similarly, many farmers who do not adopt may complain of a lack of cash or credit as the principal factor limiting their adoption. But the interpretation of this data is aided by a knowledge of the sources of credit available to farmers. What are the rules and regulations associated with official credit programs in the research area? What procedures do farmers have to go through to obtain a loan? Is the credit provided in cash or as inputs? The workings of the local informal credit market should also be investigated. Such information should be analyzed before the questionnaire is designed so that the survey can distinguish accurately between farmers who may or may not have access to credit.

Rather than facilitating access to new technology, credit programs are sometimes responsible for obligating farmers to use a particular technology. The credit may be offered as a package that provides a set of inputs to farmers. Parts of the package may be "adopted" simply because of this obligation, although farmers may feel that they are inappropriate or unprofitable. If this is the case, the adoption study can provide valuable data for refining and making more efficient both the recommended package and the credit program.

Equipment and machinery. Farmers' ownership of equipment or machinery may influence their ability to adopt technology. Farmers who own draft animals or tractors can be more flexible in changing their tillage practices than farmers who must rent or borrow equipment (Box 17). If a recommendation involves a new type of equipment or machinery, the degree of adoption may depend on the number of farmers who are able to acquire the equipment and whether or not an effective rental market develops. An adoption study that examines technology related to equipment and machinery may need to ask how and where farmers rent the necessary equipment.

Land tenure. An issue that is much debated in the adoption literature is the degree to which land tenure affects a farmer's ability to adopt. This issue is of practical interest for an adoption study if it helps us understand the degree to which all farmers are able to take advantage of a new technology, and whether different technologies are required for farmers without secure access to their land.

Researchers will need to be acquainted with the specific details of rental or sharecropping arrangements. In the case of sharecropping, how are obligations divided between sharecropper and owner, and how is the harvest divided? Different arrangements may make a technology more or less attractive for the sharecropper.

Another important element of the land tenure issue is the fact that in many cases renters or sharecroppers will be less interested in technologies that have long-term effects, such as soil fertility maintenance or enhancement, because they have no guaranteed access to the land. In other cases, rental or sharecropping may go beyond a simple economic contract between owner and tenant and involve particular obligations that restrict the tenant from using a new technology, such as when a tenant is required to plant varieties that provide crop residues for the owner's animals to graze after harvest.

The Farming System

One of the basic principles of on-farm research is that technologies must be compatible with the farming system if they are to find acceptance. For this reason, a good part of the diagnostic and planning phases of on-farm research is devoted to examining the possible interactions between a proposed technology and the management of the crops and animals that constitute the farming system. Experience has shown that many times a technology that appears as a reasonable innovation is rejected by farmers not because of any intrinsic quality of the technology itself, but because it conflicts with other elements of the farming system. An adoption study should examine the degree to which that technology is consistent with the rest of the farming system.

The principal audience for this aspect of an adoption study is researchers themselves. The idea is to take this opportunity to monitor the compatibility of the technology with the farming system and, if any problems are detected, to use this information to refine the technology.

We will consider below some of the parameters associated with an analysis of farming systems: the allocation of labor among various enterprises in the system, the management of other crops planted in the same field or in rotation, the biological conditions of the field, the soil conditions, and climatic factors. In addition, we will examine the concept of risk. Much of this type of analysis is useful only if it is done with reference to a specific field, so it is important that the survey be organized to collect this information on particular fields and for particular years.

Labor in the farming system

A basic element of farming systems diagnosis is the development of a labor calendar that gives an idea of how farm household labor is allocated over the year. It is essential to know if the labor demands of a new technology conflict with a particularly busy time of the year for farmers or rather take advantage of a period when labor is available. It is important to remember that this labor profile is determined not only by operations on the target crop but also by demands from various other enterprises in the farming system. Thus it may seem that farmers should be able to do an additional weeding on the target crop, for instance, but actually at that time they are busy planting another crop.

An adoption study is not the place to develop a complete labor profile. This should have been done previously, in the earlier stages of research. But questions can be asked about the availability of labor and/or competing activities during those periods of peak labor demand for the technology being promoted. Simply asking the farmers their perceptions of the labor requirements of the new technology also can be useful (Box 18).

Other crops in the system

Intercropping and relay cropping are common practices in many farming systems. New varieties or practices for one crop may thus have to be compatible with the presence and management of other crops. This may affect the choice of variety (e.g., does the new maize variety support the intercropped climbing beans?) or management practice (is the new weed control method compatible with the intercrop?). In some cases, what appear to be "weeds" are actually volunteer or sown species that may be used as food or fodder. The adoption study should pay attention to the degree to which recommended practices are being used for the target crop in various intercropping systems. Significant differences may signal the necessity to target the recommendations better.

Crop rotations are also an important part of farming systems, and the acceptance of the recommended technology may be affected by practices or conditions of the preceding or following crop. A rotation pattern may affect the timing of operations in the following crop (see Box 19). Carryover effects from fertilizers or herbicides may also affect the management of the following crop. Cropping history itself is important, and the practices appropriate for newly cleared fields may be quite different from practices suitable for fields with a longer cropping history. Again, the study of rotation patterns is part of farming systems diagnosis, but the adoption study should pay careful attention to the relative use of recommended practices as part of various rotation patterns.

Biological circumstances

The adoption of technology may be affected by the weeds, diseases, and insect pests prevalent in the area or in specific fields. Weed control techniques will be more or less appropriate depending on the weed populations or the presence of particular problem weeds in the field. New varieties may be more or less susceptible to diseases or insect pests, and certain management practices (such as planting time) may reflect farmers' attempts to avoid these problems. The examination of the interaction of these factors with technology acceptance will require that researchers are familiar with local names for the weeds, diseases, or insects.

Soils

Land quality and soil type may be important factors influencing the acceptance of a new technology. The selection of sites for on-farm experiments needs to take account of variations in soil type or land type in the research area. Researchers should have a good idea of the response and appropriateness of the new technology under the major soil conditions of the area. Not only may management practices differ by type of soil, but other conditions, such as slope or moisture retention capacity, are often important as well. To examine the influence of these factors on the acceptance of technology in an adoption study, researchers should be familiar with local terms for variations in soil or land type.

Climate

Climatic factors play an obvious role in the management of farming systems. Rainfall patterns limit the crops that can be grown and regulate planting and harvesting schedules. The possibility of drought or flooding makes farmers wary about investing in some technologies (see next section). Seasonal temperature changes also regulate cropping patterns, as when frosts at the end of the growing season dictate early planting and/or use of early maturing varieties. By the time an adoption study is carried out, the researchers should have analyzed available secondary data on climatic variables and have a clear idea of how they may interact with the new technology. Climatic factors in one area may set limits on the acceptability of a technology, and farmers may be asked their opinions and experiences in this matter. Or adoption patterns may differ significantly between two research areas, based in part on differences in climate (Box 20). Researchers should also be aware of any climatic abnormalities during the year of the adoption survey and understand how these may affect either the short-term or long-term use of the technology.

Risk

The failure of a new technology to be accepted is sometimes attributed to risk aversion on the part of farmers, but this is a difficult parameter to assess, especially in an adoption study. One important element of risk is certainly the compatibility of the technology with climatic circumstances described above. If secondary data show that there is a high probability of mid-season drought at the end of June, it is not surprising that farmers would find a maize variety that flowers in late June to be unacceptable. Farmers would be able to articulate this reasoning in response to a question on a survey.

There is also the perception that some farmers are more willing to take risks than others. Besides the obvious fact that wealthier farmers will almost certainly be more willing to invest in testing a new technology, there is little in the literature that gives us a firm grounding for comparing risk attitudes to adoption behavior. Certainly in many cases resource-poor farmers have come to adopt practices, such as growing high value cash crops, that entail considerable risk.

Another element related to risk is the variability in prices. Farmers' experience may be that input or product prices are so variable that the adoption of a particular technology presents unacceptable risks.

In adoption studies that seek to explore the influence of risk on the acceptance of a technology, it is best to either use what is known about climatic factors from secondary data or ask farmers specifically to give their perceptions of the advantages and disadvantages, including risks, of the new technology.

Post-Harvest Utilization and Markets

The adoption of a new technology can be hindered or enhanced depending on whether it is in accord with the system of post-harvest utilization and marketing and the organization of input markets. A technology may lead to significant increases in crop production, but if the inputs needed are not available or if the extra production cannot be utilized effectively, then the technology may be rejected. An examination of these issues may be helpful for two potential audiences. The first is research itself; if a technology is incompatible with post-harvest conditions, or if farmers cannot obtain the required inputs, then the technology may have to be adjusted to these conditions. But if the technology is underutilized because of problems with input or product markets, then the results of an adoption study may be used to demonstrate to policymakers the advantages of improving these markets.

Post-harvest utilization and output markets

The introduction of new crop varieties to resource-poor farmers requires an understanding of their food consumption patterns and preferences. If a new variety is to be used for home consumption, it will have to be acceptable for local processing and cooking practices. This issue needs to be explored from the early stages of research, so as not to waste time on varieties that are incompatible. Farmer participation in the research is essential, and simple taste tests or panels may be devised to sort out which varietal characteristics are crucial for achieving farmer acceptance.

One difficulty, however, is that farmers' tastes are subject to change as well, and a variety that is not ideal for certain purposes may have agronomic or other characteristics that offset the disadvantages. Thus at times a period of testing is necessary, when farmers get better acquainted with the variety and see to what degree it can be used. An adoption survey offers a chance to monitor farmers' experience with a variety that has been released and to provide feedback to plant breeders regarding acceptable and unacceptable characteristics (Box 21).

If farmers market a considerable proportion of their harvest, then the acceptability of the new variety on the market needs to be investigated as well. The characteristics required for market acceptance may be considerably different from those that determine acceptability in the household. Researchers will want to talk to both farmers and merchants to identify the principal characteristics that regulate the market price of a crop variety. The survey can get more information about how and where farmers sell particular varieties, and can explore differences in price among varieties.

A more general look at crop marketing may also be called for. Not only do markets affect the acceptability of a new crop variety, they may also influence farmers' interest in any technology that promises higher yields. If markets are inefficient, there may be little incentive to invest in improved technology. In addition, characteristics such as seasonal variation in market prices may affect the acceptability of technologies that change the timing of harvest (e.g., a technique that allows earlier planting).

