An Economics Training Manual

From Agronomic Data to Farmer Recommendations

CIMMYT

ECONOMICS PROGRAM

The International Maize and Wheat Improvement Center (CIMMYT) is an internationally funded, nonprofit scientific research and training organization. Headquartered in Mexico, the Center is engaged in a worldwide research program for maize, wheat, and triticale, with emphasis on food production in developing countries. It is one of 13 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 40 donor countries. international and regional organizations. and private foundations.

CIMMYT receives support through the CGIAR from a number of sources, including the international aid agencies of Australia, Austria, Brazil. Canada. China, Denmark. Federal Republic of Germany. France, India, Ireland, Italy, Japan. Mexico. the Netherlands. Norway. the Philippines. Saudi Arabia. Spain, Switzerland, the United Kingdom and the USA, and from the European Economic Commission, Ford Foundation. Inter-American Development Bank. International Development Research Centre, OPEC Fund for International Development. Rockefeller Foundation. UNDP. and World Bank. Responsibility for this publication rests solely with CIMMYT.

Correct Citation: CIMMYT. *1988. From Agronomic Data to Farmer Recommendations: An Economics Training Manual.* Completely revised edition. Mexico. D.F.

ISBN 968-6127-18-6

Preface

This document is a completely revised version of the CIMMYT Economics Program manual, *From Agronomic Data to Farmer Recommendations: An Economics Training Manual,* written by Richard Perrin, Donald Winkelmann, Edgardo Moscardi, and Jock Anderson. Since its publication in 1976 that manual has been through six printings and has been translated into six languages. The manual has been used by countless students and researchers for learning a straightforward method of analyzing the results of on-farm agronomic experiments and making farmer recommendations.

We approach the revision of such a successful manual with considerable caution. Our work over the past decade has given us a chance to present this material, in the classroom and in the field, to agricultural researchers in a wide variety of settings all over the world. This experience has led us to propose and test some new ways of explaining and presenting key concepts. We gradually began to consider the possibility of incorporating some of those ideas in a revised manual.

One of the first steps in the process was to introduce a set of exercises for classroom teaching, developed by Larry Harrington. Later, Robert Tripp and Gustavo Sain developed further exercises and methods of presentation which they tested in training courses. Tripp and Sain wrote the first draft of the present document and guided its review by the entire staff of the CIMMYT Economics Program.

Just as this revised manual has built on the experience of hundreds of researchers with the original version, we hope that those who use this new version will provide suggestions for its improvement. We believe it will be useful in the classroom as well as for individual study and reference. A book of exercises has been developed to accompany this manual and can be obtained from CIMMYT. We hope that the new version of the manual will find an acceptance as wide as that of its predecessor.

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Acknowledgements

Many people have contributed to the production of this manual. Jock Anderson and Richard Perrin, two of the authors of the original manual, were kind enough to read the final draft of this revised version and to offer detailed comments and suggestions. Miguel Avedillo, Carlos Gonzalez, Peter Hildebrand, Roger Kirkby, Stephen Waddington, and Patrick Wall also read the final draft and provided valuable ideas. In addition, participants in the courses and workshops presented by the CIMMYT Economics Program over the past decade have made significant contributions.

The document passed through several drafts, which would not have been possible without the superb organization and typing of Maria Luisa Rodriguez. Editing was in the very competent hands of Kelly Cassaday and design was skillfully directed by Anita Albert. Typesetting, layout, and production were carefully managed by Silvia Bistrain R., Maricela A. de Ramos, Miguel Mellado E., Rafael De la Colina F., Jose Manuel Fouilloux B., and Bertha Regalado M.

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Chapter One
Overview of Economic Analysis

This manual presents a set of procedures for the economic analysis of on-farm experiments. It is intended for use by agricultural scientists as they develop recommendations for farmers from agronomic data. Developing recommendations that fit farmers' goals and situations is not necessarily difficult, but it is certainly easy to make poor recommendations by ignoring factors that are important to the farmer. Some of these factors may not be very evident.

