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BASIC PROCEDURES FOR AGROECONOMIC RESEARCH

1984
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FOREWORD

With the establishment of the Asian Cropping Systems Network (ACSN) in 1975, the Economics Committee of the Network Working Group began developing methods for economic analysis of cropping systems. Between 1975 and 1981, Network economists developed analytical procedures and accumulated them in loose leaf binder form known as the *Handbook for Economic Analysis of Cropping Systems*. The present volume is the culmination of these efforts, and is intended for interested agroeconomic researchers. It contains parts of the earlier work, but largely comprises new perspectives on basic procedures for economic analysis by field-level researchers.

Milestones along the way were the economics research methods at the 1976 *Symposium on Cropping Systems Research and Development for the Asian Rice Farmer*, the 1979 *Workshop on the Economics of Cropping Systems*, the 1980 *Workshop on Cropping Systems Research in Asia*, and *A Methodology for On-Farm Cropping Systems Research*, by H. G. Zandstra, et al in 1981.

At semiannual meetings, the Economics Committee reviewed the development of procedures for economic analysis of cropping systems. Reports of those reviews are contained in the report series of the Cropping Systems Working Group.

The need for a reference manual on basic mathematical, statistical, and economic procedures for cropping systems and agricultural researchers was identified at the 1980 Workshop on Cropping Systems Research. The procedures presented here range in sophistication from those appropriate to the farm to those required at the institutional level.

Dr. Sisira Jayasuriya, Network economist at IRRI, 1979 to 1981, organized the contributors, with the assistance of Nancy Palma and Yolanda Aranguren. Dr. Richard Bernsten also contributed to the project. The volume was edited by Edwin A. Tout, assisted by Emerita P. Cervantes and Gloria S. Argosino.

M. S. Swaminathan
Director General

PREFACE

Questionnaires, summary forms, and other information schedules presented in this book were effective in the cases for which they were designed and first used. However, the forms have not been widely tested across countries in various agricultural systems. For that reason they may require adaptation to specific research situations.

Users are encouraged to comment on problems or particular successes in the use of the materials and to suggest ways in which they might be improved. Comments or questions about the use of the materials may be addressed to the Cropping Systems Economics Program, International Rice Research Institute, P. O. Box 933, Manila, Philippines. Please refer to specific chapters and page numbers where appropriate.

Many of the examples contain data originally denoted in national currencies. The methods of computation and interpretation, however, are of greater importance than the resulting values. To avoid confusion that might result from attempting to convert one national currency to another, the symbol ₥ is used to denote monetary units. It is not intended to represent the currency of any particular country.

Additional materials that are available from IRRI and which might be useful to agro-economic researchers include:

Asian Farming Systems Network, International Rice Research Institute. 1983. *Papers Presented at the Crop-Livestock Workshop. April 25-28, 1983, Los Baños, Laguna, Philippines.* International Rice Research Institute, Los Baños, Laguna, Philippines.

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CHAPTER 1

SOME BASIC ECONOMIC CONCEPTS

T. B. PARIS AND R. W. HERDT

This chapter introduces basic concepts used in economic analysis. To determine if a new technology will be attractive to farmers, we need to know how they decide whether or not to use a practice.

Economics uses simple behavioral rules to predict farmer choice. These rules essentially say that given two or more alternatives farmers will choose the more economically profitable alternative.

Unless commodities and inputs have prices, economic well-being cannot be judged. Therefore, economic concepts discussed here are easily applied when there are markets for the commodities considered in the analysis. However, it is not necessary that the farmer buy all inputs and sell all products. As long as he participates in market activities to some extent, economic principles will hold. Of course, most farmers, especially those in developing countries, consume a large part of their produce and use many inputs supplied from family resources.

PROFIT MAXIMIZING

Profit maximizing is the behavioral rule often credited with determining farmers' actions. It says farmers will choose the production alternative that provides highest monetary profit. However, because so many farmers choose alternatives other than maximum profit, profit maximization alone is not a satisfactory way to predict behavior. In fact, much farm management research in developing countries attempts to explain behavior that is more conservative than that implied by profit maximization. Still, profit maximization is a valuable concept.

In explaining the operation of a farm there are three basic decisions in which economic analysis is useful:

- *what* commodities or products to produce,
- *how much* of a product to produce, and
- *how much* of an input to use.

The economic tools in this chapter will largely concentrate on how much input to use, assuming farmers have established how much and what commodities to produce. Those issues are more complex, but they use the same economic principles as are explained here. Some of these principles will be discussed in later chapters.

Choosing the best set of inputs from a number of alternatives uses similar principles. In this chapter we will explain profit maximizing concepts in terms of *how much* of an input should be used to obtain maximum profit.

Agricultural researchers often invent new technologies that require large inputs of cash or labor. If these technologies are introduced to farmers who have traditionally used little cash or labor, the new technology may not be adopted. The decision not to adopt the recommended new technology is often cited as conservative or irrational behavior by farmers. However, two cases of nonadoption must be distinguished:

1. where because of lack of awareness of economic principles recommendations are made that inputs be applied to a level beyond the profit maximizing level, and
2. where farmers use inputs lower than the profit maximizing level.

Obviously, researchers who recommend excessively high input levels are irrational in the first case. The second case is more difficult to understand and explain. The following discussion will attempt to show how farmers may arrive at input use levels lower than the profit maximizing level.

The profit maximizing statement most useful for our purposes takes a negative form: a farmer will not increase use of an input to a level that leaves him economically worse off; he will apply additional inputs only if doing so will leave him economically better off. *His economic well-being will be increased as long as the added cost of another unit of input is less than the added revenue generated by the input change.*

Economists call added costs *marginal costs.* Added returns are called *marginal returns* or *marginal benefits.* The word *marginal* means added.

Marginal analysis involves comparing additional returns with additional costs that result from a change in output or inputs. Assuming the objective of a farm is to obtain the highest possible profit, the marginality principle states that additional inputs should be applied only if marginal return is greater than marginal cost. In other words, output level (or the level of input use) should not be increased if the extra return is less than the extra cost. Net return is maximized when extra return is equal to extra cost.

This basic principle can be applied several ways, as illustrated below.

THE SINGLE VARIABLE INPUT-OUTPUT PRODUCTION RELATIONSHIP

Consider a product Y (rice, in kg), whose yield depends only on one input x (fertilizer, in kg) assuming all other inputs are used at a constant level. When a unit of fertilizer is added, total output increases by some amount. Extra output resulting from 1 kg increase in fertilizer is called the *marginal product* of fertilizer (MPx). When multiplied by the price per kilogram of paddy we obtain a monetary measure called the *marginal value product* (MVPx). The MVP represents the value of extra paddy resulting from the application of an additional kilogram of fertilizer. On the cost side, the addition of a kilogram of fertilizer increases costs by a certain amount. This is called the *marginal factor cost* (MFC). It is equal to the price of the fertilizer, since increasing the use of fertilizer by one unit increases cost by an amount equal to the price of the fertilizer. Hence, using the rule stated above, the use of fertilizer

Table 1. Illustration of a simple input-output relationship.

Fertilizer (kg)	Yield (kg)	Marginal product (kg)	Value of extra output (₦)	Cost of extra input (₦)
0	2000	–	–	–
10	2100	100	110.00	40
20	2300	200	220.00	40
30	2600	300	330.00	40
40	2800	200	220.00	40
50	2900	100	110.00	40
60	2950	50	55.00	40
70	2980	30	33.00	40
80	3000	20	22.00	40
90	3010	10	11.00	40
100	3010	0	0	40
110	3000	-1	-11.00	40

should be increased as long as its MVP is greater than its MFC.

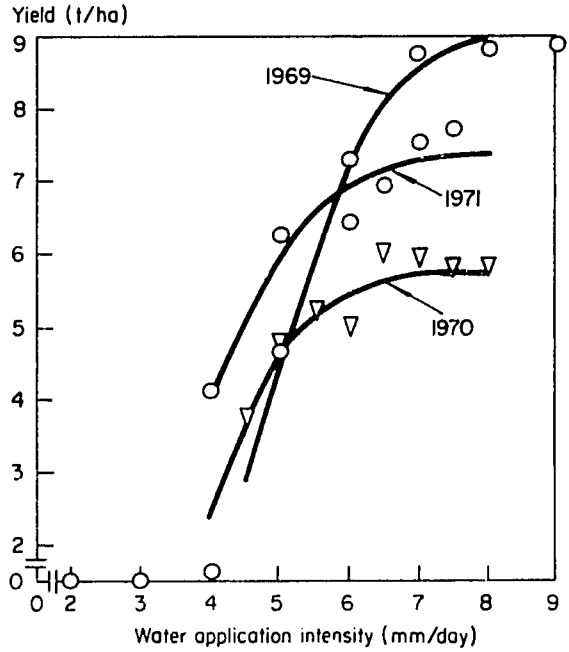
To identify the optimum level of fertilizer, that is, the level where profits are maximized, we need to observe how production responds to fertilizer application. Assume that the output-input relationships are as shown in columns 1 and 2 in Table 1. These show that when fertilizer (x) is increased, paddy yield (Y) generally increases. At low fertilizer levels, the increase in yield from each 10 kg of fertilizer used is large. However, the yield increases from each unit of input (10 kg fertilizer) become smaller at successively higher levels of the input. In other words, extra yield (marginal product) tends to decrease at successively higher fertilizer levels if all other inputs are held constant. This observation is usually referred to as the *law of diminishing marginal returns* and applies to all input-output situations. In Table 1, percentage of yield increase begins to decrease when more than 30 kg of fertilizer is applied. This reflects the law of diminishing returns. Total yield begins to decrease when more than 100 kg of fertilizer is applied, but this decrease in total yield is not a necessary condition of the law of diminishing returns.

Figure 1 illustrates the same pattern for water applied to rice. Increasing the water applied increased yields, but as water input level increased, yield increased by smaller and smaller amounts. Each year the experiment provided different results, but in each year the pattern of diminishing returns was evident. The same pattern holds for all production processes where one input is varied and all other inputs are fixed.

Column 3 of Table 1 shows the marginal product as fertilizer is increased in 10 kg units. At fertilizer levels above 30 kg, yield increases but marginal product decreases. We say diminishing returns has set in at 30 kg fertilizer.

Assuming rice price is ₦1.10 /kg[1], column 4 shows the value of extra output, or the marginal value product (MVP), which is obtained by multiplying MP by the unit price of paddy. MVP equals the additional value of output resulting from each 10-kg increase in fertilizer.

[1] ₦ is used as monetary unit.



1. The functional relationship between rice yield and water application intensity for 3 IR8 crops with 100 kg N/ha. IRRI, 1969-71 dry season.

Column 5 shows the cost of extra input or the marginal factor cost (MFC), which equals the increased cost of each additional 10-kg bag of fertilizer. If fertilizer price is ₱ 4/kg, a 10-kg increase in fertilizer will raise cost by ₱ 40. Therefore, marginal factor cost equals ₱ 40 because we are dealing with 10-kg bags of fertilizer.

Using this information, we can determine the quantity of fertilizer that will maximize profits by following the rule that additional fertilizer should be applied as long as extra return (MVP) is greater than extra cost (MFC). It is sufficient to compare columns 4 and 5. We can see it pays to increase fertilizer use up to 60 kg because value of additional output (MVP) is greater than additional fertilizer cost at levels lower than 60 kg.

Does it pay to increase the fertilizer level up to 70 kg? The larger value of the paddy obtained from using more fertilizer is ₱ 33. Additional cost is ₱ 40. The farmer would be losing ₱ 7. Clearly, this will mean a reduction in net profit. Hence, he should stop at 60 kg where profit maximization occurs.

To confirm that profit is maximized at 60 kg of fertilizer, compute total profit at each fertilizer level. This is illustrated in Table 2.

Columns 1 and 2 are the same figures as in Table 1. Column 3 is obtained by multiplying yield by the paddy price (₱ 1.1 0/kg). Column 4 is obtained by multiplying the amount of fertilizer applied by its price per kg (₱ 4/kg). Column 5 shows net return, which equals value of production less total cost.

Note that profit increases as fertilizer is increased from 0 to 60 kg. Maximum profit is obtained at 60 kg fertilizer. Beyond 60 kg, net return decreases. Note also that maximum yield (at 90-100 kg fertilizer) does not mean maximum profit.

Although this illustration is simple, it provides a basic guideline for determining

Table 2. Illustration of how to compute total profits.

Fertilizer (kg) 1	Paddy (kg) 2	Total value of production[a] 3	Total cost of fertilizer[b] 4	Net returns[c] 5
0	2000	2200	0	2200
10	2100	2310	40	2270
20	2300	2530	80	2450
30	2600	2860	120	2740
40	2800	3080	160	2920
50	2900	3190	200	2990
60	2950	3245	240	3005
70	2980	3278	280	2998
80	3000	3300	320	2980
90	3010	3311	360	2951
100	3010	3311	400	2911
110	3000	3300	440	2860

[a]Column 2 × 1.10. [b]Column 1 × 4. [c]Column 3 less 4.

maximum profit level of input use. We compare the marginal value product with the marginal factor cost. This analysis shows information on marginal productivity of an input can be expressed in monetary terms and compared with the input price. When MVPx > Px, less input is being used than would maximize profits. When MVPx < Px, too much input x is being used.

Because the law of diminishing returns generally holds for all input-output relations, the profit maximizing level of any input will be less than the yield maximizing level. Note that yield was highest at 90 kg fertilizer but profits were highest at 60 kg fertilizer.

Opportunity cost

The concept of opportunity cost supplements the principle of profit maximization in leading to an understanding of the behavior of semisubsistence farmers who combine farming with a way of life. *Opportunity cost is the value that a resource has in its best alternative use.* Opportunity cost is a part of each of our daily lives.

Time is a scarce resource. By one way or another you will attempt to allocate your time optimally by making choices to bring the highest personal reward or payoff. Occasionally you make a mistake — you say you have wasted your time. What you mean is that your level of satisfaction would have been higher if you had used your time some other way. For example, at present you are reading this chapter in the hope of gaining knowledge. You could be doing something else, perhaps more rewarding, like growing rice or seeing a movie. These alternatives can be looked upon as opportunity costs.

Farmers also have opportunity costs for their time. They may choose to intensively cultivate their rice fields or do a less intensive job and enjoy leisure time, or they may work for some other farmer, or even work on a nonfarm job. Opportunity for leisure is always available, and other possibilities are often available. Because of these opportunity costs, researchers must recognize that farmer-owned resources

Table 3. Illustration of yield response on two types of land with different response.

Urea (bags)	Land type L			Land type U		
	Yield (kg/ha)	Added yield (kg/ha)	Added[a] value (₱/ha)	Yield (kg/ha)	Added yield (kg/ha)	Added[a] value (₱/ha)
0	1900	–	–	1700	–	–
1	2275	375	563	1950	250	375
2	5589	314	471	2150	200	300
3	2842	253	380	2290	140	210
4	3034	192	288	2370	80	120
5	3166	132	198	2390	20	30
6	3237	71	107	2330	-60	-90
7	3247	10	15	2230	-100	-150

[a]Price is ₱1.50/kg.

used in agriculture have a value and cannot be assumed to be free. Therefore, if one technology requires substantially more labor than some other technology, it may not be adopted even though it gives higher yield and value of output.

Similarly, there are opportunity costs for farmers' capital. Most farmers have limited capital: they cannot obtain credit to purchase all the fertilizer, insecticides, and weedicides needed to give them maximum profit. They must choose how to allocate their scarce capital. The principle of opportunity cost states that profits will be greatest if capital (or any other scarce resource) is divided among its various alternatives so the return on the last unit of capital is essentially equal in each alternative.

An example is illustrated in Table 3. It examines the case of a farmer who has 2 ha, 1 ha each of lowland (L) and upland (U). As illustrated, the yield and, therefore, the added return obtained by applying fertilizer on the two types of land differs. A farmer who has ₱ 600 to spend on fertilizer will use opportunity cost principles to allocate the fertilizer. He will apply 4 bags on 1 ha of land L and 2 bags on 1 ha of land U because that allocation will give the highest added value of output. If, for example, he uses 3 bags on L and 3 on U, he gives up an added value of ₱ 288 on L to get an added value of ₱ 210 on U — thereby losing a net of ₱ 78/ha.

Note that if the farmer had more capital, he would maximize his profit by applying six bags on land L and four bags on land U. However, with limited cash he uses opportunity cost principles to make his profits as large as possible.