Storage practices may also deserve attention in a varietal adoption survey. Indeed, new storage techniques may be one of the subjects of such a survey. In addition, crop storage practices may affect the acceptability of technologies that increase the harvest or change its timing. New varieties may have quite different storage characteristics, and this may be a limiting factor for acceptance. An adoption survey can explore the degree to which such storage problems are best addressed through plant breeding or through improved storage techniques.

Crop production may not only be important for human consumption, but may also be important for animal production as well. The place of animals in the farming system needs to be explored in relation to new technologies. New varieties may have less acceptable forage qualities, for instance. New crop management techniques related to plant populations, weeding, or harvest may increase grain yield but affect the production of byproducts destined for animals. The sale of crop byproducts may be an important source of income. The use of damaged or spoiled grain or tubers for on-farm animal feed may diminish farmers' interest in certain crop protection technologies.

Input markets

If a recommendation involves the use of purchased inputs, the adoption study can check to see if farmers are able to acquire them. Preliminary investigation should develop information on points of sale, available supplies, and form of sale, and the survey can then compare this to farmers' experience. Do farmers know where the inputs are sold? Are there difficulties in getting to the location? Are the inputs always available when they are needed (Box 22)? What price does the farmer have to pay? Is input quality reliable?

The use of new crop varieties and seeds requires particular attention to the source of the input. Seed is frequently saved from year to year, exchanged among farmers, or purchased at a local market, besides being acquired from official sources. Not only is it important to ask the source of seed, but also the number of years since the farmer first obtained seed from that source.

This type of information can be valuable for developing communication with policymakers and demonstrating ways in which relatively minor changes in input policy may significantly affect the use of new technology (Heisey 1990).

Information

For farmers to adopt a technology they must first know about it. The information may come from several sources. It is important to explore the degree to which farmers have received the necessary information. This will help in analyzing the degree to which low adoption may not be a function of the technology itself, but rather of the information that is available. This analysis is useful for improving extension policies and programs.

In order to explore these issues on a survey, researchers need to be familiar with existing extension programs and other media for providing information to farmers. They need to know whether field days, demonstrations, farm visits, or other methods are used by the extension service, and which terms farmers use to refer to them. Radio, television, newspapers, or magazines may be important sources of information in some places.

One simple way of addressing this question is to estimate the degree of contact that each farmer has had with extension activities and to compare this with adoption behavior, in order to see if the extension contact has had an influence. Another strategy is to ask farmers where they learned about a technology (Box 23), although farmers' memories often are not perfect on this subject.

It also must be borne in mind that much information comes from other farmers. This makes studying the effect of extension difficult, because the information may well have originated with an extension agent but passed to the respondent through another farmer. This kind of problem led Birkhauser, Evenson, and Feder (1991) to suggest that a study designed to measure the actual impact or effectiveness of an extension program is best organized by comparing communities that have had access to an extension program with those that have had no contact, rather than trying to make comparisons between individual farmers in one community.

Farmers can be asked about specific production problems to see if they are familiar with recommendations (Box 24). Finally, it is worth remembering that knowledge and use are two different things. An adoption study can examine the distribution of farmers who don't know about a technology, those who know about it and don't (or no longer) use it, and those who know about it and use it. This contrast will provide a clear indication of the degree to which knowledge is a factor in explaining adoption patterns.

Summary

The following is a checklist of factors that help explain adoption patterns. No adoption study will include all of these factors, and it is important to decide which ones to focus on. This decision will depend to a large extent on the purpose of the study. Because an adoption study can have several potential audiences, it is important that the audience be clearly defined before the survey is designed.

A checklist of factors that are important for understanding adoption

			Purpose of adoption study			
Factor	How to include in survey	Other information needed for survey design	Refining research program	Interacting with input credit or market policy	Improving extension	Assessing impact
Education	Measure years of schooling, participation in other training.	Types of training available to farmers.	√		√	√
Age	Age of decision maker. (Effect may be related to experience, education, household characteristics.)		√		√	
Gender	(Effect may be related to type of farming system or access to resources such as credit, extension, etc.)	Sampling strategy to include women farmers. What crops, systems, operations do women have responsibility for?	√	√	√	√
Ethnic group, etc.	(Effect may be related to type of farming system or access to resources.)	What are the different groups in the research area? How do they refer to themselves?	√	√	√	√
Wealth	Can be estimated by land holding, income, or other factors. (Effect may be related to specific resources.)		√	√	√	√
Farm size	(Effect may be related to farming system or resources.)	Local measures of area.	√	√	√	√
Labor force	Amount of labor available in household; hiring practices.	Labor requirements of the technology.	√			√
Credit	Participation in credit programs; source of loans for farming.	What credit programs exist for farmers? What are their requirements? Who is eligible?	√	√		
Equipment and machinery	Ownership of equipment; experience with rental.	Equipment and machinery requirements of the technology. Rental markets in the area.	√	√		
Land tenure	Decision makers' access to specific field.	What are local customs and vocabulary for renting, borrowing, sharecropping?	√		√	√
Labor in farming system	Amount of labor available in household; hiring practices; other labor demands in system.	Timing and amount of labor required by new technology. Cropping calendar.	√			√
Other crops in system	Intercropping and relay cropping in specific field. Rotation history of specific field.	Local practices for intercropping, relay cropping, rotation.	√			√

(continued...)

Checklist (cont'd.)

Factor	How to include in survey	Other information needed for survey design	Purpose of adoption study: Refining research program	Interacting with input credit or market policy	Improving extension	Assessing impact
Biological factors	Characteristics of specific field, by season.	Local vocabulary for weeds, pests, diseases. Susceptibility of new technology.	√			
Soils, land type	Soil type, slope, other characteristics of specific field.	Local vocabulary for land types. Experimental evidence of different responses of technology.	√			
Climate	Farmers' opinions about timing of technology, climatic interactions.	Secondary data on climate.	√			
Risk	Farmers' opinions of risk of technology. Other indicators of farmers' attitude to risk.	Secondary data on climate.	√			
Home consumption	Opinions on acceptability of new variety. Changes in food preparation.	Local food preparation, types, and methods.	√			√
Output marketing	Farm crop sales; amounts, timing.	How and where are crops marketed in area? How do prices vary by season?	√	√		√
Storage	How do farmers store the crop? Opinions on characteristics of new technology related to type or timing of storage.	Local storage techniques.	√			
Fodder needs	Timing of fodder requirements. Types of fodder.	Importance of animals and fodder in farming system.	√			√
Input markets	Where farmers obtain specific inputs. Knowledge of input type, source.	Local sources of inputs; availability. Local vocabulary for inputs.	√	√		
Information	Contacts with extension activities. Knowledge of technology. Source of knowledge. Time of first use of technology.	Types of extension activity in the research area.			√	

Once the purpose and audience for an adoption study have been defined, the definition and measurement criteria for changes in farmers' practices have been identified, and hypotheses have been listed regarding reasons for differences in adoption patterns, the adoption study can be designed. The next chapter discusses issues related to choosing a sample, designing questions, and implementing the survey.

Box 13. Household Development Cycle and Adoption

Although the age of the household head or decision-maker may influence adoption patterns, other household characteristics may play an even more important role. Anthropologists use the term "household development cycle" to describe the way households evolve over time, often growing larger and more complex and then declining. This is not merely a function of household size, but also reflects changes in access to resources (for example, a son may gradually acquire rights to his father's land), changing sources of income (younger households may earn more money from off-farm labor), and various kinship obligations.

The table below compares the adoption of hybrid maize in Swaziland for three types of household. It was found that hybrid adopters were no more likely to sell maize than non-adopters, and the question was then asked why some farmers would grow hybrids for subsistence and others would not. The argument made here is that younger households (type 1) have higher consumer/worker ratios and require more efficient technology for producing maize. More mature households (type 2) have lower consumer/worker ratios but have significant cash earnings to support the improved technology. Households that are in decline (type 3) have the lowest consumer/worker ratios and thus the least need for more productive technology. In addition, their wage earners earn less than those from other household types because they tend to be older and less educated. It can be seen that this classification by household type is more successful at explaining adoption than a simple analysis by age of household head.

	Adoption of hybrid maize by household type		
	Type 1 (establishment and expansion)	Type 2 (consolidation)	Type 3 (fission and decline)
Percent adopting hybrid maize	57	64	37
Average age of household head	40.3	56.7	59.7
Consumer/worker ratio	2.2	1.9	1.7
Number of wage earners	1.0	2.2	1.4

Source: Calculated from Tables 7.17, 7.19, 8.12 in Low (1986).

Box 14. Gender Analysis and Adoption

The adoption of technology by women farmers may be quite different from that by men. The planning of an adoption survey may need to include a careful examination of how responsibilities for different agricultural activities are divided between men and women. The following data from Nepal show that women participate in most agricultural decisions, and in cases related to choice of variety they are the primary decision-makers.

Farm management decisions in Nepal (%)

Type of decision	Male	Female	Joint	Total
What crop to plant	18.0	30.2	51.8	100.0
What seed to use	20.7	60.4	18.9	100.0
Amount and kind of fertilizer	32.5	39.7	27.8	100.0

Source: Acharya and Bennett (1982).

One of the reasons that women farmers may adopt technology at a lower rate than male farmers is that often women are not as well served by extension services as men are. The following data from Malawi show the strong tendency for extension to have less contact with women farmers.

Type of extension contact for male household heads (MHH), wives, and female household heads (FHH), Malawi (percentages of total in category)

	Lilongwe			Ngabu		
Type of contact	MHH (n=147)	Wives (n=35)	FHH (n=35)	MHH (n=95)	Wives (n=95)	FHH (n=31)
Personal visit	41	28	23	28	12	4
Group meeting	66	44	49	43	12	8
Demonstration	13	6	6	5	1	0
Field visit	13	9	6	15	5	2

Source: Spring (1985).

Women farmers may also have different farming systems. In a project in The Gambia, the provision of new pump-irrigated rice technology benefited men more than women farmers.

Women's participation in different rice technologies in The Gambia

	Project pump-irrigated technology	Project improved rainfed technology	Traditional rice technology
Fields under women's control (%)	10.0	77.0	91.0
Yields per hectare	5.9	2.5	1.3
Input cost (US$/ha)	294.0	154.0	20.0
Labor input by women (in % of unpaid family labor)	29.0	60.0	77.0

Source: von Braun and Webb (1989).