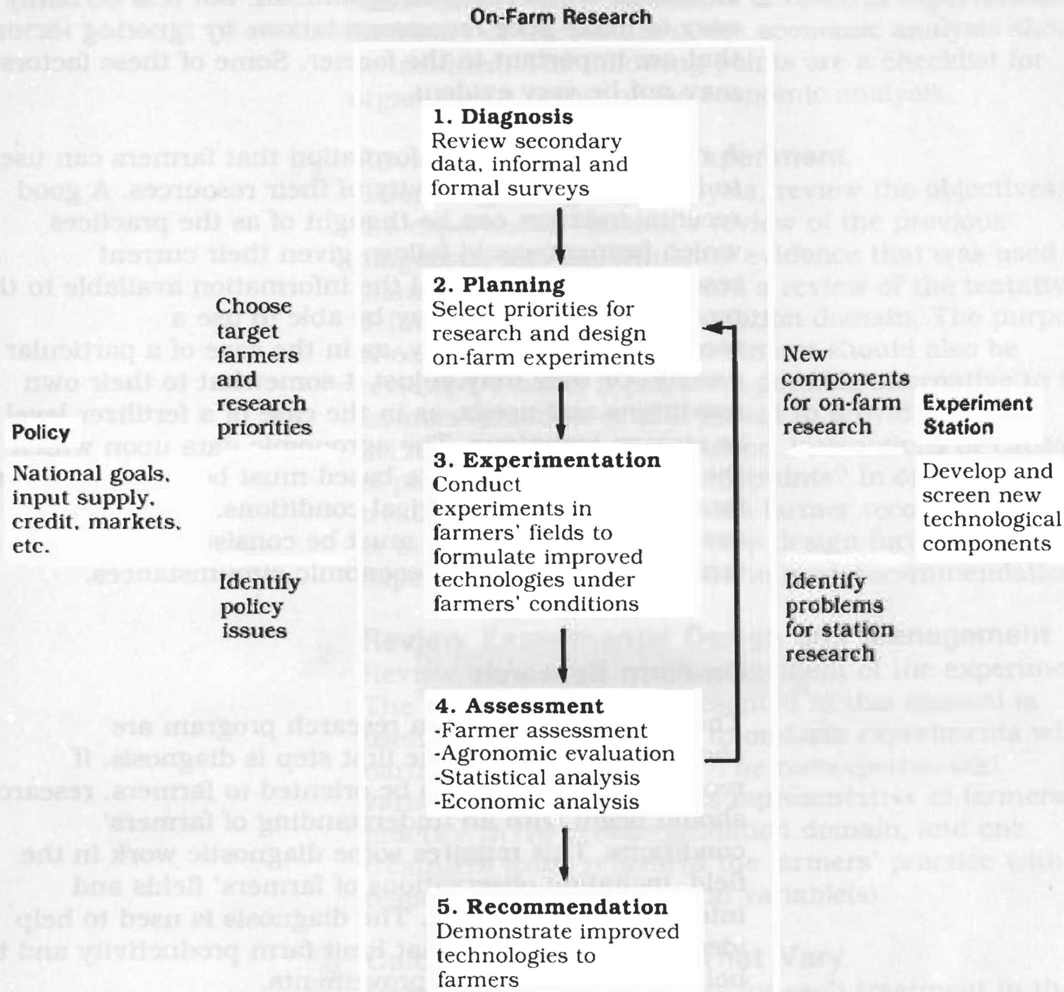
A recommendation is information that farmers can use to improve the productivity of their resources. A good recommendation can be thought of as the practices which farmers would follow, given their current resources, if they had all the information available to the researchers. Farmers may be able to use a recommendation directly, as in the case of a particular variety. Or they may adjust it somewhat to their own conditions and needs, as in the case of a fertilizer level or storage technique. The agronomic data upon which the recommendations are based must be relevant to the farmers' own agroecological conditions, and the evaluation of those data must be consistent with the farmers' goals and socioeconomic circumstances.

On-Farm Research

The stages of an on-farm research program are shown in Figure 1.1. The first step is diagnosis. If recommendations are to be oriented to farmers, research should begin with an understanding of farmers' conditions. This requires some diagnostic work in the field, including observations of farmers' fields and interviews with farmers. The diagnosis is used to help identify major factors that limit farm productivity and to help specify possible improvements.