Note that Table 3 only shows two alternative uses for cash. It is possible a farmer might have other uses for his money besides fertilizer. If one of those other opportunities gives a higher return, say ₱ 400 for every ₱ 100 invested, then it would be economically rational to spend only ₱ 200 on fertilizer, apply it to land L, apply none to land U, and invest the rest in the other opportunity. In this case, the opportunity cost of cash is ₱ 4 for every ₱ 1 invested. This case shows why a farmer would stop short of applying the profit-maximizing level of an input like fertilizer.

REVIEW QUESTIONS

1. State the principle of diminishing returns. Does the principle require that added yield will become negative? Does it require that at some very high input level yield will become negative? What diminishes, according to the law?
2. Does the profit maximizing assumption require that farmers be willing to take any action at all to increase profits? Farmers do not generally try to maximize yields. What does this imply?
3. Under what conditions will the opportunity cost of family labor be equal to zero? Under what conditions will the opportunity cost of cash be equal to zero?

CHAPTER 2

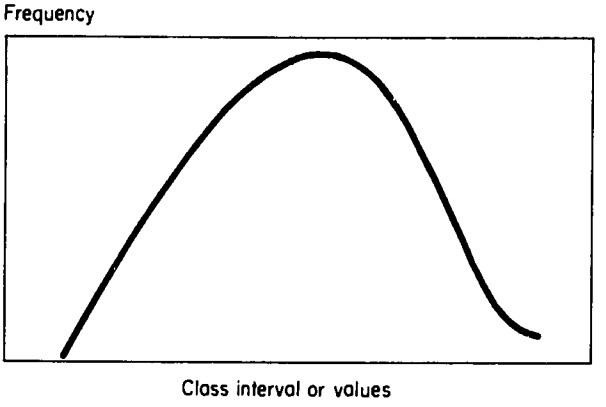
ELEMENTARY STATISTICAL CONCEPTS AND TOOLS USED IN AGROECONOMIC RESEARCH

K. KALIRAJAN

Most agroeconomic research data can be expressed in bell-shaped distributions, or curves, as illustrated in Figure 1. This graphical representation can be summarized by calculating certain measures which describe the distribution. To summarize a large set of data in simple terms, certain summary characteristics are needed. The most commonly used of these characteristics are called measures of central tendency and measures of dispersion.

Central tendency shows the central value of the data and measures of dispersion measure the degree of dispersion or heterogeneity around the central value. In combination, these two measures are usually adequate to describe any data set. However, within each value there are several distinct measures with different properties, advantages, and disadvantages.

In this chapter, we use empirical examples to show how to calculate some important measures of central tendency and dispersion and discuss basic statistical tests using these measures. The first section concerns measures of central tendency, the second section discusses dispersion measures, and the last section outlines statistical testing procedures. Although pocket calculators make most calculations easy, we discuss procedures so researchers will know what the measures mean.



1. Hypothetical data distribution curve.

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MEASURES OF CENTRAL TENDENCY

Although there are many measures of central tendency that describe central value within a distribution of values, only *arithmetic mean, median, mode, geometric mean,* and *harmonic mean* are discussed. They have the most widespread application in agricultural research. Because simple agroeconomic research analysis deals with ungrouped data, most of these measures are explained in relation to ungrouped data only.

Arithmetic mean

The most important and useful measurement of central tendency is the arithmetic mean. It is also called the average or the mean. Usually, it is represented by the symbol $\bar{x}$. It is also represented by AM. For example, assume you are interested in finding what yield a farmer can get in a certain village. Farmers' yields usually vary during a growing season. Calculate the average yield of the total yield among all farmers in the village. No farmer in the village or province may ever harvest an actual yield equal to this average, but the mean is accepted as representative.

Mean from ungrouped data

Calculating the arithmetic mean from ungrouped data is easy to understand. Individual scores or values are added and the total of these values is divided by the number of individual scores added.

If $X_1, X_2, X_3, \ldots X_n$ is a sample of n measurements, the sample mean $\bar{x}$ of the X's is defined by the following formula

$$X = \frac{X_1 + X_2 + \ldots X_n}{10}$$

$$\bar{x} = \frac{\sum_{i=1}^{n} X_i}{n}$$

For example, 10 farmers growing rice in Laguna in the Philippines harvested 2.3, 1.9, 2.0, 2.1, 2.2, 2.0, 2.3, 1.9, 2.0, and 2.2 t/ha, respectively. There are 10 data observations. The arithmetic mean is computed as:

$$\bar{x} = \frac{2.3 + 1.9 + 2.0 + 2.1 + 2.2 + 2.0 + 2.3 + 1.9 + 2.0 + 2.2}{10}$$

$$= 2.09$$

Note that none of the 10 farmers obtained a 2.09 t/ha average yield. Some harvested more and others less than the mean.

Mean from grouped data

When some farmers get the same yields, it is customary to group observations with similar values to make calculation easier. In our example, we have yield data from 10 farmers. Smallest yield is 1.9. Two farmers harvested 1.9 t/ha. Next highest yield is 2.0, obtained by 3 farmers. The next yield is 2.1. Next highest yield is 2.2. Two farmers got 2.2. Highest yield is 2.3. Two of 10 farmers harvested 2.3. This information is summarized in Table 1.

Table 1. Yields of sample farmers growing high yielding rice in Laguna.

Yields (t/ha)	Farmers (no.)
1.9	2
2.0	3
2.1	1
2.2	2
2.3	2
Total	10

Calculate the mean from Table 1 as follows:

$$\bar{x} = \frac{1.9 \times 2 + 2.0 \times 3 + 2.1 \times 1 + 2.2 \times 2 + 2.3 \times 2}{2 + 3 + 1 + 2 + 2}$$

$$= \frac{3.8 + 6.0 + 2.1 + 4.4 + 4.6}{10}$$

$$= 2.09$$

Mean from grouped data based on intervals

When manipulating large sets of data with similar values, the above method is tedious and time-consuming. To easily compute the mean of a large amount of data with similar values, a different method can be used. Instead of counting the frequency of a single value, an interval of values is considered, and the arithmetic mean is computed by using either of the following ways. Midpoints of the class intervals can be determined or arbitrary origin can be used. Both methods give identical results.

Using midpoints of class intervals

Examine the example which evaluates hired labor cost (₱) per hectare for crop (paddy) maintenance by farmers in Jarunbari, Bangladesh, as given in Table 2. Average cost of hired farm labor is computed.

Before making the calculation, it is helpful to define concepts used to compute the mean. Midpoint of a class is obtained by adding the upper and lower limits of the

Table 2. Cost of hired labor in Jarunbari, Bangladesh.

Cost of hired labor (Tk) (class interval)	Number of farmers (frequency)
72.0-73.9[a]	7
74.0-75.9	31
76.0-77.9	42
78.0-79.9	54
80.0-81.9	33
82.0-83.9	24
84.0-85.9	22
86.0-87.9	8
88.0-89.9	4
Total	225

[a]All observations having a value less than the lower limits of a class interval are included in the previous class (e.g. 73.92 is included in the class 72-73.9).

Table 3. Computation of the arithmetic mean using the midvalues of the class interval.

Class interval	Frequency (f)	Midvalue (x)	Frequency x midvalue (fx)
72.0-73.9	7	72.95	510.65
74.0-75.9	31	74.95	2,323.45
76.0-77.9	42	76.95	3,231.90
78.0-79.9	54	78.95	4,263.30
80.0-81.9	33	80.95	2,671.35
82.0-83.9	24	82.95	1,990.80
84.0-85.9	22	84.95	1,868.90
86.0-87.9	8	86.95	695.60
88.0-89.9	4	88.95	355.80
Total	225		17,911.75

class and then dividing the sum by 2. For example, upper and lower limits for the first class interval in our example are 72.0 and 73.9, respectively. The midvalue of the first class interval is

$$\frac{72 + 73.9}{2} = 72.95 .$$

X represents individual observation. X_1 stands for the first observed value of X, X_2 for the second, and X_n denotes the nth observation of X. The Greek letter sigma(Σ) is used to sum all the observations of X. Total observations of any characteristic X are usually denoted by N. The midvalues of all class intervals are calculated and entered in Table 3.

Using the calculations done in Table 3, the arithmetic mean can be computed as

$$\bar{X} = \frac{\Sigma fx}{N} = \frac{17{,}911.75}{225} = 79.61$$

Average cost of hired labor used per hectare for crop maintenance in Jarunbari, Bangladesh, is ₱ 79.61. For a frequency distribution with unequal class intervals, the same procedure can be used to compute the mean $\bar{X}$.

Median

If a frequency distribution has extreme values, arithmetic mean does not accurately describe the data. For example, consider four farmers in Laguna with the following net profits per hectare:

₱ 300 ₱ 300 ₱ 400 ₱ 1200

$$\text{The mean is } \bar{X} = \frac{300 + 300 + 400 + 1200}{4} = 2200$$

$$= ₱\ 550$$

The mean of the first three profits is

$$\frac{300 + 300 + 400}{3} = ₱\ 333$$

If the high profit, ₱ 1,200, is included, the mean becomes ₱ 550. It is clear that ₱ 550 does not accurately characterize the frequency distribution of net profits in the sample. In such cases, another central tendency measurement, called the median, is more suitable to describe the data. The median is defined as that value which divides a distribution, after values are arranged in ascending or descending order, so an equal number of items is on each side. Therefore, the median divides the distribution into two equal parts, and is determined only after data are ordered.

Median from ungrouped data

There are five different wage rates in the five Philippine provinces: ₱ 8, ₱ 7, ₱ 6, ₱ 5, and ₱ 9. To calculate the median of these rates, arrange them in ascending order (₱ 5, ₱ 6, ₱ 7, ₱ 8, ₱ 9), then get the central value. It is ₱ 7, and there are two rates on either side. If there are 6 wage rates (₱ 5, ₱ 6, ₱ 7, ₱ 8, ₱ 9, ₱ 10), it is clear the median is between ₱ 7 and ₱ 8. Therefore, it is computed as the average of the two center values (₱ 7 and ₱ 8). The median is

$$\frac{7+8}{2} = 7.5 .$$

For ungrouped data it may be convenient to find the median value by counting

$$\frac{N+1}{2}$$

frequencies (items) and arranging the values in ascending or descending order.

Mode

Mode is the most easily calculated measure of central tendency. It is the value in a set of observations that occurs most frequently. Therefore, mode is not affected by the occurrence of one or a few extremely high observation values. Mode is the value that represents maximum frequency density. It is the most typical value in a series of values. In many farm management surveys in the Philippines, 1.5 ha is called the typical rice farm size because this value occurred most in the survey, not because it is the average farm size.

The mode from ungrouped data

If a series of data is unclassified, mode cannot be readily located. Mode can be located only when a data set is ordered or arranged in a frequency distribution.

The following example examines tons per hectare for seven farms growing IR36 in Camarines Sur in the Philippines. Farmers produced 1.6, 1.8, 2.0, 2.0, 2.1, 2.2, and 2.3 t/ha. Data are already in ascending order. Modal yield is 2.0 t/ha, because 2.0 occurs twice in the data set and the other values appear only once.

This example evaluates daily wage paid landless workers in Bangladesh. Workers earn ₱ 6, ₱ 7, ₱ 7, ₱ 8, ₱ 9, ₱ 9. There are two modes, ₱ 7 and ₱ 9, because each wage appears twice.

There is no mode in this set of wages: ₱ 6, ₱ 7, ₱ 8, ₱ 9, ₱ 10.

The mode from grouped data

To explain how to locate the mode within a grouped frequency distribution we used data first shown in Table 2. Table 2 information is rewritten in Table 4 to include midvalues and class intervals.

Table 4. Determined mode from grouped data.

Cost of hired labor (Tk) (class interval)	Number of farmers (frequency)	True class intervals
72.0-73.9	7	71.95-73.95
74.0-75.9	31	73.95-75.95
76.0-77.9	42	75.95-77.95
78.0-79.9	54	77.95-79.95
80.0-81.9	33	79.95-81.75
82.0-83.9	24	81.95-83.95
84.0-85.9	22	83.95-85.95
86.0-87.9	8	85.95-87.95
88.0-89.9	4	87.95-89.95
Total	225	

In Table 4, the mode is 78.0-79.9 because this range appears most frequently in the data set. If midvalue is considered representative of the class, the mode is 78.95. But midvalue of a modal class will not always be the best estimate of the mode. If there are more frequencies preceding the modal class than there are following the class, actual concentration is nearer the limit of the class. For example, our illustration shows 42 observations in the set preceding the modal class and only 33 in the set following the modal class. In such cases, it is necessary to use the frequencies in the two adjacent classes to locate the correct mode in the modal class. The following formula can be used to compute mode from frequency distribution:

$$\text{Mode } l = 1 + \frac{d_1}{d_1 + d_2}$$

where l = the true lower limit of the modal class (the frequency is the maximum);

d_1 = the difference between the frequency of the modal class and the frequency of the preceding class, neglecting the sign;

d_2 = the difference between the frequency of the modal class and the frequency of the following class, neglecting the sign; and

i = the width of the class interval.

For illustration using the above formula,

$$\begin{aligned}
\text{Mode} &= 77.95 + \frac{(54\text{-}42)}{(54\text{-}42) + (54\text{-}33)} \times 2 \\
&= 77.95 + \frac{12}{12 + 21} \times 2 \\
&= 77.95 + \frac{12}{33} \times 2 \\
&= 77.95 + \frac{24}{33} \\
&= 77.95 + 0.73 \\
\text{Mode} &= 78.68
\end{aligned}$$

Geometric mean

Another widely used measure of central tendency in agricultural economics is the geometric mean. Geometric mean is the nth root of the product of n observations. It is denoted by the letter G. If there are n values of x: $X_1, X_2, \ldots X_n$, then the geometric mean $G = \sqrt[n]{X_1 \times X_2 \times X_3 \times \ldots X_n}$. If one value of x in the series is zero, the geometric mean equals zero. If one or more values are negative, the geometric mean can be computed but may be without meaning.

The geometric mean from ungrouped data

The geometric mean of the daily wage rates for laborers doing different field operations; ₱ 5, ₱ 6, ₱ 8, and ₱ 10 is:

$$\text{Geometric mean, } a = \sqrt[4]{5 \times 6 \times 8 \times 10}$$
$$= \sqrt[4]{2400}$$
$$= 7.$$

When there are more than four observations, the geometric mean is not easy to compute manually. By using logarithms, however, the geometric mean is easily calculated for any number of observations. Convert the original values into logarithms first. Divide the sum of the logarithms of these values by the number of observations and the antilog of the quotient is the geometric mean. Rewrite the above formula as:

$$\log G = \frac{\log X_1 + \log X_2 \ldots + \log X_n}{n}$$

Antilog of the above quantity is the geometric mean. Using the example, wage rates for different field operations are:

$$\log G = \frac{\log 5 + \log 6 + \log 8 + \log 10}{4}$$
$$= \frac{0.669 + 0.7782 + 0.9031 + 1.0000}{4}$$
$$= 0.8451$$
$$\text{Antilog of } 0.8451 = 7$$
$$G = 7$$

Harmonic mean

Although relatively less important than measures mentioned earlier, the harmonic mean is useful in averaging rates. For example, if it takes 5 men 15, 13, 11, 10, and 9 man-days, respectively, to plow 1 ha of a field, we may want to find the average number of man-days needed to plow a hectare, assuming time differences observed reflect variations in efficiency.

The simple arithmetic mean of 15, 13, 11, 10, and 9 is not the desired answer because plowing efficiency is not the same for the 5 men. Because efficiency is represented by reciprocals of man-days required, it is necessary to calculate area plowed per man-day by each man, then find the arithmetic mean of these results and use the reciprocal of this mean.

The harmonic mean for ungrouped data

In the example, hectares plowed per man-day are 1/15, 1/13, 1/11, 1/10, and 1/9. The harmonic mean, represented by the letter H, is calculated as:

$$\frac{1}{H} = \frac{1/15 + 1/13 + 1/11 + 1/10 + 1/9}{5}$$

$$= \frac{0.07 + 0.08 + 0.09 + 0.10 + 0.11}{5}$$

$$\frac{1}{H} = .09$$

$$H = 11$$

Methods of computing this measure for grouped data may be found in any standard introductory statistics text book.