Box 15. Farm Size and Adoption

A study in Eastern Province, Zambia, showed that adoption of new technology was related to farm size, but the relationship depended on the technology. The adoption of hybrid maize, a cash crop, is very dependent on farm size. Ox cultivation varies as well with farm size, partly because farmers who have more land are more likely to own oxen. Fertilizer use, on the other hand, is only weakly related to farm size, and fertilizer rates do not vary across different farm size classes.

Size of farms and adoption of technology in the Plateau Zone of Eastern Province, Zambia

Indicator	Less than 1 ha	1-2 ha	2-3 ha	3-4 ha	More than 5 ha
Farm size					
Households (%)	23.6	31.7	15.4	18.7	10.6
Average size (ha)	0.6	1.5	2.4	3.8	8.0
Hybrid maize					
Farmers using hybrids (%)	6.9	30.8	42.1	52.2	96.1
Maize area under hybrids (%)	3.1	15.1	17.6	24.2	49.2
Cultivation with oxen					
Farmers using oxen (%)	25.9	56.4	65.8	87.0	96.2
Farmers owning oxen (%)	17.2	17.9	36.8	58.7	76.9
Fertilizer					
Farmers using fertilizer (percent)	51.7	67.9	65.8	67.3	100.0
Crop area fertilized (percent)	45.5	49.8	52.3	43.5	72.3
Average rate of application (kg of plant nutrients per fertilized hectare)	102.5	92.2	94.6	104.5	93.9

Source: Jha et al. (1991).

Box 16. Labor Availability and Adoption

A study of the adoption of dry-seeded rice (DSR) in the Philippines examined a number of factors. One of the most important was labor availability in the household, because the dry-seeding technology demands more labor for weeding. Farmers who adopt dry-seeding must either use more household labor or hire labor.

A logit regression showed that labor availability, knowledge, and farm area had significant associations with the adoption of dry-seeding. The first table shows the output of the logit regression. (For more information on logit regressions, see pp. 76-81.)

Logit regression analysis for adoption of DSR in Iloilo, Philippines, 1982

Explanatory variable		Coefficient	Standard error	Asymptotic t-value	Significance level
b_0	Constant	-1.0154	1.1258	-0.902	n.s. [a]
X_1	Farmer's age	-0.0143	0.0160	-0.895	n.s.
X_2	Education	-0.0623	0.0539	-1.156	n.s.
X_3	Labor index	0.3132	0.1545	2.027	5%
X_4	Draft index	-0.2643	0.2331	-1.134	n.s.
X_5	Extension visits	0.00373	0.00829	0.451	n.s.
X_6	Knowledge	0.4922	0.1109	4.437	0.1%
X_7	Credit	-0.4662	0.4190	-1.113	n.s.
X_8	Tenancy	0.000130	0.00417	0.031	n.s.
X_9	Rainfed lowland area	0.0000558	0.0000227	2.455	5%

Log likelihood ratio statistic $[-2(\log L_0 - \log L_{max})]$	=	44.6 (9 d.f.)
Cases predicted correctly	=	70.5
Sample size	=	173

Source: Denning (1991).
[a] n.s. = not significant.

The second table looks more specifically at the independent effects of the three factors on the adoption of the DSR technology. It uses the results of the logit regression to calculate the probability of adoption for different types of farmers. With respect to labor availability, it shows that the higher the labor index, the more likely farmers are to adopt DSR, independent of the effects of knowledge or farm area.

Predicted probabilities of DSR adoption for an average farmer, for different sizes of rainfed lowland area being farmed and different levels of labor availability and farmer knowledge, Iloilo, Philippines

	Small rainfed lowland area (1 ha)			Medium rainfed lowland area (2 ha)			Large rainfed lowland area (3 ha)		
	Labor index			Labor index			Labor index		
	1	2	4	1	2	4	1	2	4
Mean knowledge level	0.45	0.53	0.69	0.59	0.66	0.79	0.72	0.78	0.87
High knowledge level	0.59	0.66	0.79	0.71	0.77	0.86	0.81	0.86	0.92

Source: Denning (1991).

Box 17. Access to Machinery and Equipment

The availability of machinery or equipment may affect farmers' ability to follow recommendations. The following data from Kenya show that machinery owners (who tend to be larger farmers) are able to prepare their land for wheat closer to the recommended time than those who must rent machinery.

Relationship between wheat planting date and machinery ownership, Kenya

Farm size	Land preparation		
	Date preparation begins	Percent within recommended date	Percent using own machine
Small (n = 24)	March (1)[a]	0	8
Medium (n = 18)	February (1)	16	28
Large (n = 17)	December (4)	52	94

Source: Hassan, Mwangi, and Karanja (1992).

[a] Numbers in brackets refer to the week (e.g., first, second, — fourth) of the month.

Box 18. Farming System Trade-offs

Farmers must often make trade-offs in the management of their resources, and labor often presents a particular challenge. Farmers in western Ethiopia were encouraged to switch from broadcasting maize to row planting. About half of the farmers changed to row planting, but a survey that included questions on farmers' opinions of the recommendations showed that the greatest limitation to further adoption was the extra labor required by row planting.

Farmers' opinions on row planting, western Ethiopia (n = 64)

Opinion	Row planting is better (%)	Broadcasting is better (%)	Same (%)
Labor saving	7.8	92.2	0.0
Seed saving	98.4	1.6	0.0
Convenience for oxen-cultivation	90.6	4.7	3.1
Reduce lodging	96.9	0.0	3.1
Yield	93.8	3.1	1.6

Source: Beyene Seboka et al. (1991).

Box 19. Crop Rotations

Adoption of technology for one crop may be affected by interactions with another crop in the rotation. In the example below, wheat that is planted after fallow in the Punjab of Pakistan is much more likely to be planted at the recommended (early) date than wheat that follows cotton, since the cotton harvest can extend into the time for preparing land for wheat. Other practices, such as number of plowings and fertilizer use, tend to differ somewhat between the two systems as well.

Major differences in production practices in two cropping patterns in cotton-wheat areas, Pakistan, 1985

Practice	Wheat after cotton	Wheat after fallow	Significance level
Percent planted before 30 Nov.	5	51	
Percent planted during 1-15 Dec.	27	31	.00
Percent planted after 15 Dec.	68	18	
Number of plowings and plankings	6.9	8.0	.09
Average fertilizer use (kg/ha)			
Nitrogen	98	86	.09
Phosphorus	50	40	.08
Number of irrigations	6.0	5.9	.69
Average wheat yield (kg/ha)	2,178	2,401	.04

Source: Akhtar et al. (1986).

Box 20. Climate

The adoption of technology is influenced by climatic circumstances. In an adoption study in Central Mexico, it was found that barley farmers in a higher rainfall area were more likely to adopt recommendations than those in a lower rainfall area. In addition, the technological components were adopted differently in each area. The majority of farmers in both areas adopted improved barley varieties, but the use of herbicide and fertilizer was much higher in the higher rainfall area, where response to these inputs was greater. In addition, farmers in the wet zone tended to adopt herbicide before fertilizer, while those in the dry zone, where weeds were less of a problem, tended to adopt fertilizer first.

Adoption of three technological components in two zones of Central Mexico, 1975 and 1980

	Percent of farmers		
Zone/component	Used in 1975	Used in 1980	Ever used in 1980
Wet zone			
Improved varieties	76	91	96
Herbicide	77	74	82
Fertilizer	46	62	65
Dry zone			
Improved varieties	29	61	61
Herbicide	11	13	17
Fertilizer	14	26	30

Source: Byerlee and Hesse de Polanco (1986).

Box 21. Post-Harvest Characteristics

It is often useful to ask farmers their opinions on various characteristics of a new variety. Rarely will a new variety be judged superior to a local one on all counts, but farmers are able to balance the advantages and disadvantages of a new variety in making adoption decisions.

The data below show that a new maize variety in Ghana is judged to have a number of superior agronomic traits, but is found to be deficient in both storage and cooking quality. These deficiencies did not keep the variety from being widely adopted, but more attention to storing and cooking qualities in breeding future maize varieties would certainly lead to even higher acceptance of new varieties.

Farmers' opinions on local and new maize varieties

Characteristic	Number of farmers expressing opinion	Local variety is better (%)	New variety is better (%)	Same (%)
Yield without fertilizer	66	22.7	74.2	3.0
Yield with fertilizer	63	4.8	93.7	1.6
Lodging resistance	60	28.3	70.0	1.7
Germination	61	3.3	60.7	36.1
Storage quality	72	77.8	13.9	8.3
Cooking quality	55	72.7	23.6	3.6

Source: Tripp et al. (1987).

Box 22. Source of Purchased Inputs

In order to understand the input distribution system it is useful to ask farmers where they acquired their inputs. In a study on wheat varietal adoption in Pakistan, researchers found that very few farmers were using government seed depots or merchants as sources of seed.

Sources of wheat seed of new varieties and other popular varieties, Mardan, Pakistan

Source of seed	Percentage of fields sown to:			
	Pak-81	Blue Silver	SA-42	"Mexipak"
Own	35	53	56	81
Other farmers	35	35	37	19
Seed depot	15	12	..	..
Research/extension	15	..	..	..
Shopkeeper/grain merchant	..	..	7	..
Total	100	100	100	100

Source: Heisey (1990).

When asked about the location of the seed depots, only about half of the farmers could say where these were located. These data provided evidence to show that seed was not being distributed from seed depots in the way that policymakers believed.

Percentage of farmers who knew seed depot location and had visited a depot, Pakistan

	Rice zone	Cotton zone	Mardan
Knew correct location	51	46	52
Stated other location	14	11	38
Did not know location	35	44	10
Visited depot[a]	38	36	21

Source: Heisey (1990).

[a] Includes only farmers with correct knowledge of depot location.

Box 23. Source of Information

Knowing where farmers get information about new technologies may be important. If one of the purposes of a particular adoption study is to evaluate information transfer, this sort of data is essential.

The table below shows farmers' answers to a question on how they learned about a new maize variety, row planting, fertilizer, and fertilizer application methods. Although extension is the most important source of information, the degree to which farmers also obtain information from other farmers, especially in the case of new varieties, is noteworthy.