The information from the diagnosis is used in planning an experimental research program that includes experiments in farmers' fields. The on-farm experiments should be planted on the fields of representative farmers. After the first year, the experimental results form an important part of the information used for planning research in subsequent crop cycles. Other diagnostic work continues during the management of the experimental program as researchers continue to seek information about farmers' conditions and problems which will be useful in planning future experiments.

Figure 1.1. Stages of on-farm research



The results of the on-farm experiments must be assessed. There are several elements in such an assessment. First, researchers must discuss the results with farmers to get their opinions of the treatments they have seen in their fields. The farmers' assessment is very important. The experimental results must also be subjected to both an agronomic evaluation and a statistical analysis. Finally, an economic analysis of the results is essential. The economic analysis helps researchers to look at the results from the farmers' viewpoint, to decide which treatments merit further investigation, and which recommendations can be made to farmers. The procedures for carrying out such an economic analysis are the subject of this manual.

The results of an assessment of on-farm experiments can be used for several purposes. First, they may be used to help plan further research. Some experiments will have as their goal the clarification of production problems: Is production limited by the availability of phosphorus? Will improved weed control give an important increase in yields? The answers to such questions provide researchers with information for further work. As Figure 1.1 shows, that information can be used to plan subsequent experiments. It also may help orient work on the experiment station.

Second, the results may be used to make recommendations to farmers. Some experiments will compare possible improvements to farmers' current practices: Which level of phosphorus should be applied? Which weed control method gives the best results? The answers to these questions provide information to guide farmers in their management decisions.

Finally, the results of on-farm experiments may sometimes be used to provide information to policymakers regarding current policy toward such matters as input supply or credit regulations. Experimental results can be used to help analyze policy implementation: Given a significant response to phosphorus, is the appropriate fertilizer available? Do local credit programs allow farmers to take advantage of new weed control methods? Although the emphasis in this manual will be on the economic analysis of on-farm experiments for guiding further research and making recommendations to farmers, at several points links between on-farm research and policy implementation will be mentioned.

Goals of the Farmer

In order to make recommendations that farmers will use, researchers must be aware of the human element in farming, as well **as** the biological element. They must think in terms of farmers' goals and the constraints on achieving those goals.

In the first place, many farmers are primarily concerned with assuring an adequate food supply for their families. They may do this by producing much of what their family consumes, or by marketing a certain proportion of their output and using the cash to obtain food. Farm enterprises also provide other necessities for the farm family, either directly or through cash earnings. In addition, the farm family is usually part of a wider community, towards which it may have certain obligations. To meet all of these requirements, farmers often manage a very complex system of enterprises that may include various crops, animals, and off-farm work. Although the procedures of this manual concentrate on the evaluation of improvements in particular crop enterprises, it is essential that these new practices be compatible with the larger farming system.

Second, whether farmers market little or most of their produce, they are interested in the economic return. Farmers will consider the costs of changing from one practice to another and the economic benefits resulting from that change. Farmers will recognize that if they eliminate weeds from their fields they will likely benefit by harvesting more grain. On the other hand, they will realize that they must give up a lot of time and effort for hand weeding, or that alternatively they must give up some cash to buy herbicides and then expend some time and effort to apply them. Farmers will weigh the benefits gained in the form of grain (or other useful products) against the things lost (costs) in the form of labor and cash given up. What farmers are doing in this case is assessing the difference in *net benefits* between practices—the value of the benefits gained minus the value of the things given up.

As farmers attempt to evaluate the net benefits of different treatments, they usually take risk into account. In the weed control example just mentioned, farmers know that in the case of drought or early frost they may get no grain, regardless of the type of weed control. Farmers attempt to protect themselves against risks of loss in benefits and often avoid choices that subject them to these risks, even though such choices may on average yield higher benefits than less risky choices do. That farmers may prefer stable returns to the highest possible returns is referred to as risk aversion.

Another factor in farmers' decision making, related to risk aversion, is the fact that farmers tend to change their practices in a gradual, stepwise manner. They compare their practices with alternatives, and seek ways of cautiously testing new technologies. It is thus more likely that farmers will adopt individual elements, or small combinations of elements, rather than a complete technological package. This is not to say that farmers will not eventually come to use all the elements of a package of practices, but simply that in offering recommendations to farmers it is best to think of a strategy that allows them to make changes one step at a time.