Frequency distributions

Table 1, Column 2 (no. of farmers), is called frequency. *Frequency is defined as total number of times a particular value appears in a sample.* In grouped data, frequency is the number of observations falling within a class or interval. Relative frequency is the proportion of observation within each class. In Table 5 relative frequency in each class is obtained by dividing frequency by total number of observations.

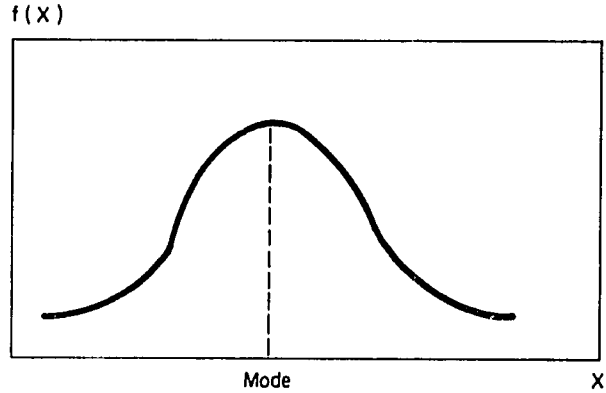
A frequency curve may have more than one mode. If the frequency curve maximum is as in Figure 2, there is only one mode and the distribution is said to be unimodal. If the curve has two (or more) maxima (Fig. 3), the distribution has two (or more) modes and the distribution is called bimodal.

Cumulative frequency expresses a relationship between a class interval and the frequency of cases falling at or below the upper limit of that interval. Using Table 5, we can say the number of observations falling below 250 is 96. When expressed as relative frequencies, the sum of relative frequencies will equal one. Relative frequencies can be interpreted as probabilities. Cumulative relative frequency equals cumulative probability. Therefore, the probability of an observation being within the range

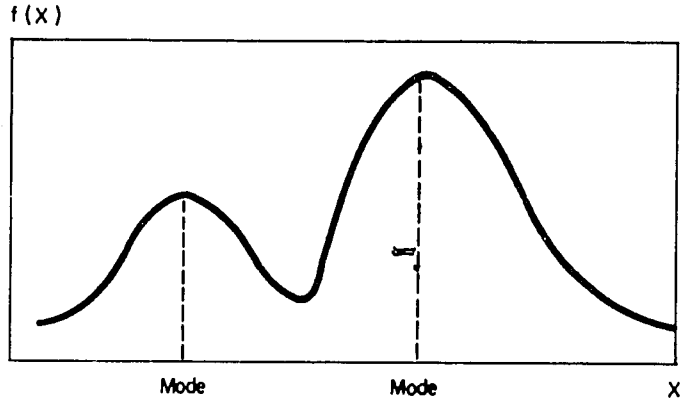
Table 5. Frequency, cumulative frequency, relative frequency, and cumulative probability.

Cost of hired labor	Number of farmers (frequency)	Cumulative frequency	Relative frequency[a]	Cumulative probability
150-175	6	6	.054	.054
175-200	10	16	.088	.144
200-225	30	46	.264	.414
225-250	50	96	.440	.860
250-275	12	108	.105	.960
275-300	3	111	.026	1.000
Total	111			

[a]The sum of relative frequencies should sum to 1.00 exactly but does not do so due to rounding errors in this table.



2. A hypothetical curve with one mode.



3. A hypothetical distribution with two modes (a bimodal distribution).

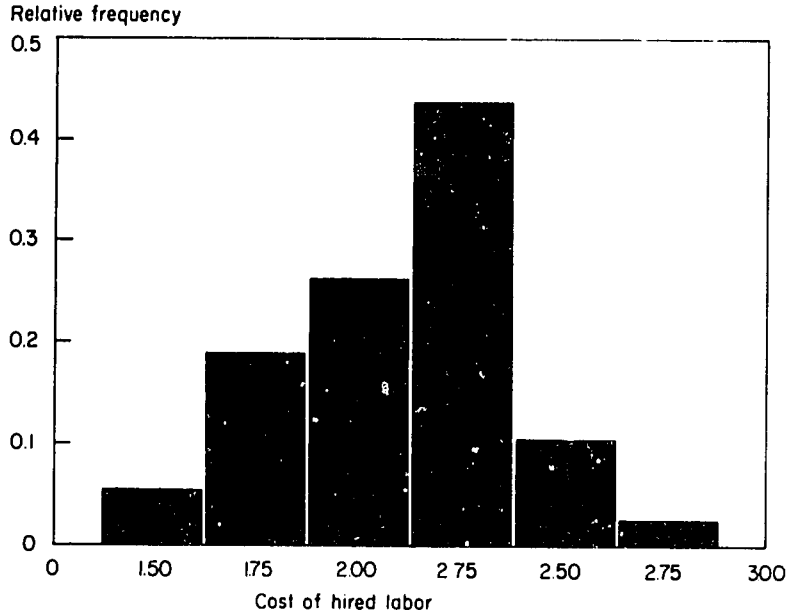
200 to 225 (excluding 225) is $\frac{.30}{111} = .264$. Probability of an observation having a value less than 225 is .414.

These frequencies can be represented in a histogram (Fig. 4). The resulting distribution is called a frequency distribution. The sum of all columns is 1.00. The area of any single column representing an interval or class is the probability for that interval or class.

If observed values (e.g. height, weight) can be measured with some precision, regardless of multiple decimal places, then we can think in terms of continuous variables. In theory, we can use extremely small measurement intervals and still expect a non-zero probability that some observation will have these values. In this case, a histogram can be made for smaller and smaller intervals until a curve represents the distribution (Fig. 5).

In a continuous distribution, the area under the curve is the total probability. When intervals are small, the probability of an observation having a value falling in that interval also tends to be small. In a continuous distribution, the probability of an exact value of the variable is zero.

Continuous distribution variables are evaluated in terms of the probability that they will fall within specified intervals of the distribution rather than as having an



4. Relative frequencies shown in a histogram.

exact value. The area under the curve between two specified values of the variable represents the probability that the value of an observation will be in that range.

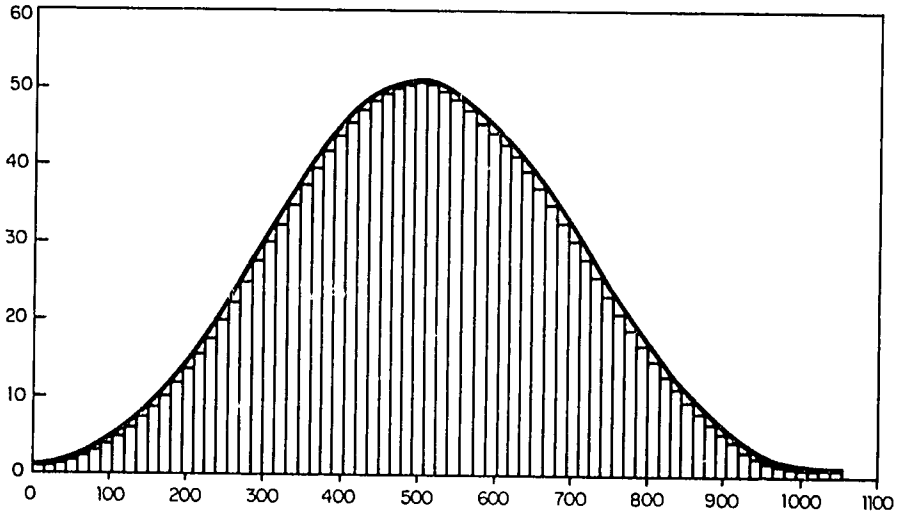
Usually, a series of discrete numbers is obtained even when measuring continuous variables. It is often useful to think of these as coming from an underlying continuous distribution, however.

Many types of distributions are commonly used in statistical analysis. One of the most useful frequency distributions used is the normal distribution. A normal distribution is symmetric around its mean value. It is unimodal and its mean, median, and mode are the same (Fig. 5). As with all continuous distributions, the area beneath the curve of any interval is a probability. Total area under the curve represents a probability of 1.00.

MEASURES OF DISPERSION

The preceding section discussed measures that describe central tendency. We also need to determine the spread of a distribution. Data from Pakistan and Sri Lanka may each show an average paddy yield of 2.4 t/ha. This does not mean the two countries have identical yield distribution among farmers. If data are considered by farm, individual yields may deviate from mean value in one country more than in the other. This deviation is illustrated in curves A and B of Figure 6.

To understand the shape of the data or the frequency distribution, a measure is needed to find how individual observations are spread around the central value of the data. In this section, the most commonly used measures of dispersion around central value in frequency distributions are examined: 1) range, 2) mean deviation, 3) standard deviation and variance, and 4) coefficient variation.



5. Histogram approximates a continuous distribution as class intervals become very small.

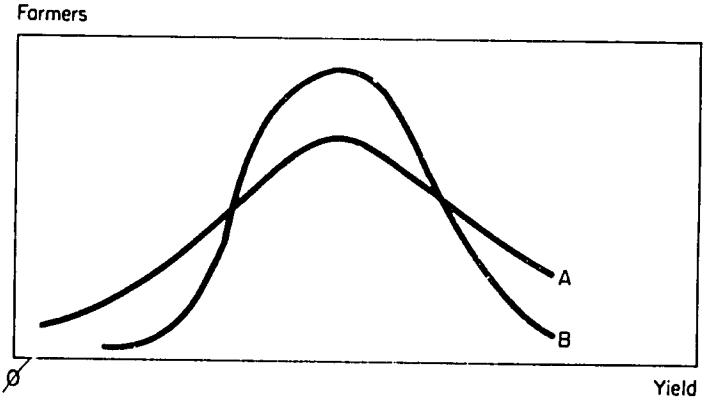
Range

Range is the simplest measure of dispersion. It is the difference between the maximum value and the minimum value of the data. When comparing two sets of yield data, the one with the larger difference is said to be more dispersed from the central value. Ten farmers in Laguna reported an income of ₱370, ₱400, ₱430, ₱500, ₱520, ₱470, ₱480, ₱600, ₱650, and ₱700/ha. The range is calculated as (₱700 - ₱370) = ₱330.

Range considers only the two extreme observations in the data set. It does not consider the values between these extremes. Range is not a very useful measure if the extreme values are unusual. However, range is helpful in determining class interval size while constructing a frequency distribution from a large data set.

Mean deviation

Mean deviation measures variability of all observations from their central value. The deviation of each value from some measure of central tendency (mean or median) is



6. Hypothetical distribution of yields in two countries.

calculated. The average of the deviations is computed to control for the number of observations contained in the data. If the median is used as the central value from which the deviations are to be measured, there is no problem. However, the mean is usually the more satisfactory measure of central value. When individual value deviations from the mean are summed, the sum will be zero. This is a property of the arithmetic mean. To compute mean deviation, ignore the signs and take the absolute value of deviations from the mean. By ignoring the sign of deviation, mean deviation (M.D.) is calculated as:

$$\text{M.D.} = \frac{|x_1 - X| + |x_2 - X| + \ldots |x_n - X|}{n}$$

$$= \frac{\sum_{i=2}^{n} X_i - X}{n}$$

This notation is called modulus. It means that the signs are ignored.

If the yield of rice per hectare for 6 Java farmers is 3.0, 3.2, 2.8, 3.4, 3.6, and 3.8 t, what is the average yield difference from the mean?

$$\text{Mean } x = \frac{3.0 + 3.2 + 2.8 + 3.4 + 3.6 + 3.8}{6}$$

$$= 3.3$$

$$\text{M.D.} = \sum_{i=1}^{6} | x_i - \bar{x} |$$

$$= \frac{(3.3\text{-}3) + (3.3\text{-}3.2) + (3.3\text{-}2.8) + (3.4\text{-}3.3) + (3.6\text{-}3.3) + (3.8\text{-}3.3)}{6}$$

$$\text{M.D.} = 0.3$$

The average individual yield differs from the mean by 0.3 t.

Standard deviation

Standard deviation is the most useful and most frequently used measure of dispersion. It is derived by squaring the differences of values from the mean so the sum of deviations does not equal zero. Standard deviation is the square root of the arithmetic mean of the squared deviations from the mean. The greater the spread around the mean, the larger the standard deviation. The square of the standard deviation is called variance. Variance is widely used when making statistical inferences. For ungrouped data, standard deviation is calculated as:

$$S = \sqrt{\frac{\sum_{i=1}^{n} (X_i - \bar{X})^2}{N}}$$

$$= \frac{\sum_{i=1}^{n} x_i^2}{N} \quad \text{where } x_i = X_i - \bar{X}$$

Using data from Table 6, the steps to compute standard deviation are:

a. Find the mean $\overline{X}$.
b. Calculate the deviation $(X_i - \overline{X})$ of each item from $\overline{X}$ which gives x_i.
c. Square each of these deviations.
d. Sum them up.
e. Divide the sum by the total number of observations N.
f. Take the square root.

$$\overline{X} = \frac{3.0 + 3.2 + 2.8 + 3.4 + 3.6 + 3.8}{6}$$

$$= 3.3$$

$$S = \frac{(3-3.3)^2 + (3.2-3.3)^2 + (2.8-3.3)^2 + (3.4-3.3)^2 + (3.6-3.3)^2 + (3.8-3.3)^2}{6}$$

$$= 0.35$$

Most pocket calculators can calculate standard deviation without having to use a formula.

If computation needs to be done manually the following formulas which do not require the computation of the mean and the subtraction of the mean from each score are simpler to use.

$$1)\quad S = \sqrt{\frac{\sum_{i=1}^{n} X_i^2 - (\overline{X})^2}{N}}$$

$$2)\quad S = \sqrt{\frac{1}{N} \cdot \sum_{i=1}^{n} X_i^2 - \sum_{i=1}^{n} X^2}$$

Note that X_i in formulas 1 and 2 is the actual value, not the deviation. Almost all pocket calculators have facilities for calculating X_i^2.

In a normal distribution, about 68% of all data lie within 1 standard deviation of the mean. About 95% lie within 2 standard deviations and 99% are within 3 standard deviations.

Table 6. Computing standard deviation.

Yields (X_i)	$X_i = (X_i - \overline{X})$	$x_i^2 (X_i - \overline{X})^2$
3.0	−0.3	0.09
3.2	−0.1	0.01
2.8	−0.5	0.25
3.4	0.1	0.01
3.6	0.3	0.09
3.8	0.5	0.25
19.8	0	0.70

Coefficient of variation

Standard deviation measures absolute dispersion and is expressed in the same units as the observations. This standard deviation property does not allow the dispersion of two series of values expressed in different units to be compared. Because a large mean usually results in a large standard deviation, it is best to measure standard deviation in relationship to the mean. The coefficient of variation is obtained by dividing standard deviation by the mean.

$$\text{Coefficient of variation} = \frac{S}{\bar{X}}$$

It is also customary to represent the coefficient of variation, V, as a percentage:

$$V = S \times 100$$

For example, consider a set of data about weekly wage rates of male and female farm laborers which have the following means and standard deviations:

Male : $\bar{X}$ = ₱ 150 × = ₱ 5
Female : $\bar{X}$ = ₱ 40 × = ₱ 4.2

Male wages appear to show greater dispersion than female wages, but the level of male wages is higher. To calculate the coefficient of variation for these two groups:

$$\text{Male}: V = \frac{5}{50} \times 100 = 10\%$$

$$\text{Female}: V = \frac{4.4}{40} \times 100 = 11\%.$$

Results show female wages have greater relative dispersion than male wages.

Measures of central tendency and dispersion summarize data. Other measures such as skewness, which measures asymmetry around the mean, and Kurtosis, which deals with the peaks of a distribution, can also be computed, but are not discussed.

BASIC STATISTICAL TESTS

Agricultural research often seeks to discover and evaluate differences between variables. Gomez and Gomez (1976) provide an excellent presentation of statistical procedures commonly used in biological and agronomic research. Two of the most widely used statistical tests are the t-test and the chi-square (X^2) test.

To compute the difference in net income earned by two farmers using different cropping patterns, a researcher might compare mean farm incomes.

Sometimes researchers are interested in measuring effects of experimental crop treatments. If effects of insecticide application on paddy yield are to be studied, scientists may choose two similar groups of farms to study.

Insecticides are used on one group of farms. No insecticides are sprayed on the second group of farms. The second group of farms is called a control group for evaluating the effect of insecticide application.

Researchers must determine if there is a significant difference in the mean yields of

paddy for the two groups. Significant difference is a comparative statistical measure used to test experimental results for sampling error.

Any error in judging the true difference between treatment and control group results is considered a sampling error.