How farmers first learned of technology (Ghana, 1990)

How learned	Variety (n = 241)	Row planting (n = 199)	Fertilizer (n = 158)	Fertilizer application (n = 149)
Demonstration by extension (%)	17	30	22	30
Visit by extension (%)	29	24	41	35
Other extension method (%)	3	3	5	2
(Total extension) (%)	(49)	(57)	(68)	(67)
From another farmer (%)	48	36	29	27
Other or don't know (%)	4	8	4	6

Source: Ghana Grains Development Project (1991).

Box 24. Knowledge of Recommendations

It may be useful to ask about farmers' knowledge of specific recommendations. The data below are from a study that examined the effectiveness of a training and visit extension program in India. A number of questions were asked regarding technologies presented by the extension program, and the answers of contact farmers were compared to those of non-contact farmers. In some cases contact farmers were more aware of the recommendations than other farmers, while in other cases there was no difference.

Farmers' knowledge and adoption of selected extension recommendations on groundnut in Dhenkanal District, Orissa, India (recommended practices indicated by an asterisk)

Question	Answer	Non-contact farmers (%) (n = 66)	Contact farmers (%) (n = 73)	χ^2 significance
1. What can be done to control the attack of termites in groundnut?	Seed treatment*	6.1	11.0	
	Soil treatment*	25.8	34.2	
	Fertilizer	22.7	16.4	
	Seed and soil treatment*	1.5	4.1	n.s.
	Soil treatment and fertilizer	10.6	9.6	
	Ashes	4.5	1.4	
	Do not know	28.8	23.3	
2. What can be done to control the Tikka disease in groundnut?	Seed treatment*	1.7	0.0	
	Spraying*	27.3	57.5	
	Seed treatment and spray*	0.0	1.4	.001
	Do not know	71.2	41.4	
3. What kind of seed treatment should be given to groundnut?	No answer	0.0	1.4	
	Rhizobium culture*	0.0	1.4	.04
	Chemical treatment*	45.5	64.4	
	Do not know	54.5	32.9	
4. Do you practice the seed treatment of groundnut?	Yes*	22.7	41.1	
	No	77.3	58.2	.03
5. What is the best row-to-row spacing in groundnut (erect, semi-erect type)? (+ 20 cm)	Correct ($17 < X \leq 25$cm)	22.7	15.1	
	Not correct	65.2	75.3	n.s.
	Do not know	12.1	9.6	

Source: Hoeper (1988).

Survey Organization

Introduction

Chapter 1 emphasized that the study of adoption is an integral part of the technology generation process. Most of the factors that affect the potential acceptability of a new technology must be identified and monitored while agricultural research is being planned and carried out. The study of adoption is not something that can be left until the last minute.

Although a number of methods can be used to assess adoption once a technology has been released (see Box 2, p. 9), this manual focuses on the management of formal farmer surveys. There is an ample literature on survey techniques and design, and this chapter will emphasize only those factors that are of particular relevance to adoption surveys.

Before approaching the adoption survey design, researchers need to address several issues. First, researchers must carefully define the nature of the technology change they hope to analyze. What types of changes in farmers' practices do they propose to study? Second, they need to identify the audience for their study. Is the purpose to provide feedback from farmers to the research or extension program to make it more effective? Is the audience another institution that helps determine the policy environment in which the technology generation process operates? Is the purpose to document the impact of a research or extension effort? And third, a decision on the purpose of the study will determine whether the study will emphasize documenting the degree of adoption (Chapter 2) or whether it will also explore the reasons for the observed pattern of adoption (Chapter 3).

Sampling

Objectivity

The adoption studies described in this manual are aimed at providing information to improve the efficiency of research and extension activities. This information can also be used to assess the effectiveness of particular investments in research or extension. Although donor development projects or other special investments are often subject to outside evaluation, in the majority of cases studies of agricultural technology adoption will be carried out by the institutions that developed the technology. This places a special responsibility for objectivity on those doing the study. It must be remembered that the study is done to assess and to understand, rather than to "prove" success. The sampling for the study must be undertaken with special care, avoiding biases that may show the institution in an unreasonably favorable light and making sure not to ignore issues that should be addressed. For instance, if the adoption of a new technology may be more rapid with farmers who have better access to roads, extension services, or markets, it is important that the sampling for a study be carried out so as to avoid favoring such farmers and giving the impression that adoption is more widespread than it really is.

Sampling frame

Techniques for drawing samples for surveys are described elsewhere and will not be discussed here in detail (see Casley and Kumar 1988, Scott 1985). It is assumed that the adoption study will look at a relatively small number of technological changes in a well-defined area of a country.

It is important to define the population to be sampled. Is it, for instance, all the farmers in a specified region? All the rice farmers? All farmers who grow at least a half hectare of rice? All rice farmers who have participated in a special extension program? The answers to these questions will depend on the purpose of the study, but a clear definition of the population is essential. Once this decision has been taken, the next step is to decide what units will be sampled. This may prove more difficult than it sounds. If households are the units, how do we define a household? In some cases it may consist of members of an extended family who share certain agricultural resources and responsibilities but who also manage other agricultural enterprises independently. Are the interviews to be conducted with the head of the household? In many cases the household head may be a male, but females may take key decisions or have significant responsibilities for crop management. In other cases, certain fields or crops may be the responsibility of particular household members. Preliminary investigation will be necessary to decide how respondents are to be chosen and who will be the subject of the interviews.

Once the study population has been defined, it is necessary to identify a sampling frame. The sampling frame is constructed so that random sampling can be carried out (in other words, so that — theoretically — every unit in the population has a known chance of being chosen for the survey). In many of the procedures described here, the probabilities of selection for each farmer will be equal. The sampling frame is, ideally, a list of all the units that could be sampled. In many cases, however, such a complete list will not exist and may be impossible to assemble. In these cases, alternative procedures can be defined that still allow for random selection. One alternative is to draw a map of the households in the study area. Another possibility is to devise rules for sampling; for instance, a number of randomly selected points on a map may be chosen and enumerators are instructed to take the first (or n^{th}) unit in a randomly selected direction.

A common strategy when complete sampling frames are not available is to do two-stage sampling. If the study area consists of a large number of villages, for instance, the first stage of sampling would be a random selection of a certain proportion of those villages. The second stage would be to assemble complete lists of farmers or households in the selected villages and then draw samples from those lists. Special care must be taken in assembling the lists to ensure that all farmers (e.g., including all women farmers) are represented. Two-stage sampling may be the only feasible alternative in areas where complete population or residence lists are unavailable. It requires careful planning, especially if the first-stage units (e.g., villages) are very different sizes. Scott (1985) discusses two approaches to this problem. One is to recombine the first-stage units so they are of roughly equivalent size. The second is to select the units with a probability approximately equivalent to their size, and then to choose equal numbers of farmers from each sampled unit.

The size of the sample will depend to some extent on the nature of the study and the resources available. The appropriate sample size is also determined by the amount of variability in the population. If the study area farmers are very heterogeneous in their practices or adoption behavior, a larger sample will be required. One way of reducing some of the sampling error related to this variability is to stratify the sample. If part of the variability in the sample results from differences between, let's say, farmers who have access to irrigation and those who do not, it will be more efficient to stratify the sample by access to irrigation, rather than to rely on purely random sampling to provide sufficient numbers of each class of farmer for the analysis. When a stratified sample is used, however, researchers need to be able to estimate the proportion of each category in the general population so that they can assign weights to each subsample when estimating important parameters, such as adoption rates, for the entire population. The adoption studies described in this manual may be carried out with as few as 50-60 respondents, but the complexity of the adoption process is such that 80-120 respondents will be a more usual sample size.

At times the existence of previous studies may help determine the nature of the sampling frame. If a formal survey was conducted in the area several years earlier as part of the diagnosis for the research program or to provide baseline data, an adoption study carried out using similar sampling procedures will provide valuable comparative data. In some cases, an adoption study with the same sample used earlier may be useful. In some cases a "panel" of farmers is visited every few years to follow technological change. There are both advantages and disadvantages to repeatedly surveying the same farmers (see Scott, 1985). Although this is at times an attractive option, in most cases the sample for an adoption study will be drawn without benefit of previous surveys.

Sampling for comparisons

In many instances an adoption study attempts to answer questions about differences in the rate of adoption between groups of farmers. Have larger- or smaller-scale farmers tended to adopt the technology? Are participants in extension programs more likely to adopt? Does distance from markets make a difference in adoption behavior? These and similar questions may be addressed in two possible ways. In the majority of cases it is likely that these characteristics will appear with sufficient frequency in a randomly drawn sample that the appropriate comparisons can be made. But if a particular comparison is important enough for the purposes of the study, and if it is not certain whether a randomly drawn sample will provide a sufficient number of each category, then the sampling may be done in a purposive manner. For instance, if it is important to judge whether the participants in an extension program have reacted differently to a new technology than non-participants, then part of the sample may be drawn from a list of program participants and part may be drawn from the general population. In this example the sampling is fairly straightforward because a list of program participants exists. But in other cases (such as large-scale versus small-scale farmers) it may take considerably more effort to develop appropriate samples, and researchers will have to decide if this is worthwhile. As with stratified sampling, for each purposively chosen group, researchers need to know the proportion of farmers in order to know what weight to assign each subsample to assess overall adoption rates.

Sampling fields

Besides deciding on an appropriate sampling frame for farmers, it may also be necessary to define a sampling procedure for fields. If farmers in the study area have several fields, researchers will have to decide whether they are going to assess adoption of the technology on all of the farmer's fields, on fields with certain characteristics, or only on the largest field. This decision will depend partly on the definition of adoption selected for the study and the purpose of the study. If the purpose is to inventory the use of a particular technology, then all fields may have to be sampled. If the purpose is more to understand the context in which a technology is used, then a subsample of fields may be sufficient, or the farmers themselves may be the only sampling unit and be classified as adopters or non-adopters.

Timing of the Survey

In most cases the best time to do an adoption study will be shortly after the harvest, when farmers may have more time to answer questions and when they will be able to report on their experience during the season. If more than one season per year is being studied, the timing question is more complex. The timing may also depend on the specific purpose of the survey. For certain surveys it may be useful to include field observations in the study (to observe the effectiveness of a weed control technology, for instance), in which case the survey will be done during the crop season. Or it may be that storage or marketing issues are important, and researchers may wait until some time after harvest and then survey farmers about their marketing experience. The timing of the survey may be affected by natural circumstances. Although it is often impossible to carry out a survey in the proverbial "normal" year, unusual conditions such as a severe drought may mean that conditions are not appropriate for assessing farmers' experience with a particular technology, and the survey might have to be postponed or at least redesigned. In certain areas where the performance of a technology is chronically variable (because of uncertain rainfall, for example), it may be necessary to assess adoption and technology performance over several years.