Characteristics of On-Farm Experiments

What are the characteristics of agronomic experiments that will allow an appraisal of alternative technologies in a way that parallels farmer decision making? The following are five requirements of on-farm experiments that must be fulfilled if the procedures described in this manual are to be useful:

1 The experiments must address problems that are important to farmers. It may be that farmers themselves are not initially aware of a particular problem (e.g., a nutrient deficiency or a disease), but if research does not lead to possibilities for significantly improving farm productivity, it will neither attract the interest of farmers, nor merit assessment. Thus the experiments demand a good understanding of farmers' agronomic and socioeconomic conditions.

2 The experiments should examine relatively few factors at a time. An on-farm experiment with more than, say. four variables will be difficult to manage and may be inappropriate given farmers' stepwise adoption behavior.

3 If researchers are to compare the farmers' practice with various alternatives in order to make a recommendation. then the farmers' practice should be included as one of the treatments in the experiment. The farmers will want to see this comparison in any case.

4 The nonexperimental variables of an experiment should reflect farmers' actual practice. It is sometimes tempting to use higher levels of management for the nonexperimental variables to increase the chances of observable responses to the experimental variables. This type of experiment may certainly be justified in some cases, but the results usually cannot be used to make recommendations to farmers.

An example may be useful. Assume that researchers wish to carry out a fertilizer experiment in an area where insects cause crop losses but farmers do not control insects. There are four possibilities:

- Carry out the fertilizer experiment with good insect control. The experiment will give interesting information on fertilizer response but will probably not provide a relevant fertilizer recommendation for farmers who do not use insect control. An analysis of this experiment using the procedures in this manual will give misleading results.

- Carry out the fertilizer experiment without insect control (the farmers' practice). The results can be analyzed, using the procedures in this manual, to decide what level of fertilizer is appropriate, given farmers' current insect control practices.

- If insects are indeed a very serious problem, it may be better to experiment first with insect control methods before experimenting with fertilizer. The diagnosis and planning steps of on-farm research are meant to help set these priorities. The methods of this manual could then be used to help identify an appropriate insect control method for recommendation to farmers.1/

- If insects and fertility are both serious problems, then an experiment can be designed which takes both insect control *and* fertilizer as experimental variables. As long as one treatment represents the farmers' practice with respect to both insect control and fertility, the experiment can be analyzed using the procedures in this manual.

5 Finally, not only must the management of nonexperimental variables be representative of farmers' practice, but the experiments must be planted at locations that are representative of farmers' conditions.

1/ Once this work has been done, and there is evidence that farmers will adopt the new insect control method. it could be used as a nonexperimental variable in the fertilizer experiments. as long as it is understood that the fertilizer recommendation to be developed from such trials depends on the farmers first adopting the insect control method.

If most of the farms are on steep slopes, the results of experiments planted on an alluvial plain will probably not be relevant. Similarly, if most farmers plant one crop in rotation with another, experiments from fields that have been under fallow may provide little useful information. More will be said in the following section about selecting locations.

Experimental Locations and Recommendation Domains

The development of recommendations for farmers must be as efficient as possible. The conditions under which farmers live and work are diverse in almost every respect imaginable. Farmers have different amounts and kinds of land, different levels of wealth, different attitudes toward risk, different access to labor, different marketing opportunities, and so on. Many of these differences can influence farmers' responses to recommendations. But it is impossible to make a separate recommendation for each farmer.

Recommendation domain

As a practical matter, researchers must compromise by identifying groups of farmers who have similar circumstances and for whom it is likely that the same recommendation will be suitable. In this manual such a group of farmers is called a *recommendation domain.* Recommendation domains may be defined by agroclimatic and/or by socioeconomic circumstances. The definition of the recommendation domain depends on the particular recommendation. For example, a new variety may be appropriate for all farmers in a given geographical area, whereas a particular fertilizer recommendation may be appropriate only for farmers who follow a certain rotation pattern or whose fields have a certain type of soil. Thus the recommendation domain for variety would be different from the recommendation domain for fertilizer.