Student's t-test

Usually we assume sample observations have a normal distribution and samples from two groups have the same variation of individual observations around the mean, then a t-test may be constructed.

Then, we can construct a measure known as the 't' statistic which enables us to test whether differences between the mean values of the two groups are statistically significant.

To test whether $\bar{X}_1 - \bar{X}_2$:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\frac{(N_1S_1^2 + N_2S_2^2)}{(N_1 = N_2 - 2)} \frac{(N_1 + N_2)}{(N_1N_2)}}$$

where $\bar{X}_1$ = the arithmetic mean of effect in group 1. (In the first example, effect was net income and in the second example, effect was yield of paddy per hectare);

$\bar{X}_2$ = arithmetic mean of effect in group 2;

N_1 = number of observations or sample size of group 1;

N_2 = sample size of group 2;

S_1^2 = variance of group 1. It is calculated as described in the earlier section on standard deviation. Variance is standard deviation squared;

S_2^2 = variance of group 2; and

$N_1 + N_2 - 2$ = degrees of freedom (the values given in the first column of Table 1).

If the calculated t-value (neglecting the sign) is greater than the t-value given in Table 7 for the corresponding $N_1 + N_2 - 2$ (degrees of freedom) and $\alpha = .05$ level, then $\bar{X}_1$ is significantly different from $\bar{X}_2$ at $\alpha = .05$ level. If the calculated t-value is not greater than the tabulated t-value for the corresponding $N_1 + N_2 - 2$ (degrees of freedom) and $\alpha = .05$, we say that $\bar{X}_1$ is not significantly different from $\bar{X}_2$ at the 5% level.

In Table 7, α has 6 different values: .20, .10, .05, .02, 0.1, and .001 which are called levels of significance. These are used to test if the difference in mean is significant at different levels. Usually, the .05 level of significance is acceptable.

For example, examine two groups of rice farms, A and B. A is treated with fertilizer and B is not. In all other ways A and B are the same. A consists of five farms and B consists of six. Does adding fertilizer actually raise yields? In statistical terms this means testing whether the mean yield per hectare of fertilizer-treated farms is significantly different from the mean yield of farms with no fertilizer treatment.

Table 7. Distribution of t.

	Level of significance					
	< = .20	< = .10	< = .06	< = .02	< = .01	< = .001
1	3.078	6.314	12.706	31.821	63.657	636.619
2	1.886	2.920	4.303	6.965	9.925	31.598
3	1.638	2.353	3.182	4.541	5.841	12.941
4	1.533	2.132	2.776	3.747	4.604	8.610
5	1.476	2.015	2.571	3.365	4.032	6.859
6	1.440	1.943	2.447	3.143	3.707	5.959
7	1.415	1.895	2.365	2.998	3.499	5.405
8	1.397	1.860	2.306	2.896	3.355	5.041
9	1.383	1.833	2.262	2.821	3.250	4.781
10	1.372	1.812	2.228	2.764	3.169	4.587
11	1.363	1.796	2.201	2.718	3.106	4.437
12	1.356	1.782	2.179	2.681	3.055	4.318
13	1.350	1.771	2.160	2.650	3.012	4.221
14	1.345	1.761	2.145	2.624	2.977	4.140
15	1.341	1.753	2.131	2.602	2.947	4.073
16	1.337	1.746	2.120	2.583	2.921	4.015
17	1.333	1.740	2.110	2.567	2.898	3.965
18	1.330	1.734	2.101	2.552	2.878	3.922
19	1.328	1.729	2.093	2.539	2.861	3.883
20	1.325	1.725	2.086	2.528	2.845	3.850
21	1.323	1.721	2.080	2.518	2.831	3.819
22	1.321	1.717	2.074	2.508	2.819	3.792
23	1.319	1.714	2.069	2.500	2.807	3.767
24	1.318	1.711	2.064	2.492	2.797	3.745
25	1.316	1.708	2.060	2.485	2.787	3.725
26	1.315	1.706	2.056	2.479	2.779	3.707
27	1.314	1.703	2.052	2.473	2.771	3.690
28	1.313	1.701	2.048	2.467	2.763	3.674
29	1.311	1.699	2.045	2.462	2.756	3.659
30	1.310	1.697	2.042	2.457	2.750	3.646
40	1.303	1.684	2.021	2.423	2.704	3.551
60	1.296	1.671	2.000	2.390	2.660	3.460
120	1.289	1.658	1.980	2.358	2.617	3.373
∞	1.282	1.645	1.960	2.326	2.576	3.291

Source: Fisher and Yates, 1963.

Use a t-test to determine if the mean yield of A equals the mean yield of B. If mean yields are different, the yield of fertilizer-treated farms is significantly different from the yield of untreated farms. Fertilizer affects yields.

Let the rice yields (t/ha) be,

Group A Farms:	2.1	2.0	2.2	2.3	1.9	
Group B Farms:	3.0	3.2	2.8	3.4	3.6	3.8

$$t = \frac{\bar{X}_A - \bar{X}_B}{\dfrac{(N_A S_A^2 + N_B S_B^2)}{(N_A + N_B - 2)} \dfrac{(N_A + N_B)}{(N_A B_A)}}$$

$$\bar{X}_A = \frac{2.1 + 2.0 + 2.2 + 2.3 + 1.9}{5}$$

$$= 2.1$$

$$\bar{X}_B = \frac{3.0 + 3.2 + 2.8 + 3.4 + 3.6 + 3.8}{6}$$

$$= 3.3$$

$$\text{Now, } S_A = \sqrt{\frac{\sum_{i=1}^{5} (X_i - \bar{X}_A)^2}{N_A}}$$

$$S_A^2 = \frac{\sum_{i=1}^{n} (X_i - \bar{X})^2}{N_A}$$

$$= \frac{(2.1-2.1)^2 + (2.0-2.1)^2 + (2.2-2.1)^2 + (2.3-2.1)^2 + (1.9-2.1)^2}{5}$$

$$= \frac{.10}{5} = .02$$

$$= \frac{.09 + .01 + .25 + .01 + .09 + .25}{6}$$

Similarly, $S_B^2 = 0.12$

$$\text{Now } t = \frac{2.1 - 3.3}{\dfrac{(5\,(.02) + 6\,(0.12))}{(5 + 6 - 2)} \dfrac{(5 + 6)}{(5 + 6)}}$$

$$t = -6.7$$

Calculated t-value is 6.7 (neglecting the sign). Tabulated t-value from Table 1 for $5 + 6 - 2 = 9$ degrees of freedom at $\alpha = .001$ is 4.781.

Therefore, the calculated t-value 6.7 is greater than the tabulated t-value 4.78. This means that $\bar{X}_A$ is significantly different from $\bar{X}_B$ at 5% level. That is, mean yield of fertilizer-treated farms differs from mean yield of farms without fertilizer application.

Chi-square test (X^2-test)

In the previous section we discussed how to test if the means of two groups are statistically significantly different. Sometimes we need to know if the means of a number of groups are different from each other, or if two types of treatments (or characteristics) can influence some variable. A t-test cannot be used. Chi-square (X^2) test is often used.

In most applications of this test a contingency table is used. A contingency table is a way of organizing data in various cells, each of which represents different combinations of categories within the data set.

Examine a sample of 82 rice farmers from Camarines Sur in the Philippines. Forty-four were growing modern varieties (MV) and 38 were not. These two groups were divided into four categories of educational status. Of 44 adopters, 6 were illiterate, 10 had elementary school educations, 12 had attended high school, and 16 had college educations. Of 38 nonadopters, 10 were illiterate, 9 had elementary school educations, 11 had attended high school, and 8 had college educations.

Table 8 organizes this information. Table 8 is a contingency table. It is often called a 2 by 4 (2 × 4) contingency table meaning there are 2 rows and 4 columns in the table. There are two criteria. One criterion is classified into four categories and the other into two categories. Number of rows should be mentioned first followed by number of columns. This is two-way organization which classifies sample farmers by MV adoption and education level.

Is level of education related to adoption? Or, are education and adoption independent of each other? A X^2-test is used to find independence in a contingency table. Some definitions (concepts) used in constructing a X^2-test statistic follow (Table 9).

Cell is a unit or box showing a distinct category. In the example there are eight cells showing different categories of farmers: A, B, C, D, E, F, G, and H.

Observed value (OV) is the actual number of samples in each cell. In the example, observed value of cell A is 6.

Expected value (EV) is calculated, for any cell, by multiplying row total by the column total in which the cell is located, then dividing this product by total sample size.

Table 8. Contingency table.

Criteria	Farmers' education				Total
	Illiterate	Elementary	High School	College	
Adopters	6 A	10 B	12 C	16 D	44
Non-adopters	10 E	9 F	11 G	8 H	38
Total	16	19	23	24	82

Table 9. Computation for chi-square from contingency table.

Cell (1)	Observed value (2)	Expected value (3)	(Observed value)^2 (4)	$\frac{(\text{Observed value})^2}{\text{Expected value}}$ (4)/(3)
A	6	8.6	36	4.2
B	10	10.2	100	9.8
C	12	12.3	144	11.7
D	16	12.9	256	19.8
E	10	7.4	100	13.5
F	9	8.8	81	9.2
G	11	10.7	121	11.3
H	8	11.1	64	5.8
Total	82	82.0		85.3

In the example, expected value of cell A is calculated by multiplying the row total 44 by the column total 16, then dividing this product by 82. Expected value of cell A is

$$\frac{44 \times 16}{82} = 8.59.$$

Expected value E_{ij} of the cell located at the ith row and j^{th} column which is also called i, j^{th} cell is:

$$E_{ij} = \frac{n_i \times n_j}{n}$$

where n_i = the total of the ith row,
n_j = the total of jth column, and
n = total sample size.

Note that the X^2-test cannot be used effectively if the expected value of any cell is less than 5. If the expected value of a cell is less than 5 units, the category should be deleted or the observed values should be added to the next most similar category cell.

Degrees of freedom

In t-test, degrees of freedom are determined using the number of observations (sample size). For contingency tables, degrees of freedom depend on the number of criteria and categories. If these are p criteria (rows) and q categories (columns), then degrees of freedom equal (p-1) (q-1).

In the example, there are two criteria and four classifications, that is, two rows and four columns. Degrees of freedom for the contingency table are $(2-1)(4-1) = 1 \times 3 = 3$.

The X^2-test statistic used to test for the relationship between the criteria and categories is constructed as:

$$X^2 = \Sigma \frac{(\text{observed value} - \text{expected value})^2}{\text{expected value}}$$

In the example:

$$X^2 = \frac{(OV-EV)^2}{EV} \text{ for cell A} + \frac{(OV-EV)^2}{EV} \text{ for cell B} + \frac{(OV-EV)^2}{EV}$$

$$\text{for cell C} + \ldots + \frac{(OV-EV)^2}{EV} \text{ for cell H.}$$

For easy computation, the above formula of X^2 can be reduced to:

$$X^2 = \Sigma \frac{(\text{observed value})^2 - N}{\text{expected value}}$$

where N is total sample size.

Is there a statistically significant relationship between MV adoption and farmer education?

Table 10. Distribution of X^2.

	Level of significance α					
df	.20	.10	.05	.02	.01	.001
1	1.642	2.706	3.841	5.412	6.635	10.827
2	3.219	4.605	5.991	7.824	9.210	13.815
3	4.642	6.251	7.815	9.837	11.341	16.268
4	5.989	7.779	9.488	11.668	13.277	18.465
5	7.289	9.236	11.070	13.388	15.086	20.517
6	8.558	10.645	12.592	15.033	16.812	22.457
7	9.803	12.017	14.067	16.622	18.475	24.322
8	11.030	13.362	15.507	18.168	20.090	26.125
9	12.242	14.684	16.919	16.679	21.666	27.877
10	13.442	15.987	18.307	21.161	23.209	29.588
11	14.631	17.275	19.675	22.618	24.725	31.264
12	15.812	18.549	21.026	24.054	26.217	32.909
13	16.985	19.812	22.362	25.472	27.688	34.528
14	18.151	21.064	23.685	26.873	29.141	36.123
15	19.311	22.307	24.996	28.259	30.578	37.697
16	20.465	23.542	26.296	29.633	32.000	39.252
17	21.615	24.769	27.587	30.995	33.409	40.790
18	22.760	25.989	28.869	32.346	34.805	42.312
19	23.900	27.204	30.144	33.687	36.191	43.820
20	25.038	28.412	31.410	35.020	37.566	45.315
21	26.171	29.615	32.671	36.343	38.932	46.797
22	27.301	30.813	33.924	37.659	40.289	48.268
23	28.429	32.007	35.172	38.968	41.638	49.728
24	29.553	33.196	36.415	40.270	42.980	51.179
25	30.675	34.382	37.652	41.566	44.314	52.620
26	31.795	35.563	38.885	42.856	45.642	54.052
27	32.912	36.741	40.113	44.140	46.963	55.476
28	34.027	37.916	41.337	45.419	48.278	56.893
29	35.139	39.087	42.557	46.693	49.588	58.302
30	36.250	40.256	43.773	47.962	50.892	59.703

Source: Fisher and Yates, 1963.

Use:

$$X^2 = \Sigma \frac{(OV)^2}{EV} - N.$$

Compute the expected value for each cell by the formula explained earlier:

$$E_{ij} = \frac{N_i \times N_j}{N}.$$

$$X^2 = \Sigma \frac{(OV)^2}{EV} - N.$$

$$= 85.3 - 82$$

$$X^2 = 3.3$$

Tabulated value (Table 10) of X^2 for $(2-1)(4-1) = 3$ degrees of freedom at $\alpha = .5$ level is 7.815. This is not greater than the calculated value 3.3.

Therefore, the relationship between adoption of MV and farmer educational status is not statistically significant. Adoption of MV by farmers in Camarines Sur is not related to their educational level.

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CHAPTER 3

ENTERPRISE, PARTIAL, AND PARAMETRIC BUDGETS

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Budgets are one of the simplest yet most widely used techniques in economic analyses. They are building blocks for some of the most powerful analytical tools used in agricultural economics research. Budgets are used:

- to compare economic profitability of different production activities or enterprises within or among farms,
- to indicate whether a proposed change will be profitable under a given set of circumstances, and
- to explore conditions under which certain farm practices become profitable or unprofitable.

Enterprise budgets, *partial* budgets, and *parametric* budgets are discussed in this chapter. We will examine:

- data needed for their construction,
- commonly encountered problems, and
- budget limitations.

ENTERPRISE BUDGETS

The process of producing a particular farm commodity is called a farm enterprise. Small farms in tropical Asia usually are multi-enterprise farms — they produce more than one commodity. A farm that produces rice, vegetables, and livestock has three enterprises.

Farms may also produce the same commodity using different techniques. If a farmer grows transplanted and direct-seeded rice, there are two rice enterprises. If the same crop can be grown in different seasons, wet-season rice and dry-season rice, two different rice enterprises are identified. When discussing an enterprise precise definition is essential.

Enterprise budgets enable us to evaluate costs and returns of production processes. Comparing relative profitability of new technology with existing farm technology helps to show how the farm business can be more profitable. The new technology may change existing technology to show a better way to grow a crop (e.g. minimum tillage versus plowing and harrowing). Enterprise budgets are also used to compare possible new cropping patterns or crops with existing production patterns.

Data requirements

A budget is a formalized way to compare production process benefits and costs. If benefits exceed costs, profit was earned. If benefits are less than costs, a loss was incurred. The difference between gross returns and variable costs is called the *gross margin* (also referred to as returns above variable costs). Gross margin measures the contribution of an enterprise to farm profitability. Input quantities and values used in production process (costs) and output quantities and values (benefits) are the basic data required for budgets. Budgeting data may be obtained by:

- measuring input levels used by farmers and crop yields obtained from their fields, and valuing inputs and outputs using market data,
- requesting farmers to list the input levels used, time spent on production activities, crop yields, and prices paid and received,
- using experimental data as a proxy for estimating on-farm performance,
- asking persons in the area who are knowledgeable about the crops of interest (key informants), and
- using secondary data sources (reports, references, etc). These methods are discussed in detail in this volume.

Budget construction

The first step in constructing a budget is to accurately specify all production costs and revenue sources.

Costs

Costs are often divided into two categories —*variable* (recurrent) and *fixed* (overhead).

Fixed costs are costs that must be paid even if no output is produced. They often relate to the whole farm rather than to a particular activity. These costs are incurred no matter what crop or cropping pattern is used. Building depreciation, canal and ditch maintenance costs, land taxes, etc are fixed costs.