Survey Design

This manual discusses the development and analysis of short, well-focused questionnaires for studies of adoption. Such questionnaires can be used to document and quantify the degree of adoption of particular technologies and to collect information that helps explain the patterns and extent of adoption. It is very important that the purpose of the survey be identified clearly so that the questionnaire is an efficient instrument for collecting priority information, not a device for exploring a wide range of issues.

The section on sampling discussed the importance of an objective approach to assessing adoption. The same advice is relevant when designing the questionnaire. The questions should be presented to the farmer in as neutral a manner as possible. The best way to do this is simply to document the relevant practices that the farmer is using, much as would be done in a diagnostic survey of farming practices. The interviewers should explain to the farmers that they are interested in farming practices and problems, not that they are trying to see if farmers are following recommendations. Thus questions on varietal use should not begin with, "Do you use new variety X?", but rather with more general questions that ask farmers to list the varieties that they grow. *It is very important that no leading questions are asked and that the farmers do not feel they are being tested with regard to their knowledge or use of recommendations.*

The survey questions will be determined by the objectives of the study. In documenting adoption, for instance, the goal may simply be to estimate the proportion of farmers using a practice, or it may be to estimate the proportion of area or production associated with the practice. The goal chosen for the survey will determine the type of question to be asked. Similarly, if one goal is to understand why some farmers have adopted a practice and others have not, researchers will need to form specific hypotheses to guide the types of questions that are asked. These hypotheses may be pursued directly, by asking farmers' opinions, or indirectly, by statistical comparisons between adoption behavior and specific characteristics of the farmers' circumstances (Chapter 5).

There are a number of good sources available on survey design, and only general guidelines will be offered here. The reader is referred to Byerlee, Collinson, et al. (1980), Casley and Kumar (1988), Bernsten (1980), Alreck and Settle (1985), and Murphy and Sprey (1982) for more detail.

1. **Open versus closed questions**
   Questions may either be precoded so that the farmer's response should correspond to one of a limited number of choices, or the space for the response on the questionnaire may be open and the interviewer records whatever the farmer says. There are advantages and disadvantages for each of these types of questions, but for an adoption study it is to be expected that the vast majority of questions will be closed. This is not only more efficient for analysis, but also reflects the fact that the adoption study will be quite well focused; will be carried out in an area where researchers should have a good idea of local practices, vocabulary, and so forth; and will be designed after a good informal survey.

2. **Leading questions**
   No survey should contain leading questions, but this is particularly important for an adoption study. There should be no "hints" or encouragement that might lead a farmer to respond positively about particular practices. For instance, farmers should not be told what is "correct" and then be asked if they follow that practice. Similarly, farmers should be allowed to give the names of varieties or purchased inputs that they use and should not be provided these names beforehand. If farmers cannot remember the name of the input, this fact should be recorded on the questionnaire.

3. **Specificity**
   Questions about adoption should be as specific as possible. "Do you use fertilizer?" is rarely a sufficiently precise question, for instance. The fertilizer use should be specified by season and field. If input rates are required for the study, questions should be asked about specific fields and the interviewers will have to be familiar with local units of measure for both inputs and field size.

4. **Order of questions**

The questionnaire should follow a logical order. The introductory questions should be of a general nature. These would be followed by questions about specific aspects of crop management. Sensitive questions, such as those about use of credit, are best left until near the end. As well, if the study requires information on farmers' knowledge of recommended practices, this type of question should be left until after the farmer's actual practices have been recorded.

Examples of questions for an adoption study

Appropriate questions for a questionnaire should be based on understanding developed during an informal survey. No manual can provide "standard" questions to be used on a survey. The following examples are presented only to show some appropriate formats for questions.

A. Many questions regarding the adoption of technology can be asked in the context of an inventory of practices by field. It is almost always preferable to ask about practices in specific fields, rather than in general. If complete information on the area of adoption is required, the question can be repeated for all fields. In other cases, questions about the major field may suffice.

The following table illustrates how questions about weeding practices in cassava might be organized:

Field	1	2	3
Size of field (no. of acres)	______	______	______
Date of planting cassava[a]	______	______	______
Name of cassava variety(ies)	______	______	______
Intercrop[b]	______	______	______
Date of planting intercrop[a]	______	______	______
Date of 1st weeding[a]	______	______	______
Method of 1st weeding[c]	______	______	______
Date of 2nd weeding[a]	______	______	______
Method of 2nd weeding[c]	______	______	______

a Week and month, e.g., 2/4 = 2nd week of April.
b 0 = monocrop, 1 = maize, 2 = sorghum, 3 = other.
c 1 = machete, 2 = hoe, 3 = plow.

B. Measurements for input use may be necessary if it is important to estimate exact dosages. This may require using local measures and vocabulary.

In an area where farmers measured herbicides with small cans, the following questions were asked:

If you used herbicide to control weeds, can you tell us about your practice?

Size of field: ______________ "tareas" (local measure)

	1st application	2nd application
Days before (-) or after (+) planting	______________	______________
Name of herbicide	______________	______________
Cans of commercial product per sprayer tank	______________	______________
Number of tanks per field	______________	______________

C. Farmers' opinions on a new technology are often best assessed by asking about specific characteristics of the technology. The farmer may be asked to compare two or more technologies (e.g., varieties) and be asked which is best or worst.

The following is an example of questions to elicit farmers' opinions on cover crops:

1. We have heard that the cover crop that farmers call "fertilizer bean" has some advantages. Which of the following are important for you?

Improves soil fertility	________
Makes land preparation easier	________
Helps control weeds	________
Helps conserve moisture	________
Controls erosion	________

1 = Very important advantage   3 = Not important
2 = Some advantages   4 = Don't know

2. We have also heard that the "fertilizer bean" has some disadvantages. Which of the following are disadvantages?

Planting the cover crop means losing one cycle of maize	________
Brings more insects	________
Brings more rats	________
Causes landslides on steep slopes	________

1 = Very important advantage
2 = Some advantages
3 = Not important
4 = Don't know

D. Studying varietal use may require careful questioning regarding the source of the seed.

1. Name of principal variety planted in this field: ________

2. Where did you obtain the seed that you planted this year?
   1. From last year's harvest
   2. Purchased from the seed depot
   3. Purchased from the market
   4. Purchased from another farmer
   5. Gift from another farmer
   6. Other ________________

3. If the seed is from last year's harvest, in what year did you first acquire this variety? ____________________________

4. How did you first acquire the seed?
   1. Purchased from the seed depot
   2. Purchased from the market
   3. Purchased from another farmer
   4. Gift from another farmer
   5. Other ________________

E. Extension contact and source of knowledge.

To be able to attribute a change in farmers' practice to an extension program, questions need to elicit when the farmer first began using the practice and the source of the materials and knowledge required to carry out the practice.

1. If you are using leucaena for alley farming on part of your farm, in which year did you begin this practice? ____________

2. Where did you acquire the seed?
   1. Another farmer
   2. The farmer's club
   3. An extension agent
   4. Other ____________________

3. How did you learn how to plant the leucaena?
   1. From another farmer
   2. Attending a field day organized by farmer's club
   3. Attending a field day of extension service
   4. Visit from extension agent
   5. Reading extension bulletin
   6. Own experiments
   7. Other ____________________

4. How did you learn how to prune the leucaena?
   1. From another farmer
   2. Attending a field day organized by farmer's club
   3. Attending a field day of extension service
   4. Visit from extension agent
   5. Reading extension bulletin
   6. Own experiments
   7. Other ____________________

Survey Implementation

Guidance on survey implementation can be found in a number of sources (Byerlee, Collinson, et al. 1980; Casley and Lury 1981). Any questionnaire should go through several drafts as it is reviewed by colleagues and pre-tested with farmers. It is difficult to overemphasize the importance of careful questionnaire testing. The field testing of the questionnaire should be done by the people who will work as enumerators, so that they can participate in developing the final version and have a thorough understanding of the questions. Besides participating in the field testing of the questionnaire, the enumerators should undergo additional training to ensure that they are able to present and interpret the questions correctly.

The logistics of carrying out the survey need to be carefully thought out. Enumerators are assigned specific portions of the sample, and are given explicit instructions regarding rules for replacing sample farmers who are unavailable. The enumerators may be deployed singly, or in teams of two, with one responsible for asking the questions and the other for recording. Completed questionnaires should be turned in to a supervisor every evening, and they should be checked so that gaps or inconsistencies can be addressed immediately.

The coding and analysis should begin immediately after the completion of the survey. For an adoption survey to be useful, a report should be written and distributed as soon as possible.

Summary

The choice of sample for an adoption study will be determined in part by the objectives of the study. The study area needs to be defined (political boundaries, ecology, etc.). Farmers may be selected at random from the study area, or the sample may include farmers with particular characteristics. The sample size will depend on the variability of the farming population being studied and the resources available. Decisions will also have to be made about sampling within the farm: are all fields to be studied, or only particular ones?

The design of questions for an adoption study should follow the rules of survey design in general, with attention to clarity, specificity, and logical ordering. In an adoption study, particular care must be given to ensuring that the questions do not bias the farmer towards positive responses regarding the technologies being studied.

The survey should be implemented as efficiently as possible, and timely analysis and write-up are crucial. The following chapter provides some guidelines for analyzing the results of an adoption survey.

Chapter 5

Methods for Analyzing Adoption Patterns

The results of an adoption survey require careful analysis and presentation. The form and focus of the final report will depend very much on the purpose of the study. If the purpose is only to document the degree of adoption, then thought must be given to the factors discussed in Chapter 2 regarding the definition of adoption, the best way to present the degree of present adoption, and the necessity of analyzing historical adoption patterns. This type of analysis is useful for considering the rate of progress of a technology generation effort and for helping to investigate the impact of such an effort.

But very often we also wish to analyze the adoption patterns and to try to explain why a technology may be reaching certain farmers and not others. Some of the possible reasons for differences in adoption were outlined in Chapter 3. Explaining adoption patterns requires additional analysis, which is the subject of the present chapter.