Recommendation domains are identified. defined, and redefined throughout the process of on-farm research. They may be tentatively described during the first diagnosis. Experimentation adds precision to the definition of domains. The final definition may not be developed until the recommendation is ready to be passed to farmers.

When interpreting agronomic data to make their recommendations, researchers must have a fairly clear idea of the group of farmers who will be able to use this information. Researchers must consider not only the agroclimatic range over which the results will be relevant, but also whether such factors as different management practices or access to resources will be important in causing some farmers to interpret the results differently from others.

For the purposes of this manual, it is important that the on-farm experiments be planted at locations that are representative of the recommendation domain. The economic analysis is done on the ***pooled data*** from a group of locations of the same domain. The economic analysis of results from a single location is not very useful because, first, researchers cannot make recommendations for individual farmers, and second, one location will rarely provide sufficient agronomic data to be extrapolated to a group of farmers. Thus all of the examples in this manual will represent data from several locations of one recommendation domain.

Introduction to Basic Concepts

To make good recommendations for farmers, researchers must be able to evaluate alternative technologies from the farmers' point of view. The premises of this manual are:

1. Farmers are concerned with the benefits and costs of particular technologies.

2. They usually adopt innovations in a stepwise fashion.

3. They will consider the risks involved in adopting new practices.

These concerns will be treated in subsequent sections of the manual. Part Two describes the construction of a partial budget, which is used to calculate net benefits. Part Three presents the techniques of marginal analysis. This is a way of evaluating the changes from one technology to another by comparing the changes in costs and net benefits associated with each treatment. Part Four describes ways of dealing with the variability that is characteristic of farmers' environments. Variability in results from location to location and from year to year, and in the costs of the inputs and prices of crops, is of concern to farmers as they make production decisions. Part Five summarizes the first four sections and provides general guidelines for reporting research results.

The following sections offer a brief overview of these topics.

The Partial Budget

Partial budgeting is a method of organizing experimental data and information about the costs and benefits of various alternative treatments. As an example, consider the farmers who are trying to decide between their current practice of hand weeding and the alternative of applying herbicide. Suppose that some experiments have been planted on farmers' fields, and the results show that the current farmer practice of hand weeding results in average yields of 2,000 kg/ha, while the use of herbicides gives an average yield of 2,400 kg/ha.

Table 1.1. Example of a partial budget

	Hand weeding	Herbicide
Average yield (kg/ha)	2,000	2,400
Adjusted yield (kg/ha)	1,800	2,160
Gross field benefits ($/ha)	3,600	4,320
Cost of herbicide ($/ha)	0	500
Cost of labor to apply herbicide ($/ha)	0	100
Cost of labor for hand weeding ($/ha)	400	0
Total costs that vary ($/ha)	400	600
Net benefits ($/ha)	3,200	3,720

Table 1.1 shows a partial budget for this weed control experiment. There are two columns, representing the two treatments (hand weeding and herbicide). The first line of the budget presents the average yield *from all locations in the recommendation domain* for each of the two treatments. The second line is the *adjusted yield*.

Although the experiments were planted on representative farmers' fields, researchers have judged that farmers using the same technologies would obtain yields 10% lower than those obtained by the researchers. They have therefore adjusted the yields downwards by 10% (yield adjustment will be discussed in Chapter 3).

The next line is the *gross field benefits*, which values the adjusted yield for each treatment. To calculate the gross field benefits it is necessary to know the field price of the crop. The *field price* is the value of one kilogram of the crop to the farmer, net of harvest costs that are proportional to yield. In this example the field price is $2/kg (i.e., 1,800 kg/ha x $2/kg = $3,600/ha).[2/]

Farmers can now compare the gross benefits of each treatment, but they will want to take account of the different costs as well. In considering the costs associated with each treatment, the farmers need only be concerned by those costs that differ across the treatments, or the *costs that vary*. Costs (such as plowing and planting costs) that do not differ across treatments will be incurred regardless of which treatment is used. They do not affect the farmers' choices concerning weed control and can be ignored for the purpose of this decision. The term "partial budget" is a reminder that not all production costs are included in the budget—only those that are affected by the alternative treatments being considered.