Variable costs apply specifically to a particular enterprise. They vary according to production level. Farmers can normally control or change the level of variable costs. (Variable costs are only incurred when an enterprise is produced.) Inputs such as labor for land preparation, planting, or harvesting; amount of fertilizer or insecticide applied; and use of animal or machine power are examples of variable costs.

In this chapter, variable costs are most important because our objective is to compare relative profitability of present practices with potential farming activities.

The following information is needed to compute variable costs:

- inputs to include in the calculations,
- quantity of each input, and
- price of each input.

Inputs usually fall into three broad categories: labor, materials, and machinery/equipment. However, to measure costs accurately (and clearly identify the enterprise being examined) we need to define each input carefully for a budget analysis.

Labor is used for land preparation, crop establishment, weeding, and harvesting. How these operations are done may require us to consider different production methods separately. For example, a rice crop may be direct-seeded or transplanted.

These two methods have different labor requirements. Labor for different tasks usually requires different wages — the costs of a day's labor for breaking clods may be higher than the cost of a day's labor for weeding. Wage rates also may vary by sex and age (adult or children), and by time of year as influenced by labor demand by other farmers. Therefore, the cost of a specific operation will depend not only on the amount of labor needed, but also on the nature of the operation. This precise cost should be included in budget calculations. For a more detailed discussion of wage calculations refer to Chapter 4.

Similar questions arise in relation to material and machinery/equipment use. Type of material (fertilizer, pesticides, etc) and machinery/equipment (tractors, sprayers, etc) used and the corresponding cost must be identified to construct an accurate budget.

Total cost of each input is obtained by multiplying quantity of inputs used by unit price. In small-farm agriculture the farmer's real price of an input is not always easy to estimate. Market price may deviate from the farmer's input cost. This real price to the farmer is called opportunity price.

Frequently, values must be estimated or imputed to derive input cost. For example, if production is used on the farm rather than sold (rice straw used to feed cattle), it should be valued at market price. Similarly, if the farmer uses his own equipment (bullock and plow), opportunity cost is usually assumed to equal the income he could earn by hiring the equipment out for an equivalent time.

Effective price paid for most inputs tends to be higher than market purchase cost. This is because transport costs, handling costs, credit and interest charges, etc must be added to the purchase price to estimate actual crop input cost. Labor to apply the input must be included in the labor section of the budget. Transport costs can be particularly important components of farm prices when market centers are distant or transport facilities poor. Similarly, if a farmer is paying 100% interest on a loan, real input cost may be double its market price.

Labor as an input

Labor cost (wage rate) for a particular operation should equal wage rates paid in the community for the same work. Frequently, real wages consist of a cash component and a noncash component (meals, harvester retains some of the crop, transport costs). Actual cost of hired labor is usually higher than cash cost. The value of noncash components to the cash payment must be included to compute the real wage rate. An example of estimating the real labor cost is shown in Table 1. Sometimes the entire payment is in kind, as when harvesters are paid a share of the crop. Cash wage then is the value of the crop share at harvest. Ways to estimate different kinds of wage rates are discussed in Chapter 4.

Family labor is a major component of total labor use in small farm production. Determining family labor cost often causes difficulties — and arguments. The simplest way is to value family labor for a given operation at the wage rate that would be paid hired labor. The implicit assumption is that the opportunity cost of family labor equals market wage rate. Wage rate for the operation is what the farmer (or the family member) could have earned by selling labor services to other farmers.

This assumption is not always valid. During slack agricultural seasons there is

Table 1. Estimating the real cost of hired labor to a farmer.

Item	Value
Cash wage (M/day)	6
Meal (M/meal)	2
Refreshments (M)	1
Rice (kg)	1
Real cost of hiring a day's labor (M)	10

little or no off-farm work for farmers, even if they want work. The alternative to working on his own farm may be not to work at all. On the other hand, during peak agricultural seasons, labor demand may be high. When budgeting, these facts may be taken into account by imputing a family labor value lower than the market wage during slack season, and higher than the market wage during periods of labor scarcity. It is impossible to exactly estimate the correct value, but it has been suggested 75% of the wage rate in slack season and 125% during peak season may be a satisfactory compromise (Perrin et al 1976).

Capital cost

There are costs of using capital (cash) in crop production as well as household labor costs. These costs fall into one of two categories:

- direct costs, such as interest charges on a loan to buy fertilizer or hire laborers, or an opportunity cost on savings representing earnings lost by not investing the money elsewhere, or
- a risk premium to cover a farmer's investment in an uncertain situation.

Effective interest rates (direct capital cost) sometimes may be 100% or more for farmers who must borrow from moneylenders. When a farmer does not use credit, the real cost of buying an input will still be higher than cash cost because of the foregone benefits of not investing the cash elsewhere. For example, instead of buying fertilizer, the farmer might have bought low-priced crops to sell when prices were higher. In rural societies lending and borrowing rates for small farmers often differ. Although a farmer may pay high interest charges if he borrows, he may not have the opportunity to lend money at similar rates. Indeed, if he lends money to family or friends, the loan may be interest free. If farmers loan cash for interest, an interest charge on the cash outlay should be included as part of the cost of a purchased input.

Table 2 shows one way of evaluating the cost of borrowed capital. If the annual interest rate is 100%, but the loan must be repaid in 6 months, the interest cost equals 50% of the loan. There are often loan costs such as fees, time and travel, or other payments. The real loan cost is the interest charge plus other costs necessary to obtain the loan. Normally, a farmer will want a greater return on his loan than its direct cost (62.5% in the example). How much more he will need to earn before he is willing to borrow the money is difficult to estimate. This premium, often referred to as a risk premium, partly depends on investment risk, and partly on the farmer's willingness or ability to invest in this, rather than some other enterprise. Table 2 assumes the farmer will not borrow unless the return is 85%. The risk premium equals 22.5%.

Table 2. Estimating capital cost.

Item	Value
Amount of loan to buy inputs (₥)	160
Interest for 6 months (100%/year) (₥)	80
Cost of negotiating loan (₥)	20
Total cash outlay (₥)	260
Real cost of loan (100/160) (%)	62.5
Risk premium (%)	22.5
Total cost of loan in enterprise (%)	85.0

Land input

Land is the third major controllable input in the production process. In many countries the farmer pays a direct cost for the land he farms. This is usually a cash rent or a share of the crops harvested. If cash rent is not dependent on the crop grown or yields, the rent is a fixed cost and does not enter the budget calculation. If the land payment is a share of the crop, then this cost will be as a budgeted item, to be deducted from the farmer's gross margin for the crop.

Land also has an opportunity cost — its value in the best alternative use. This alternative may be another crop, renting the land out, or in some cases, simply leaving it fallow. Land opportunity cost is frequently left out of enterprise budgets, partly because it is difficult to measure. Returns to land and management are considered residual after the value of other inputs (cash costs, labor, capital) have been deducted from gross benefits. In this way, budgets help compare the profitability of allocating land — normally a fixed factor — to different uses.

Assembling an enterprise budget

Data necessary to construct a budget have been discussed in previous sections. Table 3 gives an example of a budget for a wet-seeded rice crop. Note that it is important to describe when, where, and how the crop is grown; the variety; and the land type, including the field's landscape position and irrigation status. This information enables others to compare results from other sites.

Gross benefits

First, calculate gross benefits (part 2, Table 3). In this example, a cash value for rice harvested and an opportunity value for rice straw retained to feed livestock are given. Rice yield received is the harvested yield less harvester's, thresher's, and landlord's shares. If harvesters are paid in kind, and the cost of this operation is deducted from gross yields, then harvest labor cost must not be duplicated in the labor portion of the budget. In the example, the farmer does not require all the straw. Some is retained for livestock feed (1 t). The remainder is burned or given away. Note that giving the straw away does not imply the cost of straw is zero to the person receiving it. The recipient still must pay labor and transport costs to bring the straw to his farm.

Variable costs

Variable costs (part 3, Table 3) are often divided into four categories:

- nonlabor inputs,

Table 3. Example of an activity budget for wet-seeded rice, in ₱ per hectare.

1. Crop description				
Crop: Rice, wet seeded, rainfed			Variety: IR36 (120 days)	
Site: Iloilo, Philippines			Position: Plateau, impeded drainage	
Planted: Early May			Harvest: Early September	
2. Gross benefits	*Unit*		*Level*	
Rice grain				
Rough rice	kg/ha		2,400	–
Harvester's share	1/6 production		400	–
Landlord's share	1/3 remainder		666	–
Effective yield to tenant	kg/ha		1,334	–
Effective price to farmer	₱/kg		1.05	–
Benefit from grain product	₱/kg/ha		–	1,400
Straw for livestock feed				
Straw for forage	tons		2.0	–
Quantity of use to farmer	tons		1.0	–
Opportunity cost of straw	₱/ton		50	–
Benefit from straw	₱/ha		–	50
Total gross benefits	₱/ha		–	1,450
3. Variable costs	*Unit*[a]	*Level*	*Effective cost/unit*	*Total cost*
a) Nonlabor inputs				
Seed	kg/ha	120	1.10	132
Fertilizer (48-0-0)	kg/ha	48	1.67	80
Fertilizer (14-14-14)	kg/ha	21	5.00	105
Weedicide (granular)	kg/ha	25	2.80	70
Insecticide (2 applications)	kg/ha	2	12.50	25
Sacks	sacks	30	1.00	30
Subtotal (a), cash costs	–	–	–	442
b) Labor inputs – family (opportunity costs)				
Clearing, fixing bunds	md/ha	10	8.00	80
Plow, harrow, and level	md/ha	16	10.00	160
Broadcast seed	md/ha	3	8.00	24
Weeding and replanting	md/ha	10	8.00	80
Fertilizer, spraying	md/ha	6	8.00	48
Harvesting	md/ha	2	10.00	20
Hauling crop	md/ha	3	10.00	30
Subtotal (b) opportunity cost, household labor			–	442
c) Labor inputs – hired labor				
Weeding	md/ha	14	8.00	112
Harvest/thresh/bagging	md/ha	13	0	0
Subtotal (c) cash cost of hired labor		–		112
d) Interest on cash costs				
Nonlabor inputs (sub. a)	₱/ha	412	0.50	206
Hired labor (sub. c)	₱/ha	112	0.50	56
Subtotal (d) interest on cash costs				262
Total variable cash costs				816
4. Net returns				
Return to household labor, management, land, and capital				634
Total variable costs (cash plus opportunity)				1258
Net benefit to management and land (NB)				192

[a]md = man-days.

Table 4. Estimating the real costs of inputs to the farmer.

	Unit	
Market price of input	₱/kg	₱/kg (A)
Procurement costs		
Transport costs	₱/kg	–
Credit/interest charges	₱/kg	–
Other transaction costs	₱/kg	–
Total procurement costs	₱/kg	₱/kg (B)
Real cost/unit of input	–	₱/kg (A+B)

- household labor,
- hired labor, and
- interest on cash costs.

One reason for separating these items is that it eases subsequent factor share analysis (see Chapter 13).

Nonlabor inputs. Seed, fertilizer, agrochemicals, animal power, tractor hire, irrigation water, etc are nonlabor inputs. Most of these have a cash market price. Real money input cost is estimated in Table 4. Procurement costs must be added to purchase price to estimate real costs to the farmer. If inputs do not have cash market values opportunity costs are used.

Household labor. In Table 3 household labor is valued at the assumed cost of hiring labor for that task. For plowing, harrowing, and leveling, the farmer uses his carabao which is charged at an opportunity cost of ₱10/day for man and beast. For crop maintenance, labor is charged at ₱8/day. During harvest household labor is valued at ₱10/ day.

Hired labor. Laborers were hired to weed and harvest the crop. Harvest laborers were paid in kind. This amount of rice was deducted from rice yield when computing gross revenue. If the rice had been transplanted and had the farmer hired labor to transplant the seedlings, this hired labor use would appear in the budget with weeding labor.

Interest on cash costs. Interest is normally charged on cash expenses paid early in the growing season. This reflects that cash invested has an opportunity cost. Using the money to grow this crop precludes investment elsewhere.

Net returns

Two measures of gross margin or returns above variable costs per hectare are listed in part 4, Table 3. The first measures differences between total gross benefits and total variable cash costs (₱634) and does not include a family labor opportunity cost. This measurement is the return accruing to the tenant for his and his family's labor and management skills, a residual return to the land he cultivates (over and above the landlord's share of the crop as rent), and a return to fixed assets (carabao, plow, etc) used to produce the crop. This figure is referred to as returns above cash costs. The second measure of net return (₱192) deducts the opportunity cost of the

household labor from gross revenue. This net return is the return to the household's management skills, capital, and a residual to land. It is referred to as returns above full cost.

In many cases, enterprise budgets use the first definition of returns above variable costs as the measure of net benefit. This method is used when the budget is incorporated in simplified or linear programming models. In these models family labor is a fixed resource to be distributed between production processes. The opportunity cost of labor for the model is estimated internally.

When profitability of competing activities is being compared, the opportunity cost of family labor should be deducted from the gross revenue in the same way as cash costs. The two enterprises are then compared by returns above all variable costs.

Estimating returns to scarce resources

Net benefits calculated in Table 3 are per unit of land. However, land may not be the most limiting factor. As a result, it is also useful to estimate returns per unit of labor and capital. In irrigated areas, it may be sensible to estimate benefits per unit of water applied.

Returns to a factor 'A' are defined in general as equal to

$$\frac{\text{Gross benefits} - \text{Cost of all other inputs}}{\text{Cost (or amount) of factor A}}$$

This can be also written as

$$\frac{\text{Net benefits} + \text{Cost of factor A}}{\text{Cost (or amount) of factor A}}$$

Expressions for estimating returns to various factors are listed in Table 5.

Return per unit of land. The return per unit of land to the tenant is the net benefit listed in Table 3, i.e. M192/ha less the value imputed to the farmer's management skills. The household's management skills are usually regarded as part of the

Table 5. Estimating returns to factors of production.

Factor	Specific return	How calculated
Land	M/ha	NB[a] as in Table 6
Labor	M/man-day	(NB + total labor cost)/total man-days
	M/man-day family labor	(NB + opportunity cost of family labor)/man-days of family labor
	M/man-day peak labor	(NB + labor costs in peak period/no man-days used in peak period)
Capital	M/M cost	(Gross benefit/total variable cost)
	M/M cash cost	(NB + cash costs in constraint period)/cost in constraint period

[a]NB is net benefit, i.e. the last line of Table 3.
Source: Norman and Palmer-Jones (1977, p. 241-260).

opportunity cost of family labor. Return per unit of land is equivalent to the net benefit (₦192) estimated in Table 3.

Return per unit of labor. Table 3 shows the return per day of labor used to produce the rice crop to be ₦12.5. Labor unit return equals the net benefit (192) plus family labor opportunity cost (442) and actual outlay for hired labor (112+56) divided by days of labor used to grow the rice crop (64). The return to family labor alone equals net benefit plus family labor opportunity cost (634) divided by family labor input (50), i.e. ₦12.7/day.

If peak labor demand was at weeding, then labor input required for the task is used to estimate return per man-day of peak labor. In the example 24 days of labor were used for weeding, thus the return per labor day during the peak labor period is ₦16/day.

Return per unit of capital. Return per unit of capital invested (gross benefits)/(total variable costs) is 1.2 (1450/1258). Return per unit of cash costs is 1.8 (1450/816). Return per unit of cash-cost-constraint requires that the period when cash is most scarce be identified. This is normally at planting time. Because most cash costs were incurred during planting, return per unit of cash constraint is also 1.8.

For an enterprise to be financially attractive, returns per unit of scarce factors must be higher than the market prices of those inputs.

PARTIAL BUDGETS

Partial budgets are used to evaluate the effects of a proposed farm enterprise change. A partial budget is useful only when the change is relatively small.

A partial budget highlights variations in costs and returns caused by proposed changes in the enterprise. Only items affected by the change are included in the budget. Levels and costs of all unchanged inputs are not included. Take care to include all changes. Leaving out interest on added costs is a common mistake. When constructing a partial budget identify:

- costs that will increase or decrease, and
- returns that will increase or decrease.

Table 6 shows a basic partial budget. The left side shows negative effects of a proposed change — added costs and reduced returns of changing from an old to a new technology. On the right side are the positive effects — added returns and reduced costs. If positive effects exceed negative effects proposed practice is more profitable than the existing production practice.