There are two principal strategies for helping us understand why farmers accept or reject a particular technology. One is to seek the opinions and observations of the farmers, and the second is to do a statistical comparison of adoption behavior with the characteristics of the farm, farmer, or institutional environment. Both of these are valid aspects of survey analysis. This chapter discusses the analysis and presentation of this type of data.

Farmers' Opinions

Farmers usually know what they like and what they do not like about a new technology and are able to express their opinions. These opinions will reflect their own experience. If the adoption study encourages farmers to provide an honest assessment and does not make them feel that the questioning represents a test of knowledge of "modern agriculture" or "recommended practices," then very useful information will be obtained. Open questions, such as "Do you like variety X?" or "What problems do you find with reduced tillage?" may not be effective, however. The formal adoption study will be based on the experience of an informal survey (where these open questions are more appropriate), and the questionnaire should refer more to specific characteristics of the technology that have been identified. Box 25 (at the end of this chapter) shows farmers' opinions on two technologies; in one case adopters were asked to explain the reasons for using a technology, while in the second case farmers who did not adopt were asked to explain their choice.

Farmers' decisions regarding new technology can rarely be reduced to a simple set of opinions, however. Farmers use a range of criteria in deciding whether to change their practices, and a number of models and theories have been developed to try to explain farmer decision-making. Such methods are beyond the scope of this manual, but one of the most commonly used tools, "decision trees," is illustrated in Box 26.

Statistical Comparisons

Although farmers are experts regarding their own fields and practices, they may not be able to provide much information on factors that affect other farmers. In addition, the factors that influence the adoption of a technology may be so diverse or complex that it is unreasonable to ask a farmer to account for them or to try to explain the pattern of adoption. For that reason, an understanding of adoption also can benefit from a statistical comparison of the farmers' adoption behavior with various characteristics of the farmers' environment. In most instances it is the farmers themselves who will be asked to describe these characteristics, but they will not be asked to actually articulate the causal linkage between the characteristics and adoption. That is the task of the researcher, and it may draw upon a wide range of tools in statistical analysis.

Techniques of survey analysis are well described in a number of texts, including Casley and Kumar (1988), Alreck and Settle (1985), and Norusis (1991). The purpose here is only to review briefly a few of the most common methods that are relevant to the analysis of an adoption study.

In attempting to explain adoption patterns by statistical analysis, the most common approach is to compare the characteristics of farmers who have adopted a technology with those who have not adopted, to see if some of these differences might offer insights into the rationale for adoption. Thus if the proportion of farmers who have access to irrigation is much higher among adopters, we would be led to explore the possibility that the technology is more appropriate or accessible if a farmer has irrigation.

Just because these differences can be found does not of course constitute proof of an association. The differences must be explored within the context of all of the data available from the survey. Simple methods of presenting these data and statistical tests help in making the case, but the major responsibility in interpretation lies with the researcher, who must provide a consistent, coherent, and logical explanation for the adoption patterns that are observed.

One of the simplest and most useful ways of examining differences in adoption patterns is with contingency tables, in which the cells of the table compare the proportion of adopters and non-adopters with a particular characteristic. This is particularly appropriate if the characteristic of interest is a nominal one, that is, one that is represented by non-numerical categories, such as access to irrigation (yes or no) or previous crop in the rotation (potatoes, barley, or other). Even in cases where the variable is a continuous one (such as farm size or number of days between land preparation and planting), it is sometimes useful to divide it into a few simple categories (large vs. small; low, medium, high) and develop contingency tables. The relevant statistical test of this association is the chi-square test.

In the example below, the adoption of row planting for maize is examined in light of land preparation practices. It can be seen that there is a strong association. Farmers who use a tractor for land preparation are much more likely to adopt row planting; 84% of these farmers adopt row planting, while only 29% of the farmers using manual land preparation adopt row planting. The chi-square test shows that it is improbable that this association could occur by chance.

Planting method by land preparation

Planting method	Land preparation: Manual	Land preparation: Tractor	Total
Random	177 (71%)	22 (16%)	199
Row	71 (29%)	114 (84%)	185
Total	248 (100%)	136 (100%)	384

$\chi^2 = 105.0$ d.f. = 1 $p < .0001$

The contingency table does not tell us why these two factors are related, however. It could be that tractor preparation makes row planting easier; in this case tractor preparation is a cause of row planting. It is possible (although unlikely) that row planting "causes" tractor use, in the sense that a farmer who decides to row plant will rent a tractor for land preparation. The point is that we must go beyond presentation of the association and seek an explanation.

If the variable is continuous, another option is to compare the means for adopters and non-adopters. An appropriate statistical test in this case is the t-test. The table below shows that fields where farmers apply fertilizer tend to be cropped continuously for a longer time than those fields where fertilizer is not used.

Fertilizer use by cropping history

Field	Average years continuous cropping
Without fertilizer (N = 50)	3.14
With fertilizer (N = 58)	6.40

$t = 3.51$ d.f. = 106 $p < .001$.

The t-test shows that it is unlikely that this difference could occur by chance. The statistical test says nothing about whether this difference might be important, however. Neither does it say if there is any direct connection between a farmer's decision to use fertilizer and the cropping history of the field. It seems logical that cropping history might influence fertilizer use, but the researcher needs to explore and elaborate this relation.

In the discussion above we have assumed that the adoption variable is divided into only two categories, adoption and non-adoption. In some cases, however, adoption may be measured in a more disaggregated manner. There may be several categories of adoption (adopters, ex-adopters, and non-adopters; or complete, partial, and non-adopters). Contingency tables may be expanded easily to accommodate this type of categorization. If a continuous variable such as farm size is to be compared to adoption measured in several categories, a one-way analysis of variance can be performed. In certain cases, adoption itself may be represented as a continuous variable (such as kilograms of fertilizer per hectare) and other statistical methods, such as correlation or regression analysis, will then be appropriate.

It should be emphasized that the statistical tests are simply a way of providing a quantitative estimate of the likelihood that the association observed between two variables could have occurred by chance, even if there were no relation between them. Most statistics texts warn readers of the difference between statistical significance and importance. A relationship may be shown to be very significant (i.e., very unlikely to have occurred by chance) and yet be quite unimportant. We should always pay attention to the degree of difference as well as the statistical significance.

For instance, a survey may show that the average farm size for adopters is 4.7 ha, while the average farm size for non-adopters is 4.2 ha. Depending on the variability in the sample and the sample size, this difference might be shown to be statistically significant. It is probably not surprising that farm size exerts some influence on a farmer's adoption decision, but it is doubtful if we would want to give much emphasis in this case to the fact that adopters tend to operate farms that are about 10% larger than those of non-adopters. The information probably is not useful to researchers (for refining their recommendations) or to policymakers (in understanding the spread or impact of new technology). If the adopters tended to have farms that were twice as large as those of the non-adopters, on the other hand, we would have to begin thinking about better targeting or presentation of the technology.

If two factors are associated, there are a number of ways of explaining the observed association. In most cases, the analysis of adoption surveys will look for factors that may cause or contribute to the adoption (or non-adoption) of a technology. There is no standard method for doing this type of interpretation, and the researcher must be guided by his or her knowledge of the data and of the farming system. Further detail on this type of survey analysis can be found in Rosenberg (1968).

Some ways of interpreting and refining the relationship between two variables in an adoption study

Just because there is a relationship between two variables does not mean that one causes the other. In studying adoption, we try to identify factors that influence a farmer's decision to use a technology. The analysis should provide a clear and logical explanation for the contribution that a particular factor makes to the adoption decision. This requires a careful analysis of the relationship between variables. The following examples show how the relationship between two variables (A and B) can be understood better by including a third variable (C) in the analysis.

1. **Identifying specific components of the causal variable**
   In some cases a relationship may seem reasonable, but it is possible to find a more specific explanation. For example, farm size (A) may be related to the adoption of contour hedgerows for erosion control (B). The smaller the farm, the more likely the adoption. What is it about farm size that would influence the adoption of hedgerows? If we find that small farms have more family labor available per hectare (C), and that there is also a strong relationship between labor availability and hedgerow adoption, it may be sensible to emphasize this factor in our analysis of the data.

Proposed relation:	A	——→	B
Revised relation:	A(C)	——→	B

Proposed

Farm size (A) ——→ Adoption of hedgerows (B)

	Plant hedgerows (n=22)	**Do not plant hedgerows (n=29)**
Average farm size	1.2 ha	2.3 ha
	t-test prob. < .05	

Revised

Farm size (A) is associated with labor availability (C) ——→ Adoption of hedgerows (B)

	Plant hedgerows (n=22)	**Do not plant hedgerows (n=29)**
Family labor/ha	2.7 persons	1.2 persons
	t-test prob. < .05	

2. **Looking for intervening variables**
   There is another possibility, closely related to the previous one, where a search for a more specific or useful explanatory factor leads to lengthening the causal chain. If it is found that oxen ownership (A) is related to the adoption of a new, late-maturing maize variety (B), we need to ask what is the connection. We may find that farmers with oxen are able to prepare and plant their fields earlier (C) and are therefore able to use the new variety without worrying about the relatively short rainy season. The relationship between planting date (C) and variety adoption (B) is more useful than the relationship between oxen ownership (A) and variety adoption.

Proposed relation:	A	——→			B
Revised relation:	[A	——→	] C	——→	B

Proposed

Oxen ownership (A) ——→ Variety adoption (B)

	Adopt new variety	**Do not adopt variety**	**Total**
Own oxen	28 (70%)	12 (30%)	40 (100%)
Rent oxen	7 (24%)	22 (76%)	29 (100%)
	χ^2 prob. < .01		

Revised

[Oxen ownership (A) →] Early planting (C) → Variety adoption (B)

	Adopt new variety	Do not adopt new variety
Mean planting date	14 April	2 May

3. **Eliminating an extraneous variable**
   Sometimes we find an association between two variables that we do not understand. This may be because the two are related only by chance, or perhaps because the two variables happen to be related to a third. In one survey an association was found between tenancy (A) and variety adoption (B); owners rather than sharecroppers were the ones who adopted the variety. Researchers could give no clear explanation for this relationship. It was then discovered that sharecroppers were concentrated in one region where the new variety had not been promoted. When the analysis was done *controlling* for region (C), the relationship between tenancy and variety adoption disappeared.