In this case, the costs that vary are those associated with weed control. Table 1.2 shows how to calculate these costs. Note that they are all calculated on a per-

Table 1.2. Calculation of costs that vary

Price of herbicide	$250/l
Amount used	2 l/ha
Cost of herbicide	**$500/ha**
Price of labor	$50/day
Labor to apply herbicide	2 days/ha
Cost of labor to apply herbicide	**$100/ha**
Price of labor	$50/day
Labor for hand weeding	8 days/ha
Cost of labor for hand weeding	**$400/ha**

2/ The use of the $ sign in this manual is not intended to represent any particular currency, and several different currencies are assumed in the examples that follow. Additional abbreviations used in this manual are: hectare (ha), kilogram (kg), and liter (l).

hectare basis. The *total costs that vary* for each treatment is the sum of the individual costs that vary. In this example, the total costs that vary for the present practice of hand weeding is $400/ha, while the total costs that vary for the herbicide alternative is $600/ha.

The final line of the partial budget shows the *net benefits*. This is calculated by subtracting the total costs that vary from the gross field benefits. In the weed control example, the net benefits from the use of herbicide are $3,720/ha, while those for the current practice are $3,200/ha. Net benefits are not the same thing as profit, because the partial budget does not include the other costs of production which are not relevant to this particular decision. The computation of total costs of production is sometimes useful for other purposes, but will not be covered in this manual.

A partial budget, then, is a way of calculating the total costs that vary and the net benefits of each treatment in an on-farm experiment. The partial budget includes the average yields for each treatment, the adjusted yields and the gross field benefit (based on the field price of the crop). It also includes all the costs that vary for each treatment. The final two lines are the total costs that vary and the net benefits.

Marginal Analysis

In the weed control example, the net benefits from herbicide use are higher than those for hand weeding. It may appear that farmers would choose to adopt herbicides, but the choice is not obvious, because farmers will also want to consider the increase in costs. Although the calculation of net benefits accounts for the costs that vary, it is necessary to compare the extra (or marginal) costs with the extra (or marginal) net benefits. Higher net benefits may not be attractive if they require very much higher costs.

If the farmers in the example were to adopt herbicide, it would require an extra investment of $200/ha, which is the difference between the costs associated with the use of herbicide ($600) and the costs of their current practice ($400). This difference can then be compared to the gain in net benefits, which is $520/ha ($3,720-$3,200).

In changing from their current weed control practice to a herbicide the farmers must make an extra investment of $200/ha; in return, they will obtain extra benefits of

$520/ha. One way of assessing this change is to divide the difference in net benefits by the difference in costs that vary ($520/$200 = 2.6). For each $1/ha on average invested in herbicide, farmers recover their $1, plus an extra $2.6/ha in net benefits. This ratio is usually expressed as a percentage (i.e., 260%) and is called the *marginal rate of return.*

The process of calculating the marginal rates of return of alternative treatments, proceeding in steps from the least costly treatment to the most costly, and deciding if they are acceptable to farmers, is called *marginal analysis.*

Variability

In addition to being concerned about the net benefits of alternative technologies and the marginal rates of return in changing from one to another, farmers also take into account the possible variability in results. This variability can come from several sources, which researchers need to consider in making recommendations.

Experimental results will always vary somewhat from location to location and from year to year. An agronomic assessment of the trial results will help researchers decide whether the locations are really representative of a single recommendation domain, and can therefore be analyzed together, or whether the experimental locations represent different domains. This type of agronomic assessment helps refine domain definitions and leads to more precisely targeted recommendations.

Another source of variability in experimental results derives from factors that are impossible to predict or control, such as droughts, floods, or frosts. These are risks that the farmers have to confront, and if the experimental data reflect these risks, they should be included in the analysis.

Finally, farmers are also aware that their economic environment is not perfectly stable. Crop prices change from year to year, labor availability and costs may change, and input prices are also subject to variation. Although such changes are difficult to predict with accuracy, there are techniques that allow researchers to consider their recommendations in view of possible changes in farmers' economic circumstances.