Table 6. Partial budget to estimate change in annual net cash farm income resulting from some change in resource use.

a. Added costs	c. Added returns ₦_____
b. Reduced returns	d. Reduced costs ₦_____
Subtotal A:₦_____	Subtotal B:₦_____
Estimated change (B–A) ₦_____	

Table 7. Partial budget for hand weeding vs no weeding for transplanted IR36.

Added costs		Added returns	
Hand weeding labor	₱105.00	Change in palay produced	₱1575.00
Interest	302.50		
Harvest labor and postharvest labor	500.00		
Reduced returns	nil	Reduced cost	nil
Subtotal A	₱907.50	Subtotal B	₱1575.00
		Estimated change (B–A)	₱ 667.50

Table 7 illustrates how a farmer who wishes to evaluate the costs and benefits of hand weeding versus no weeding of transplanted IR36 would use a partial budget.

The yield of the hand-weeded field is assumed to be 1,500 kg more than the non-weeded field. Added return is ₱1,575. Added cost of hand weeding is ₱907.5. Labor for hand weeding was 150 man-hours (100 man-hours for the first weeding and 50 man-hours for the second). Hand weeding cost was ₱0.7/hour. Total labor cost was ₱105. Extra costs to harvest the higher yielding crop were ₱500. Interest on cash cost was 50%. To facilitate computation, it is assumed the farmer owns the land and the total harvest goes to the farmer (labor was in cash). Estimated profit change is ₱667.5.

In preparing a partial budget, make sure all revenue and cost changes are specified. Secondary effects of changes often may be overlooked. If straw is usually not sold, but is of value to the farmer, reduction in straw yield may be overlooked (although it would not have altered the final result in our example).

PARAMETRIC BUDGETS

Estimates of inputs and outputs are approximate, and prices are subject to change. Therefore, it is useful to explore how sensitive benefits are to changes in assumed levels of inputs, outputs, and prices. We often want to learn what yields and/or prices are necessary to make a change profitable. Parametric budgets, also called sensitivity analyses, answer these questions.

The simplest situation to consider is the change in profit if one parameter is varied. Gross margin is then calculated as:

$$GM = (P \times Y) - VC$$

where

GM = total gross margin,
Y = crop yield (the factor to be varied),
P = the price of the crop, and
VC = total variable cost (cash plus opportunity cost).

Gross margin can now be calculated for any yield within the range that yields are expected to vary. Table 8 presents gross margins for a range of yields between zero

Table 8. Effect of changes in yield level on gross margin.[a]

Yield (kg/ha)	Gross margin (kg/ha)
0	– 1258
1000	– 208
2000	842
3000	1892
4000	2492

[a]GM = (Y X 1.05) – 1258.

and 4,000 kg/ha. The data are also plotted in Figure 1. The figure shows that a yield of less than 1,198 kg is a loss for the enterprise. This yield is usually called break-even yield, calculated by solving for Y when (PY) – VC = 0. It is where the farmer just recovers variable costs.

Two enterprise parameters can also be examined simultaneously. In Table 9, both rice yields and prices are varied. Combinations where gross margins are positive or negative are apparent. In this example, if the farmer receives more than 1,500 kg/ha of paddy, the enterprise is profitable for a wide range of rice prices. Gross margin is sensitive to yield levels below the break-even yield even at a price higher than the current price (₱1.05) (Fig. 2). A more interesting task is to identify combinations of rice prices and yields that result in equal gross margins at some desired level. In

1. Effect of changes in yield levels on gross margin.

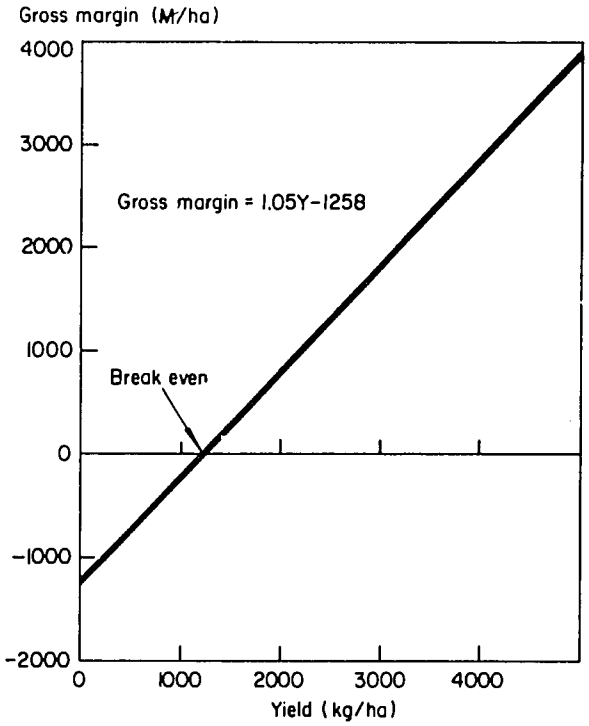


Table 9. Effect of changes in yield level and price per kilogram of rice on gross margin.

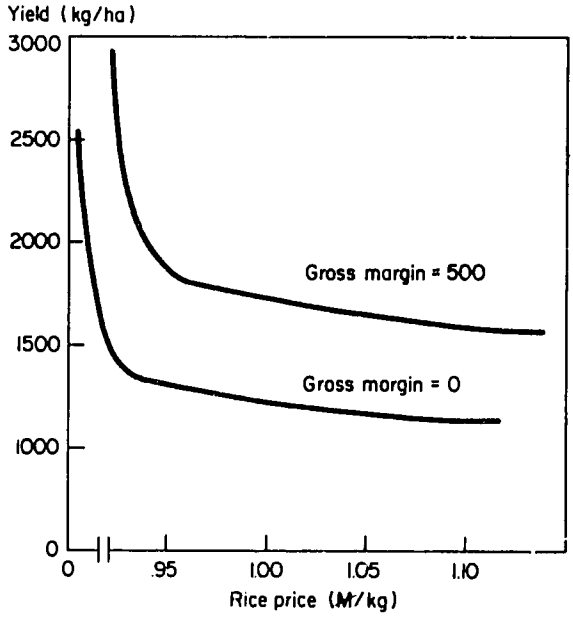
Yield (kg/ha)	Gross margin			
	₦0.95	₦1.00	₦1.05	₦1.10
0	– 1258	– 1258	– 1258	– 1258
1000	– 308	– 258	– 208	– 158
1144	– 171	– 114	– 57	0
1198	– 120	– 60	0	60
1258	– 63	0	63	126
1324	0	66	132	198
2000	642	742	842	942
3000	1592	1742	1892	2042
4000	2542	2742	2942	3142

Figure 2 yields and prices that just cover variable costs are plotted in combination with the equi-gross margin of ₦1500/ha.

Another interesting possibility is to examine the interactions of price per kilogram of rice and agrochemical prices (Table 10). The equation used is:

GM = (Yield × price/kg) − (agrochemicals × price) − .50 (agrochemicals × price) − other inputs cost.

Agrochemicals include fertilizer, insecticide, and weedicide. The first term in the equation estimates gross benefits, the second is the direct price of agrochemicals, the third reflects a 50% interest rate on the purchase price of these inputs, and the last term refers to other variable costs. The price of agrochemicals is increased from



2. Effect of yield and rice price on gross margin.

Table 10. Effect of changes in price of agrochemicals and price per kilogram of rice on gross margin.

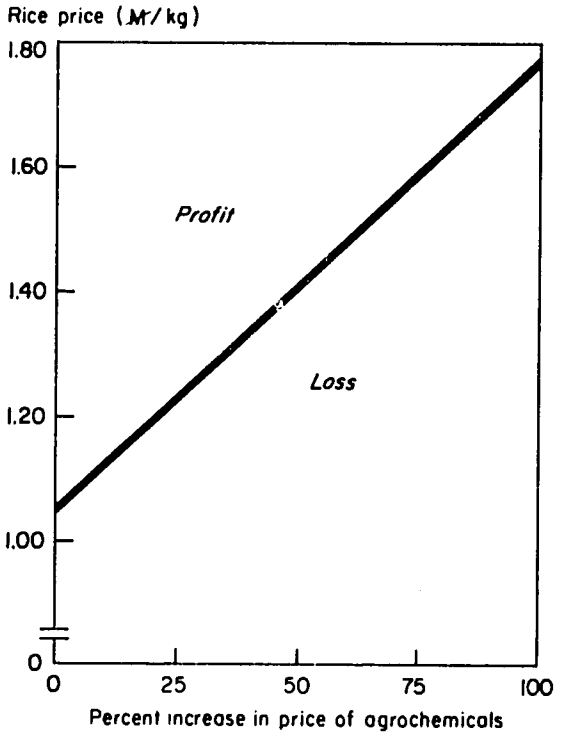
Percent increase in price of agrochemical	Price of rice (M/kg)	Gross margin (M/ha)
0	1.05	0
25	1.24	160
50	1.42	300
75	1.64	500
100	1.78	600

current price to 100% above this level. Rice price is also varied, but yield is held constant. These figures are plotted in Figure 3. They show the combination of rice prices and input costs increases that would result in a profit or loss for the farmer.

LIMITATIONS OF BUDGET ANALYSIS

Budget analysis does not consider activities within a whole-farm framework. Budgeting suffers from the following limitations:

1. correct evaluation of opportunity prices (costs) of resources which have distorted market prices (often land, labor, and capital) is difficult — the analyst must usually decide what is sensible in the particular case,



3. Effect of percentage of increase in price of agrochemicals on gross margin.

2. comparison of two (or more) alternative cropping patterns does not identify the most appropriate way to allocate fixed resources between those and other uses,
3. it is difficult to judge if input requirements for the technology are managerially feasible, given the farmer's resource base and alternative uses which the household commits to those resources.

These limitations become particularly acute when the proposed changes or new techniques involve major farm resource reallocation. One way of internalizing these issues is to analyze existing and proposed production alternatives simultaneously in a simulated whole-farm framework.

Linear programming is a widely used optimizing technique in farm planning. Although this method is computationally extremely powerful, results of such analysis are no better than the enterprise budgets researchers construct to build a programming model. Linear programming (and other, more complex methods) is expensive and time-consuming. It is applicable only when the user has computer access. Therefore, budget analysis is the most used method of evaluating and ranking the profitability of alternative farming enterprises.

EXERCISES

Introduction

1. Study a mixed farm near your hometown. List the enterprises (both crop and livestock) on this farm.
2. List the different ways the dominant enterprise (crop or livestock) is produced. (The various ways a crop is produced, e.g. wet-seeded rice, dry-seeded rice, transplanted rice, are often referred to as *activities*.)
3. Suggest why farmers in the same area produce the same crop but in different ways (activities).

Evaluating gross benefits

1. Study a farmer with a coconut plantation in full bearing. List products normally harvested from the plantation which are economically valuable to the household.
2. Which products listed in 1, above, have clear market prices? Which have opportunity prices?
3. If a measure of wheat is valued at ₦1.50 to consumers, list costs that must be deducted to reveal the effective price of wheat to the farmer.
4. List the dominant forms of payment by area tenants to landlords and harvesters. Show how these payment systems influence the crop yield received by the cultivator.

Estimating variable costs

1. Distinguish between fixed costs and variable costs. Why are fixed costs not included in enterprise budgets?
2. List the variable inputs used to produce a major crop in your country. Be sure to specify how the crop is grown. Specify whether cost will be market price or opportunity cost for each input used. Estimate the farmers' effective input costs.

Costs of labor, capital, and land

1. What is the opportunity cost of household labor? Define the next most profitable use of an individual's time for different seasons of the year. Then, estimate the seasonal opportunity cost for labor in an area you choose.
2. What are the effective interest rates of borrowed money in a village setting you are interested in? If a farmer has money to spare, what is the highest rate of return he can obtain by investing (or lending) the money?
3. A risk premium is normally added to capital cost. What factors influence the cost of capital? How do these factors vary between different farmers, and between landlords and tenants?

Assembling an enterprise budget

1. Prepare enterprise budgets for major enterprises in an important agricultural area of your country. Be sure to specify how the crop is grown, levels of inputs, tenant arrangements, etc.
2. For each budget, estimate the return to the cultivator assuming:
   a) he is an owner cultivator,
   b) he is a tenant paying for all inputs and receiving two-thirds of output, and
   c) he is a tenant paying for half of the cash inputs and receiving half the output.
   What conclusions can be drawn from this analysis?

Estimating returns to scarce resources

1. For the previously constructed enterprise budgets, evaluate:
   a) return per unit of land,
   b) return per man-day for family labor,
   c) return per man-day for total labor,
   d) return per M of cash cost, and
   e) return per M of total cost (cash plus opportunity).
2. Develop a table to compare the returns to the activity budgets constructed by the class in terms of the scarce factors of production listed above. Under what circumstances are different activities most attractive?

Partial budgets

1. Using two similar activities, create a partial budget to evaluate benefits of changing from one to the other.

Parametric budgets

1. Examine sensitivity of net benefits in an enterprise budget to changes in output price and a major input price (e.g. fertilizer price). Discuss the conclusions.

Data sources for budgeting

1. Review the data available in your country which are useful for constructing enterprise budgets. Evaluate the reliability of each of these data sources.
2. Using the operation headings provided in Table 4, list likely input and output coefficients which could be used to construct enterprise budgets.

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CHAPTER 4

ESTIMATING PRICES OF AGRICULTURAL INPUTS AND PRODUCTS FOR ANALYSIS OF AGRICULTURAL EXPERIMENTS

E. C. PRICE

Prices of inputs used in production, and prices of the output — crops or livestock that result from the experimental activity — are necessary to conduct an economic analysis of an experiment. Inputs include such items as land, labor, draft power, and fertilizer and other chemicals. Quantities of inputs multiplied by their prices are the costs of production, and amounts of produce multiplied by their prices are the value of production. The value of production from a farm activity, less the associated costs, reflects the profit from that activity, although a precise definition of profit is somewhat more complex.

Although farm activities involve many different inputs and products, monetary units can be used to express costs, value of production, and profit. Assigning monetary units makes it easy to compare different activities, examine physical quantities and relationships, and measure amounts of dissimilar items. For example, the productivity of farms in different places can be compared even though their products may be different. The agricultural output of entire regions or countries can be compared if their products are expressed in economic (monetary) terms. Trends over time in the productivity of farm labor, land, or capital are more conveniently expressed in economic units than in units of constantly changing physical inputs and products (of course, the prices used must be kept constant to make the comparisons valid).

Economic analysis of experiments is sometimes conducted for general comparative purposes. For example, in the Asian Network for Cropping Systems Research, researchers from different countries compiled a report that compares the results from some of their best experimental cropping pattern trials. They compared the productivity of farm resources and advanced technologies in different places, by using economic terms because the cropping patterns were composed of different annual crops, and many different inputs were used (Table 1).

Economic analysis of experiments often is used to determine if an experimental pattern is likely to be acceptable to farmers. Experimental practices are compared one to another, and to farmers' present practices, to determine practices that produce the most products from the inputs used (IRRI 1979). Because practices to be compared usually involve different inputs or products, cost and value of produc-

Table 1. Relative efficiency of 16 rainfed cropping patterns at different sites in the Asian Cropping Systems Network in terms of land, labor, and capital utilization, 1979-80.

Cropping pattern	Site	Total net return (M/ha/pattern)	Rate of return to Labor cost (M/M invested)	Rate of return to Total variable cost (M/M invested)
1. Rice	Pumdi Bhumdi	144	2.6	2.20
	Bhogra	722	6.1	4.42
2. Rice - rice	Bhogra	989	5.5	3.75
3. Rice - wheat	Pumdi Bhumdi	532	5.0	2.82
4. Rice - wheat - maize	Pumdi Bhumdi	999	4.8	3.44
5. Rice - rice - mung	Jrengek	874	2.8	2.32
6. Rice - rice - cowpea	Jrengek	706	2.5	2.07
7. Maize- rice - mung	Bangphae	404	2.2	1.70
8. Mung - rice - mung	Bangphae	209	2.1	1.47
9. Rice - maize + peanut	Blega	423	2.1	2.42
10. Rice - rice - maize + peanut	Blega	1050	3.0	2.74
11. Rice - rice - maize + mung	Blega	1169	3.3	2.73
12. Maize + rice - cassava + peanut	Blega	-51	0.9	0.92
13. Maize + mung - finger-millet - wheat	Pumdi Bhumdi	555	5.7	3.63
14. Maize + rice - maize + sweet potato - maize + peanut	Blega	769	2.5	2.13
15. Maize + rice - maize + peanut - maize + peanut	Blega	888	2.6	2.10
16. Maize + peanut - maize + peanut - maize + peanut	Blega	805	3.3	2.86

Source: Hoque (1982).

tion and profit are convenient standards for comparison. Profitability is the measure that farmers use to choose agricultural practices.