Proposed relationship A →(?) B

Revised relationship C → A (no relationship) B; C_0: A (no relationship) B; C_1: A (no relationship) B

Proposed

Land ownership (A) → Variety adoption (B)

	Adopt new variety		Do not adopt new variety		Total	
Owner	159	(60%)	106	(40%)	265	(100%)
Sharecropper	14	(26%)	39	(74%)	53	(100%)

χ^2 prob. < .01

Revised

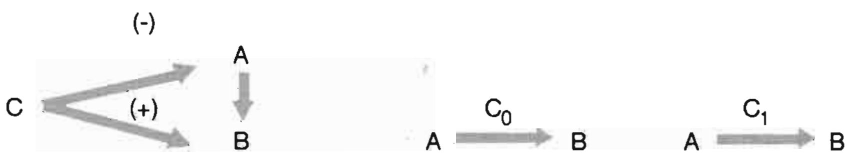
The association is tested controlling for the third factor:

	Region X (C_0) **A (no relationship) B**			**Region Y (C_1)** **A (no relationship) B**		
	Region X			**Region Y**		
	Adopt variety	**Do not adopt variety**	**Total**	**Adopt variety**	**Do not adopt variety**	**Total**
Owner	35 (30%)	81 (70%)	116 (100%)	124 (83%)	25 (17%)	149 (100%)
Share-cropper	10 (21%)	37 (79%)	47 (100%)	4 (67%)	2 (33%)	6 (100%)
		χ^2 prob. = n.s.			χ^2 prob. = n.s.	

4. **Finding a variable that suppresses a relation**
   Sometimes we expect to see an association between two variables, but we find none exists. A third variable may suppress the relation by being positively correlated with the dependent variable and negatively correlated with the independent variable. Preliminary analysis of an adoption survey showed no relationship between farm size (A) and fertilizer use (B), although researchers expected to see such a relationship. A third variable, slope of field (C), suppressed the relationship. More fertilizer was used on hillside fields than on flat fields, and most large farms were on flat land. Hillside fields were positively correlated with the dependant variable (fertilizer adoption) and negatively correlated with the independent variable (farm size).

Proposed relation: A (no relation) B

Revised relation:



Proposed

Farm size (A) (no relation) Fertilizer use (B)

	Small farms (n=53)	**Large farms (n=38)**
Average fertilizer use (bags/ha)	4.6	4.9
	t-test prob = n.s.	

Revised

The association is tested controlling for the third factor:

	Farms on flat land (C_0) A → B		Farms on hillsides (C_1) A → B	
	Farms on flat land		Farms on hillsides	
	Small farms (n=9)	Large farms (n=33)	Small farms (n=44)	Large farms (n=5)
Average fertilizer use (bags/ha)	1.7	4.3	5.2	8.9
	t-test prob. <.05		t-test prob. <.05	

5. **Looking for conditional relationships**
A causal relation may be valid, but only under certain conditions. Preliminary analysis of a survey showed that farmers who planted early (A) were the ones who used a cover crop (B). One explanation was that farmers who planted late were concerned about losing their investment in a cover crop if the rains stopped early. This would make sense, however, only where rainfall was a problem. When the relationship was tested controlling for the third factor, rainfall zone (C), it was found that the relationship was evident only in the low rainfall zone.

Proposed relation: A → B

Revised relation: C_0: A → B; C_1: A (no relationship) B

Proposed

Early planting (A) → Use of a cover crop (B)

	Plant before 1 Nov.	Plant after 15 Nov.
Percent farmers planting cover crop	40%	24%
	χ^2 prob.<.05	

Revised

The association is tested controlling for the third factor:

Low rainfall zone (C_0)	High rainfall zone (C_1)
A ⟶ B	A (no relationship) B

	Low rainfall zone		High rainfall zone	
	Plant before 1 Nov.	Plant after 15 Nov.	Plant before 1 Nov.	Plant after 15 Nov.
Percent farmers planting cover crop	34%	12%	48%	42%
	χ^2 prob. <.05		χ^2 prob. = n.s.	

Logit, probit, and tobit analysis

The examples above emphasize the fact that understanding adoption behavior often requires that the researcher look beyond relationships between single variables or searching for simple explanations. Although much can be accomplished by re-examining two-variable relationships and by breaking contingency tables into component tables, there are definite limits on our capacity to manage or interpret multifactorial relationships in this way. There are a number of well-developed methods for looking at multivariate relationships. One of the most common is multiple regression analysis, but this is appropriate only if the dependent variable is continuous. As many adoption studies will deal with adoption as a categorical dependent variable (usually "yes" or "no"), other techniques are required. Two related multifactorial analytical techniques that are particularly useful for adoption studies are logit analysis and probit analysis.

Both probit and logit models are techniques for estimating the probability of an event (such as adoption) that can take one of two values (adopt, don't adopt).

In analyzing adoption, both probit and logit models use a series of characteristics of the farm or farmer (which may be dichotomous or continuous variables) to predict the probability of adoption. The basic difference between the two models is that logit assumes that the dependent variable follows a logistic distribution while the probit model assumes a cumulative normal distribution. For most simple problems the interpretation of the same data, whether estimated by probit or logit, will be very similar, with noticeable differences occurring only in the tails of the distribution (in other words only for individuals having extremely high or extremely low probabilities of adoption).

The following example is a simple logistic regression that examines the adoption of a new variety. The dependent variable is variety adoption and the independent variables are the region of the country, land tenure, cropping practice, and farmers' age. The variables are listed below:

Variable	Values	
Variety adoption (VAR)	0 = no	1 = yes
Region (REG)	0 = forest	1 = savanna
Tenure (TEN)	0 = sharecrop	1 = owner
Monocrop (MON)	0 = intercrop	1 = monocrop
Age (AGE)	(continuous variable)	

The results of the logistic regression show a highly significant association with region, no association with tenure, a significant association with monocropping, and none with age.

Variable	Logistic regression statistics			Probability
	Coefficient	Standard error	T-ratio	
Constant	-2.087	0.549	-3.803	0.000
REG	2.332	0.325	7.169	0.000
TEN	0.465	0.400	1.162	0.245
MON	1.111	0.310	3.585	0.000
AGE	-0.012	0.010	-1.289	0.197

Sample size	=	318
Log of likelihood function	=	-162.9
Chi-square statistic for significance of equation	=	131.1
Degrees of freedom for chi-square statistic	=	4
Significance level for chi-square statistic	=	0.000
Cases correctly predicted	=	79.0%

This example draws on the same data used in the example on page 73. In that example, there was a significant relationship between variety adoption and tenure. But when we controlled for region, the relationship disappeared. The logistic regression does the same thing, and the results say that when we control for region (and cropping practice and age) there is no association between land tenure and varietal adoption.

If we were to run the logistic regression without including region, we would find that tenure appears to have a significant association with variety adoption (see the following table). The use of multivariate techniques such as logit models is therefore no guarantee that we will identify important relationships and discard unimportant ones. The opposite strategy of throwing as many independent variables as possible into the equation is not advisable either. The use of such techniques will be efficient only if we have a clear understanding of the data with which we are working.

Variable	Logistic regression statistics			Probability
	Coefficient	Standard error	T-ratio	
Constant	-1.367	0.481	-2.842	0.005
TEN	0.893	0.353	2.531	0.011
MON	1.868	0.266	7.016	0.000
AGE	-0.012	0.009	-1.445	0.148

Sample size	=	318
Log of likelihood function	=	-192.7
Chi-square statistic for significance of equation	=	71.4
Degrees of freedom for chi-square statistic	=	3
Significance level for chi-square statistic	=	0.000
Cases correctly predicted	=	72.4%

One way of presenting information from probit or logit regressions is to show how changing one independent variable alters the probability that a given individual is an adopter. In ordinary least squares regression, a coefficient can be interpreted directly as the change in the value of the dependent variable associated with a change in one unit of the independent variable associated with that coefficient. This is not true in probit or logit regressions; the change in probability of adoption given a change in one of the independent variables depends not only on the coefficient of that variable but also on the levels of all the other independent variables.

As an example, the estimated probability of adoption in a logit model is given by:

probability of adoption = F(b'x),

where:

$$F(b'x) = \frac{1}{1 + e^{-b'x}}$$

is the cumulative logistic probability distribution. The expression b'x is defined as:

$$b'x = b_0 + b_1x_1 + b_2x_2 + \ldots + b_kx_k$$

where b_0 is the constant, $b_1, b_2, \ldots b_k$ are the other estimated coefficients, and $x_1, x_2, \ldots x_k$ are the values of the independent variables. In the first model estimated above, the probability of new variety adoption for a forest zone farmer who is an owner, 41 years old, and planting an intercropped field is calculated as below:

Variable	Coefficient (1)	Value of independent variable (2)	(1) x (2)
Constant	-2.087	1	-2.087
REG	2.332	0	0
TEN	0.465	1	0.465
MON	1.111	0	0
AGE	-0.012	41	-0.492
Total (b'x)			-2.114

$$F(b'x) = \frac{1}{1+e^{-b'x}} = \frac{1}{1+e^{2.114}} = .11$$

Thus, the probability of such a farmer being an adopter is .11. A farmer with identical characteristics except for planting a monocropped field would have a probability of adopting a new variety given as follows:

Variable	Coefficient (1)	Value of independent variable (2)	(1) x (2)
Constant	-2.087	1	-2.087
REG	2.332	0	0
TEN	0.465	1	0.465
MON	1.111	1	1.111
AGE	-0.012	41	-0.492
Total (b'x)			-1.003

$$F(b'x) = \frac{1}{1+e^{-b'x}} = \frac{1}{1+e^{1.003}} = .27$$

Similar calculations show that a 41-year-old owner in the savanna zone has a predicted probability of adoption of .55 if he or she intercrops and .79 if he or she monocrops. In other words monocropping raises the predicted probability of adoption for otherwise identical farmers in both the forest and the savanna zone, but the change in predicted probabilities is different in the two different environments.

Predicted adoption probabilities in the probit model are calculated in exactly the same way, except that F(b'x) in this case represents the cumulative standard normal probability distribution. The mathematical form of the normal distribution is relatively complex, but values of F(b'x) can be found easily enough in standard probability tables.