Prices chosen to value agricultural inputs and products depend on the kind of comparison to be made. To compare levels of input and output over space (between farms or regions or countries) a set of prices that represents conditions in all the places compared should be chosen. To compare groups of inputs and products across time, constant prices should be used. The resulting value of inputs or products is called a value in *real terms*, or, in *constant* monetary units.

Choosing a representative price for an item is difficult if the price varies widely over time or space, and/or the importance of the item (the proportionate amount used or produced) varies. For example, the present production cost will be overstated if an earlier and higher price of an input is used, particularly if its importance in production has increased. LasPeyre's or Paasche indexes are sometimes used to

help solve such problems of valuation (see Yamane 1973 for methods of computation and use of price indexes).

When analyzing experiments, it will only be necessary to give special attention to price trends and spatial price variation if:

1. results from different times and places, over which prices varied, are being compared,
2. different products are being compared, and/or
3. different combinations of inputs were used.

To determine practices likely to be acceptable to farmers, alternatives in the same time and place, over which prices do not vary, are usually compared. The prices required are those a farmer expects to face when and where he will try the experimental practice.

Projecting when and where a farmer will try an experimental practice is somewhat speculative. Current prices at a typical farm in the area to which new technology will be introduced can usually be used. In the following sections, methods for calculating farm-level prices for fixed inputs, variable inputs (materials and labor), and farm products at a given time will be discussed and demonstrated. When studying the methods and planning an analysis, remember that the objective of the methods presented is to reflect as reliably as possible the conditions a farmer perceives when he decides among alternative farm activities.

PRICES OF FIXED INPUTS

Fixed inputs are items used in a production activity that cannot be adjusted once the activity is begun. The cost of fixed inputs to the farmer is the same regardless of the practices he follows. Examples are land, irrigation (when annual fees are fixed), hand tools, land preparation implements, pesticide sprayers, cart, storage bins, and buildings. Other major items owned and used by farmers may appear to be fixed inputs, but because they are frequently rented and have a short-term (hourly, daily, weekly, monthly, or seasonal) rental value, they may be treated as variable inputs. These include draft animals, water pumps, and hand tractors.

When economic analysis compares the results of different experimental or farmer practices, it is not necessary to account for the cost of fixed inputs because, by definition, the cost of fixed inputs is constant among practices. When certain items are disregarded in an analysis because their costs are constant among treatments, the resulting account is called a *partial budget*.

When comparisons among different experimental practices are not shown, and prospective users of an experimental practice are expected to make their own comparisons, it is better to show a complete accounting of costs. In a complete accounting prices of fixed inputs must be identified and used. Whether partial or full accounting is done, a report on the economic analysis of an experiment must always tell exactly what input items were included in the analysis and how their prices were derived.

Apportioning prices of annual services

Fixed inputs are not consumed in a production activity — their services are used. Prices are needed for these services. Prices for annual services of fixed inputs are

often easier to identify than prices for shorter service periods. Therefore, the analyst must decide if it is appropriate to charge a full year of service against an experimental activity. An experimental cropping pattern requires a full year of land and other fixed inputs, but a crop of sorghum to be grown after rice requires services for only part of the year. Land quality and productivity also differ from one part of the year to another. The method chosen for apportioning annual costs of fixed inputs may differ from place to place and from input to input, but should be consistent with how farmers look at their costs.

Farmers often pay a share of produce to landlords for the services of land. That is, the payment is proportionate to the value of the product. Similarly, a good rule to follow is to charge an experimental activity for a share of the annual price of fixed inputs equal to the proportion of the activity's value-product to the total value-product from all activities that use the services of the fixed input.

Identifying annual prices of fixed inputs

Fixed inputs are *depreciable* inputs like buildings and tools that decline (or depreciate) because of age or use, and *nondepreciable* inputs like land that generally do not decline in value. The cost of the service of a depreciable input includes annual depreciation plus the *opportunity cost* of capital invested in the item. The opportunity cost of an item is the value of the item in its highest-paying alternate use. One method used to measure the opportunity cost of farm investment capital is to use the current interest rate on long-term savings deposits.

To identify the total annual costs of depreciable fixed inputs, list all tools, implements, structures, and other fixed capital items that are not frequently rented by farmers. Then, assess the value of the items when new, and determine how long they might be used before being discarded.

Data may be derived from farmer interviews, from storekeepers, or may be supplied by the researchers. A rough estimate is sufficient, and accounts compiled for one experiment often can be used for similar analyses. Table 2 shows how the data might be arranged for an analysis of depreciable fixed inputs.

Depreciation is computed by dividing the original purchase price of an item by the number of years it can be used. For a plow costing ₦1000 expected to last for 10 years, annual depreciation is computed as:

$$₦1000 / 10 \text{ years} = ₦100/\text{year}.$$

It can be assumed that the ages of depreciable fixed input items owned by farmers are uniformly distributed, such that their mean capital values equal one-half their current purchase prices. The opportunity cost of the capital value of the plow, at the current long-term savings interest rate of 15%, may be computed as follows:

$$₦1000 \times .5 \times 15\% = ₦75.$$

The total annual cost of the plow services is depreciation plus the opportunity cost of capital, or:

$$₦100 + ₦75 = ₦175.$$

Similar computations for other items are shown in Table 2.

Table 2. An example of fixed input items, their prices and annual costs, in M monetary units.

Fixed input items	(1) Price when new	(2) Years it can be used	(3) Annual depreciation (1) ÷ (2)	(4) Average capital value[a] (1) X .5	(5) Interest on av value .15 X (4)	(6) Total annual cost (3) + (5)
Depreciable items						
Plow	1000	10	100	500	75.0	175.0
Harrow	500	10	50	250	37.5	87.5
Cart	1500	20	75	750	112.5	187.5
Sprayer	800	5	160	400	60 0	220.0
Hand tools	500	10	50	250	37.5	87.5
Tool shed	2000	20	100	1000	150.0	250.0
Total	6300		535	3150	472.5	1007.5
Total per ha for typical farm size (1.9 ha)						530
Nondepreciable items						
Land (per hectare) capital value (or) rental value[b]				10,000	1500	1500
Total						1500
Grand total annual fixed input costs/ha						M 2030

[a]Average capital value assumed to be one-half price when new, except nondepreciable items given at current market value. [b]If market value of land cannot be determined, its rental value may be substituted in the last column based on the average annual rents paid by sample of farmers (Table 3).

Because results of experiments are usually reported on a per hectare basis, the annual cost of depreciable inputs must also be per hectare. The total value of inputs per average farm should be divided by the area of land over which they would normally be used each year (the total area harvested on the farm during 1 year).

Land is generally considered not to depreciate, and its annual cost may be computed as the opportunity cost of its capital value. Opportunity cost of land can be computed as the current market value times the interest rate on long-term savings. Current market value can be established by interviewing farmers. A farm is often composed of land of different qualities, and perhaps only a certain portion is of equivalent productivity to that on which experiments have been conducted. If farmers are interviewed to determine the price of land, researchers must take care to obtain the price of land of appropriate quality.

As in the case of depreciable fixed inputs, land value should be computed on a per hectare basis. If farmers or other sources cannot suggest a market value for land, researchers might construct a rental value by interviewing tenant farmers. Rents often are paid as a share of harvest. If so, the researcher may compute annual land cost as an average value of product shares, per hectare, paid to landlords by a sample

of tenants. Results will be most accurate if the researcher asks about specific plots or fields that were treated in a uniform manner during the year. An example is shown in Table 3.

When annual fixed costs have been computed, and a result is obtained such as that shown in Table 3, labeled "total annual fixed input costs," the value may be apportioned to the experimental activity. The method suggested in the previous section is to charge the experimental activity a proportion of annual fixed costs equal to the proportion of the value of output from the experimental activity to the total expected output per hectare of the land where the experimental activity takes place. The computation is as follows:

$$\frac{\text{Value of output/ha of experimental activity}}{\text{Value of output/ha of experimental activity} + \text{value of output/ha of other enterprises on the same land}} \times \text{Total annual fixed input costs/ha.}$$

PRICE OF MATERIALS

Perhaps the least difficult of prices to identify and apply in an analysis of experiments are prices of materials, or *purchased inputs* (Perrin et al 1976). Quantities of materials used depend on decisions during the farming activity and are therefore variable inputs. Variable inputs are consumed during production and their entire value is charged against the activity.

Material prices are fairly stable. Infrequent price checks, once or twice a year, are sufficient. The price of materials that farmers consider when deciding input levels will probably include prices at the nearest market plus the cost of transportation. Table 4 contains a list of typical material inputs, and demonstrates the computation

Table 3. An example computation of annual land rent from a sample of farmer plots.

Farmer no.	Plot size (ha)	1st crop				2d crop				Value of shares of all crops (₱)	
		Kind	Landlords share (kg)	Price of crop (₱/kg)	Value of share (₱)	Kind	Landlords share (kg)	Price of crop (₱/kg)	Value of share (₱)	Total value	Value per ha
1	0.5	Rice	400	1.5	600	Mung	100	5.0	500	1100	2200
2	0.8	Rice	467	1.5	701	Maize	200	1.2	240	941	1176
3	1.1	Rice	1100	1.5	1650	Rice	825	1.5	1238	2888	2625
.											
.											
.											
(other farmers)											
.											
.											
.											
10	0.1	Rice	90	1.5	135	Corn	44	1.5	66	201	2010
Av											2003

of the price a farmer faces — the "farm-gate" price.

The price per unit shown in Table 4 is the price of the item at the nearest market. The unit in which the material is purchased is the amount a farmer will usually purchase at one time. Transport cost per unit of material applied is computed from the cost of transporting the total amount typically purchased and shipped to a farm. Transport costs are zero for items purchased within the village and for items that are easily hand carried.

LABOR WAGES

Labor is human physical effort spent to produce goods and services. Labor is an essential farm production factor provided by men, women, and children through various arrangements with a farm operator. It is usually measured in units of time during which effort is expended, usually in man-days or man-hours. Labor value is a variable cost that must be considered when estimating farm enterprise profitability. Cost is calculated as man-hours or man-days of labor expended times wage rates (see Chapter 3).

Estimating appropriate wage rates is a problem when calculating the profitability of an enterprise. Labor is a major production input. Wage rates assumed are an important determinant of alternative enterprise profitability. However, it is seldom clear what wage rate should be used, or how it should be estimated. In this section, we discuss simple ways to compute wage rates using direct observation of agricultural labor transactions.

The following wage rates will be discussed:

1. task wages which differ by operation but are constant for each operation over all months,
2. seasonal agricultural wages which vary by month but are the same for all operations in a month,
3. seasonal task wages which vary by operation and month, and
4. standard agricultural wages which remain constant for all operations for all months.

Before proceeding, however, some additional definitions and assumptions are needed.

Table 4. Example computation of material input prices.

Material input	Unit in which applied	Price/unit applied (₦)	Unit of purchase	Transport cost: Unit of purchase (₦)	Transport cost: Unit applied (₦/kg)	Total cost/unit (₦/kg)
Seed						
Rice	kg	1.5	(usually purchased in village)			1.5
Maize	kg	1.2	50 kg	5.0	0.1	1.3
Mungbeans	kg	8.0	10 kg	2.0	0.2	8.2
Fertilizer	kg	4.0	200 kg	10.0	0.05	4.05
Insecticide	cc	5.0	.5 l	(negligible)		5.0

Definitions and assumptions

Differential valuation of labor. Different wage rates are often paid for work performed by different sex and age groups. Wage estimations to be discussed here are based on observations taken with notation of age and/or gender. They are assumed to apply to work performed regardless of age or gender.

If the age and sex mix of worker groups is highly variable and the work capacity of laborers appears to differ, an adjustment can be made to labor time before multiplying it by the wage rate. Labor may be converted to adult-male equivalents, then a common wage applied. A typical labor time adjustment is to multiply adult female time by 0.75, child labor time by 0.5, and leave adult-male units at a full count of 1.0.

Length of workday. A standard number of hours should be used for converting labor man-days and man-hours, and for converting daily and hourly wages. A workday is normally 8 hours. In field observations actual hours worked in a day for each task should be recorded. A workday for a plowman and carabao is often about 6 hours, although a daily wage may be reported. In this case, daily wage should be divided by 6 to derive an hourly wage.

Wages in kind. Compensation for work is often paid in meals, refreshments, and in shares of produce. These items must be accounted for in monetary terms and added to cash compensation to fully value a labor payment. Examples will be given later. This partially noncash wage may be referred to as the implicit wage.

Separating human and animal wages. Where man and animal work together, as in plowing, labor cost should be separated from animal cost. A general rule is that 1 hour of animal work equals 1 hour of labor. That is, the wage for a man and animal is twice that of a man alone. This can be tested by asking "what wage would you pay a man using your work animals?"

Labor sources. Members of farm operator's family may work without receiving explicit payment. Outside labor is usually paid in cash, food, or farm products and is called hired labor. A third arrangement is labor exchange between farm households. By prior agreement farm households provide equivalent amounts of labor on each farm. Family, hired, and exchange labor are often referred to as labor sources.

Value of family and exchange labor. Valuation of labor not directly compensated, such as family labor, is discussed in Chapter 3.

However, all labor should be valued, partly because in agricultural research labor used on experiments cannot be systematically distinguished by source — i.e. hired, family, or exchange. We use the principle of opportunity cost here (see Chapter 2).

Labor opportunity cost. Labor opportunity cost is the wage rate labor would earn in its highest paying alternate employment. When estimating the profit of an enterprise, the opportunity cost of labor employed in the enterprise equals the highest amount labor could earn in an alternative job. Wage rates discussed in the succeeding sections are labor opportunity cost in any enterprise under analysis. This is because wage rates are estimated from a broader class of market labor transactions than that likely to be used in a specific enterprise analysis.

Because wages are estimated from market transactions they show the effect of employment opportunities in the surrounding nonfarm community. They can be regarded as the opportunity cost of farm and nonfarm labor.

Standard agricultural wage

Standard agricultural wage is the easiest to compute and use. It is a single value given all agricultural labor during a given time at one site. It highlights differences in physical production relationships. When standard prices of material inputs, power, and products are also used, it is possible to compare the agronomic performance of similar or different technologies across space and time. For example, to compare resource use and productivity across agroclimatic zones it would be useful to use a single wage rate, regardless of task, crop, time of year, or country.

There are several ways to identify the hourly standard wage rate. If a government minimum agricultural wage has been established farm workers and employers can verify if the legal wage is paid at various sites at different times of year. Government sources such as the Central Bank, Department of Labor, Department of Commerce, or statistical services may be able to provide information on an agricultural wage.

If there is no legal wage, or if it is apparent the wage rate given is not generally observed, survey techniques must be employed. It is probably not practical, however, for a researcher to try to establish a national agricultural wage if one is not determined from secondary sources. If survey techniques must be used, a limited space over which wage is to be applied should be identified.

By sampling farmers, or taking a key informant survey, one may be able to establish a general agricultural wage for a specific site. Be careful, however, that respondents do not report task-specific or season-specific wages. This can be avoided by asking a question like, "what would be the cost of hiring a worker for 1 day to help do various jobs on the farm?" This should be asked of several farmers or other informants and the average answer used.

Be careful to account for the value of compensation paid in meals and refreshments, and payments in kind as well as cash wages. Harvesters are often paid a share of produce. Produce should be priced at market value of the commodity if sold at the farm. Farmers can usually price meals and refreshments they give.

If a survey fails to provide a general agricultural wage rate, it may be necessary to determine task-specific wages, to weight these by percentage of total annual labor required for each task, and sum the results. Table 5 shows such a computation.

If task wage rates in Table 5 were collected from a nationwide sample, the agricultural wage is a national wage. If the sample is confined to a specific site, such as a cropping systems research site, it applies to that site alone. A computed wage rate can be used for the space where sample data were originally taken. The wage computed in Table 6 may be used for any task in any season.