In some instances one might want to analyze not only adoption but also the extent or intensity of adoption. For example, one might want to estimate both the probability that a farmer uses fertilizer and the rate of application as well. A commonly used model in this case is the tobit model. Tobit, like probit, is based on the normal distribution. As in probit or logit, coefficients are estimated for the independent variables thought to be relevant. Tobit estimates also include the standard error of the regression s, which is an estimate of the standard deviation of the error term in the regression model.

In a tobit model, the predicted probability of adoption for a farmer with characteristics x is estimated by F(b'x/s), where b, x, and s are defined as above, and F is the cumulative standard normal distribution function. The expected value of the application rate Y (or total amount used, depending on the dependent variable used in the regression) is estimated by

$$E(Y) = F(b'x/s)(b'x) + sf(b'x/s),$$

where f is the probability density function for the standard normal distribution.

The expected value of Y, the application rate or total amount used, given that Y>0 (i.e., that the farmer is an adopter), is estimated by

$$E(Y:Y>O) = b'x + s \frac{f(b'x/s)}{F(b'x/s)}$$

As with the cumulative standard normal distribution, the standard normal density function is also easily found in probability tables.

Maddala (1983) is a good source of information on logit, probit, and tobit models. Multivariate analytical techniques are available in several software packages for personal computers. It is thus quite easy to enter data on a large number of variables and obtain long printouts and an impressive list of coefficients and related significance levels. But just as with the simpler analytical techniques, the responsibility for interpreting the results rests with the researcher. A result that shows that certain variables are associated with adoption says nothing about the causal links among those variables. And a high significance level says nothing about the importance of the relationship. This warning is especially relevant for multivariate analyses, where computer technology makes it possible to examine dozens of variables. It must be remembered that a significance level of 10% means that the observed association has a one in ten chance of occurring at random. If we were to include 15 or 20 independent variables in an equation, we would expect that a couple of them would appear "significant" just by chance, especially if we ran several regressions with different combinations of variables. (This warning is of course equally valid for the practice of analyzing 15 or 20 single-variable relationships until something appears that is "significant.") A summary of some of these analytical problems related to understanding the adoption of soil conservation is presented by Lockeretz (1990).

Even sophisticated analytical techniques have severe limitations in their ability to disentangle complex relationships among a number of variables. The purpose of analyzing adoption patterns should be to identify a few key relationships or factors that not only can help us to understand the adoption process, but can help to make the research and extension effort more efficient in the future. The emphasis should thus be on simple analyses and clear presentations (Casley and Kumar 1988). We should also remember that we are limited in our ability to understand adoption not only by the statistical techniques at hand, but most of all by the skill with which we frame the questions in our adoption study and the quality of the data that are generated.

Summary

Adoption studies often attempt to analyze and understand the observed adoption patterns. In these cases, adoption survey analysis can include both an examination of farmers' opinions and observations, and a statistical comparison of adoption measures with characteristics of the farmer or the farming system. Farmers' decisions regarding a new technology are often quite complex, and the purpose of an analysis is to try to use a range of statistical procedures to identify the most important factors that influence adoption. The analysis will be successful only if the information can be used to help improve the efficiency of subsequent technology generation and diffusion efforts.

Box 25. Using Farmers' Opinions to Understand Adoption Patterns

A. An adoption survey can ask farmers' opinions about a new technology. Farmers may be able to give both positive and negative characteristics of the technology.

In the example below, farmers in Nigeria who had adopted alley farming were asked what they saw as its principal advantages.

Alley farmers' perceptions and uses of alley farms,[a] Nigeria

	% alley farmers		% alley farmers
Trees used for:		Cultivated tree species preferred by farmers:	
Mulch only	3	Leucaena	66
Feed only	5	Gliricidia	2
Mulch + feed	35	Both	24
Mulch + feed + other[b]	51		92
	94		
Perceived benefits:		Reason for preference for species planted:	
Better soil fertility	29	Liked by animals	75
Better animal performance	41	Grows fast	5
Better soil fertility and animal performance	23	Other	5
	93		85

Source: Reynolds et al. (1991).
a Based on 137 farmers. Percentages do not add to 100% because of missing data.
b Includes stakes and firewood.

B. It is equally important to ask farmers why they don't adopt. In the example below, farmers in Ghana who did not use the recommended maize variety were asked why they did not plant it. The analysis was divided between farmers who had used the variety in the past but stopped using it, and those who had never used the variety.

Reasons for not using improved varieties, Ghana, 1990

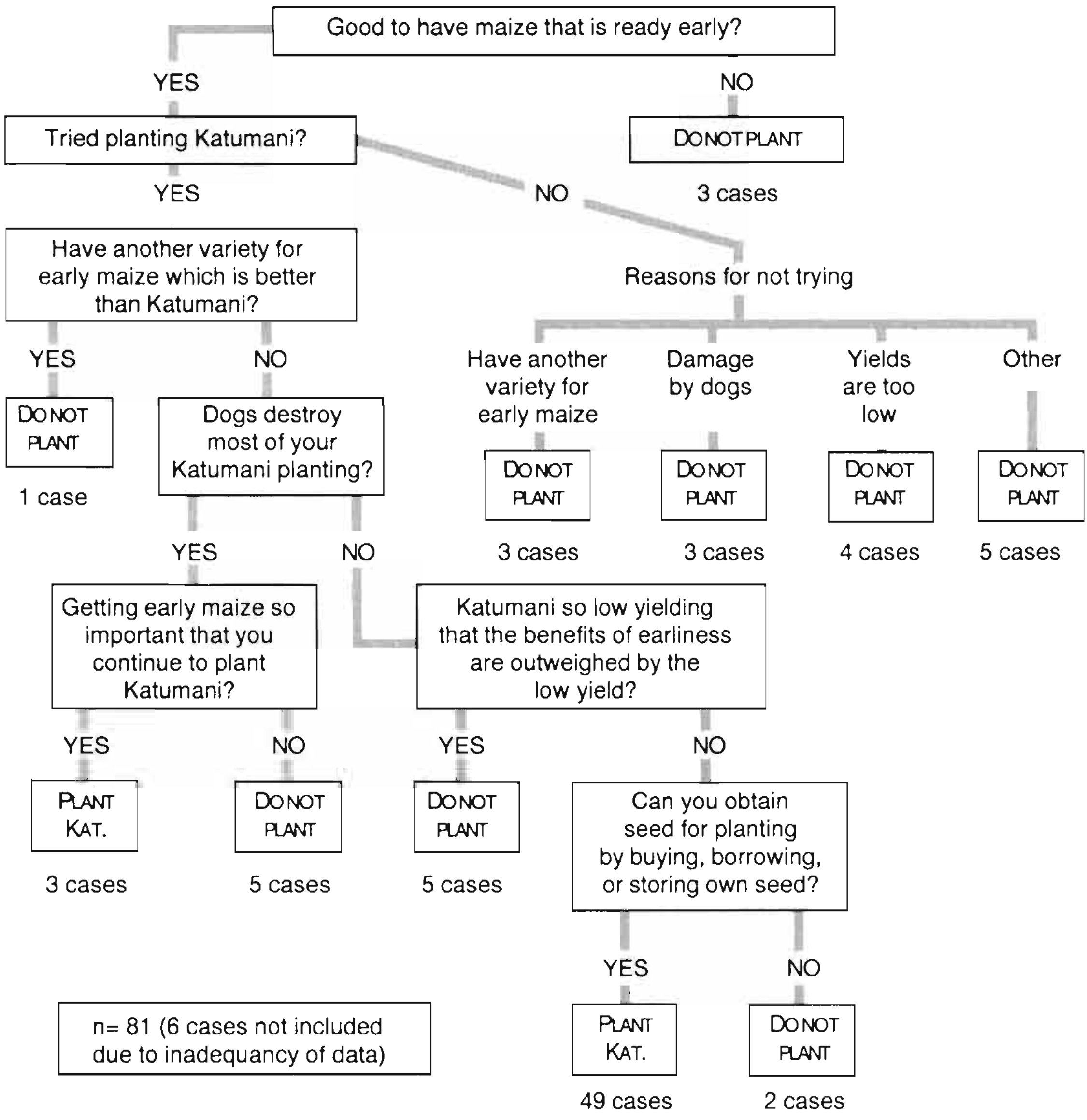
Reason	Percentage of farmers who never adopted the variety	Percentage of farmers who no longer use the variety
Seed not available	62	64
Lack of knowledge	29	0
Storage problems	27	39
Marketing problems	20	49
Cooking quality	8	6
Yield	2	6
(Number of farmers)	(98)	(33)

Source: Ghana Grains Development Project (1991).
Note: Percentage total is more than 100% because of multiple answers.

Box 26. Decision Trees

Decision trees are a method of representing a farmer's choice about a new technology as a series of decisions, arranged in a hierarchy. The method is described in detail in Gladwin (1989).

An example of a decision tree is shown below. It attempts to analyze farmers' decisions regarding the use of an early-maturing maize variety ("Katumani") in Kenya. According to this analysis, the decision to plant this variety is based on farmers' need for early maize, the availability of other early varieties, and experience with yields and dog damage.



Source: Franzel (1984).

Chapter 6

Conclusions

There is an urgent need to develop more productive technology for farmers in developing countries. The resources available to public and private institutions, and to the farmers themselves, are very limited, however. Thus it is imperative that the process of technology generation be made as efficient as possible. One way of improving the efficiency of agricultural technology development is to do a better job of describing and analyzing technology adoption.

There is no single method for studying technology adoption. Indeed, concerns with adoption and acceptability must form a part of the technology generation process from its early stages. Agricultural research that does not include a continual dialogue between farmers and researchers will have little chance of success.

As technology is developed and made available, there are several ways of following its progress. This manual has described one important method, the formal survey. Its advantages include the ability to provide systematic, quantitative information to those who must take decisions about research or extension efforts, and its ability to formally test hypotheses that explain adoption patterns.

Formal adoption studies can provide valuable information to research, extension, or rural development institutions that wish to assess their progress and take advantage of farmer experience. Adoption studies are also valuable tools for improving the efficiency of communication between institutions responsible for research, extension, and agricultural policy. And finally, an adoption study can play an important role in demonstrating the impact of a research or extension effort and in justifying continued or expanded support from funding sources.

Properly managed, adoption studies can contribute to improving the efficiency of agricultural research, technology transfer, input provision, and agricultural policy formulation. Formal adoption studies should thus be an important part of the methodology of institutions involved in agricultural development.

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ISBN: 968-6127-77-1

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