Task wages

A task wage rate is for a particular task regardless of when it is performed. Usually different task wages apply to different tasks. It is the easiest wage to identify by survey methods because questions can be specific, i.e. "How much do you pay a person to transplant rice for one day?" It is easy to apply because large blocks of labor time use the same task wage. Difficulties occur when there are unusual or non-traditional tasks with no established wage. For these, the wage rate of a similar job might be used.

Table 5. Computing the general agricultural wage by weighting task wages.

Agricultural task	Wage[a] rate (M/hour)	% of total annual labor	Weighted wage component (M/hour)
Land preparation	1.60	30	0.48
Planting	1.40	20	0.28
Weeding	0.90	15	0.14
Harvesting	2.30	35	0.81
General agricultural wage			1.71

[a]Includes value of payments in kind.

The task wage can be misleading. The cost of a job may change because overall labor availability or requirements vary. For example, weeders cannot be hired during the transplanting season at the usual wage because transplanting pays more. Transplanting task wages must be paid to induce a worker to do weeding.

Specific wage rates may become associated with a task not because of the nature of the task but because of general labor conditions that prevail when the task is usually performed. This will be discussed in the section on seasonal wages.

Different crops and different management techniques imply different labor requirements for various operations. For example, direct-seeding rice requires more labor for weeding and less for planting, as compared to transplanting rice. If weeding costs differ from transplanting costs, total costs are affected. In this case, task wage rates should be used, i.e. labor rates determined by operation.

Table 6 shows variable labor prices by operation. Appropriate operational wage rates can be determined by surveying a few farmers or interviewing key informants. Table 6 shows how information from 10 farmers can be summarized.

Seasonal agricultural wage

Agricultural wages in a given site usually vary by season depending on labor demand and supply. Demand and supply conditions are often localized. Computing a national seasonal wage is usually not practical. Seasonal wages should be used only if a region has similar crops, growing seasons, agricultural technology, and similar opportunities for nonfarm work. A seasonal agricultural wage can usually be computed for a cropping systems research site or a group of villages in close proximity.

There are many reasons for wage seasonality. In some seasons schoolchildren can work. Factory labor sometimes becomes available for farm work, and workers may seasonally migrate from regions where cropping schedules are different. Any labor increase will cause a seasonal reduction in the wage rate. Wages will increase when workers return to alternate occupations.

Village labor requirements also vary seasonally, usually by cropping schedule. Where rainfed rice dominates, labor needs increase at land preparation time, transplanting, and harvest. Seasonal livestock activities can also affect labor needs. For example, when farmland is in crops, little grazing land may be available. Feedstuff must either be cut and hauled to the animals, or animals must be driven to pastures. In general, the greater the farm labor requirements, the higher the wage rates will be.

Table 6. Computation of wages for crop operations from a survey of 10 farmers.

Interviewee	Land preparation: Compensation paid a man plus animal for 1 day (8 hours) work			Transplanting: Compensation paid 1 person for 1 day (8 hours) work			Weeding: Compensation paid 1 person for 1 day (8 hours) work			Harvesting: Compensation paid 1 person for 1 day (8 hours) work[b]			
	Cash paid	Value of food	Total value	Cash paid	Value of food	Total value	Cash paid	Value of food	Total value	Cash paid	Value of food	Value of crop share	Total value
	M												
1	15	5	20	5	5	10	7	0	7	0	5	16	21
2	12	5	17	5	3	8	5	0	5	0	3	8	11
3	20	0	20	4	3	7	8	0	8	0	6	32	38
4	18	3	21	4	5	9	4	5	9	0	8	10	18
5	12	7	19	5	3	8	6	0	6	0	3	20	23
6	17	0	17	7	0	7	5	4	9	0	6	15	21
7	12	10	22	4	2	6	7	0	7	0	4	10	14
8	25	0	25	5	4	9	5	0	5	0	7	11	18
9	10	5	15	5	6	11	7	0	7	0	7	16	23
10	12	7	19	5	2	7	5	3	8	0	6	9	15
Total			195			83			71				202
Av/day			19.5			8.3			7.1				20.2
Av/hour			2.4			1.0			0.9				2.5

[a]This value represents compensation to man plus animal. This wage is easier to obtain in an interview than that of a man alone. A man's wage for plowing with an animal is half the total value of the wage of a man plus animal, M1.20/hour in the example above. [b]Harvesters are paid a share of the amount they harvest. Interviewees were asked how much the usual share is for an adult worker for 1 day. That share was then converted into monetary units.

Agricultural wage rates vary by demand and supply. Wage rates are also affected by the kind of work being done. For example, some work is more difficult than other work. Laborers usually are less willing to perform difficult tasks. In a sense, more labor is available for easy jobs than difficult jobs. As a result, wage rates usually are higher for difficult tasks.

Agricultural wages also differ by urgency of labor needs. This occurs when timing is critical to a crop operation. Although two or more jobs — land preparation, transplanting, land weeding, harvesting — may require equivalent labor, farmers have more flexibility in the timing and intensity of certain of these operations. They may plow, soon after the last year's crop, and make other plowings and harrowings long before planting. Weeding can be distributed by doing several light weedings. Even transplanting can be done over time without sacrificing yield. On the other hand, farmers have little choice in harvesting time. Serious losses may occur if the crop is not harvested when ripe. Farmers have little bargaining power with labor at harvesting. Flexibility of operation timing and intensity, and crop yield, determine how much a farmer will pay for labor.

Agricultural wage rates may vary for different tasks because of a more complicated reason. Some jobs require more labor per unit area. When an operation that requires high amounts of labor is needed by many farmers at once, total labor requirements in the area increase. Wage rates also rise.

Under these circumstances higher wage rates are associated with seasonal tasks not because they are more urgent or difficult, but because labor demand is higher. It is wrong to assume the same high wage rate would be paid for the job at another time of year.

Seasonal wage rates are computed to reflect the amount of work performed at specific wage rates observed in all labor transactions at a given time. If harvesting is the principal activity in a given month, the seasonal wage for that month will primarily reflect the harvesting wage. Even labor employed in weeding activity is valued at that wage.

This task-wise generalization of the seasonal agricultural wage is justified because wage rates for specific tasks tend to vary by season as they are dominated by the cost of the prevalent task being performed. For example, if higher paying harvesting work is easily available, weeding labor cannot be bought unless a similar wage is paid.

Table 7 shows how to compute a seasonal wage rate by month and year. The hypothetical data are assumed to have been collected from 10 farmers during 1 year. Total man-hours of labor hired for all farm jobs are in the second column. Columns 3 through 6 show compensation paid for labor in column 2. Raw wage per man-hour is calculated by dividing column 6 by column 2. Because no data were available for March, half the average for February and April is entered. Half the average is entered because little labor is needed that month and only a low wage rate would be paid.

Because crop schedules may vary from year to year the raw wage series is smoothed by taking the 3-month moving average. For example, the January wage is the average of raw wages from December, January, and February. Because wage data are seldom accurate to the hundredths decimal place, wage rates are rounded to

Table 7. Example of a monthly summary of wages paid for hired labor for land preparation by 10 sample farmers.

Month	Total hired labor (man-hours) (2)	Total value of compensation				Wage per man-hour[a] (M/hour) (7)	3-mo. moving av wage (M/hour) (8)	Seasonal wage (M/hour) (9)
		Wages (M) (3)	Food (M) (4)	Crops (M) (5)	Sum (M) (6)			
January	127	87	23	0	110	0.87	1.11	1.1
February	83	72	15	0	87	1.05	0.79	0.8
March[b]	–	–	–	–	–	(0.46)	0.76	0.8
April	29	22	0	0	22	0.76	0.78	0.8
May	75	62	21	0	83	1.11	1.07	1.1
June	152	168	34	0	202	1.33	1.49	1.5
July	273	371	183	0	554	2.03	1.94	1.9
August	201	330	162	0	492	2.45	2.36	2.4
September	82	87	70	55	212	2.59	2.23	2.2
October	96	74	57	27	158	1.65	2.02	2.0
November	53	72	24	0	96	1.81	1.62	1.6
December	41	46	12	0	58	1.41	1.36	1.4

[a]Computed by dividing column 6 by column 2. [b]In March no labor was hired; however, wage per man-hour was interpolated as one-half the average of February and April wages as shown in parentheses.

the nearest tenth. Seasonal wage rate for each month is shown in column 9. It can be used for all labor employed in each month.

The calculation in Table 7 requires data on all labor transactions of 10 farmers for 1 year. Sometimes this amount of data is not available and there may be neither time nor resources to collect it. Seasonal agricultural wages may be approximated from task wages, which may be obtained from one-time interviews with farmers. The steps in this procedure are:

1. Construct schedule of principal operations (Table 8);
2. Construct schedule of imputed wage rates for principal operations (Table 8);
3. For each month of the year when a principal operation is taking place, enter the imputed wage rate of the dominant operation taking place (Table 9);
4. Interpolate and enter wages for months when no operation is taking place by computing one-half the average of the previous month and next succeeding month when wages are entered (Table 9);
5. Compute 3-month moving average imputed wage rate for each month of the year (Table 9).

When to use the seasonal agricultural wage

Labor requirement timing for a new agricultural technology may differ from present operation requirements. It is advantageous for the farmer if new technology employs labor when family labor resources are not normally fully used. Such technology fits into the farm family's work schedule more easily, and minimizes the need to hire extra labor. If labor must be hired, it may be cheaper when village labor demand is

Table 8. Schedule of principal operations and imputed wages.

Principal operations[a] (1)	Month when performed (2)	Value of a day's compensation (₱)				Hourly wage (₱) (7)
		Cash (3)	Food (4)	Produce (5)	Total (6)	
Rice						
Plowing and harrowing	May–Jun	10	3		13	1.63
Transplanting	Jul–Aug	6	5		11	1.38
Weeding	Sep	4	3		7	0.88
Harvesting	Nov–Dec			18	18	2.25
Upland crops						
Weeding	Jan	6	3		9	1.13
Harvesting	Feb			7	7	0.88

[a]Operations not listed are not commonly used, or do not require much labor. [b]Imputed wage accounts for in-kind and cash compensation.

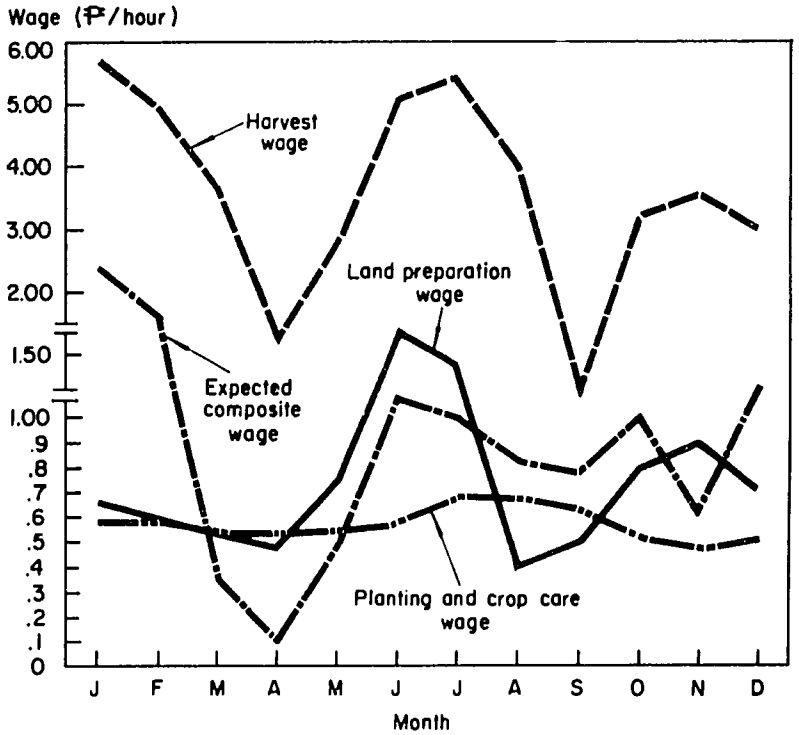
Table 9. Imputed monthly wage rates, interpolated wages, and 3-month moving average wage rates.

Month	Task wages (₱/hour)	3-month moving average (₱/hour)	Seasonal[b] wage (₱/hour)
Jan	1.13	1.42	1.4
Feb	0.88	0.94	0.9
Mar	(0.82)[a]	0.84	0.8
Apr	(0.82)[a]	1.09	1.1
May	1.63	1.36	1.4
Jun	1.63	1.55	1.6
Jul	1.38	1.46	1.5
Aug	1.38	1.21	1.2
Sep	0.88	1.01	1.0
Oct	(0.78)[a]	1.30	1.3
Nov	2.25	1.76	1.8
Dec	2.25	1.88	1.9

[a]For months when there is no significant labor-hiring activity, a wage is interpolated as one-half the average of the wages of the nearest months before and after task wages are observed. [b]3-month moving average wage rounded to the nearest tenths.

low. A new technology that competes for labor with present activities is disadvantageous to the farmer because it does not alleviate — it may even aggravate —stresses in the family work schedule, because it requires hiring labor at peak wage rates.

Advantages or disadvantages of technologies in terms of labor requirement timing may be determined by using seasonal wage rates in the budgeting analysis. When evaluating a new technology using partial budgeting methods, take care to note the periods when labor is needed. Value the labor at appropriate seasonal wages. Advantageous labor requirement timing will increase profitability of a technology.



1. Hourly wages by operation and month, Iloilo, 1976-77.

Seasonal task wage

The seasonal task wage combines features of the seasonal agricultural wage and the task wage. It reflects labor conditions faced by farmers most accurately. It responds to seasonal differences in overall labor requirements and availability and reflects task differences that determine wage rates. Seasonal task wage is a seasonally variable wage specific to major agricultural tasks.

This wage measure is more difficult to estimate than those discussed earlier. Although farmers are aware of, and may articulate, seasonal differences in wages by task, precise distinctions are difficult to determine through oral inquiry. It is better to gather and analyze information from a large number of labor transactions throughout a year as in Table 7. A table like Table 7 should be constructed for a job or task. Only labor hours and associated compensation for a given task should be summarized in each table. The wage calculated in column 9 is the seasonal task wage. Figure 1 shows seasonal task wages computed for a specific site. A composite of the wages shown in Figure 1 is equivalent to the seasonal agricultural wage. Because there is pronounced seasonality in tasks and labor requirement times it is difficult to obtain sufficient off-season observations for all jobs. A reliable wage estimate is difficult to calculate. If observations for a given task in a given season are few, the seasonal agricultural wage (a composite of all seasonal task wages) probably values labor more accurately for the farmer.

In summary, wage rates used for economic analysis may be:

- constant for all operations for all months (standard agricultural wage),
- different by operation but constant for each operation over all months (task wage),
- variable by month but equal for all operations in a month (seasonal agricultural wage), or
- variable according to operation and month (seasonal task wage).

The seasonal task wage rate is the most rigorous and is most likely to reflect the conditions farmers use to choose technology. However, because this rate is so difficult to estimate, the seasonal agricultural wage is recommended for use. It is accurate and easy to estimate.

The methods for estimating and using wage rates suggested above all derive from information on present labor practices. To the limits stated, they are useful and reliable in analyzing prospective marginal cropping systems changes. If major changes do take place in cropping systems, seasonal labor requirements and the nature of tasks are likely to change. As changes occur, task and seasonal wages, and even the general agricultural wage, will probably shift. A new analysis of labor conditions will be needed to accurately assess the profitability of new technology.

PRICES OF PRODUCTS

Prices of farm output usually vary through the year in a regular pattern according to seasonal supply and demand for products. Rice prices increase during the months just before harvest, then decline soon after harvest begins. The prices of major agricultural products, particularly storable products, fluctuate less than minor products and products that are perishable.

The attractiveness of an enterprise to a farmer can easily be affected by seasonal price fluctuations. For example, an experimental practice that results in an early harvest when prices are high might be a key aspect of its profitability, and hence acceptability, to farmers.

Because of seasonal product price fluctuations and their possible influence on adoption of an experimental technology, any regular variability in prices should be incorporated into an economic analysis. This is done most simply by visiting product markets frequently (once a month) to obtain prices from product buyers. As in the case of material inputs, contact should be made with buyers nearest to farmers who are prospective adopters of new technology, and the cost of transportation to the market should be added.

Table 10 gives an example of a monthly tabulation of product prices. Transportation costs may be added in a similar manner as shown for input costs in Table 4.

SENSITIVITY ANALYSIS

Methods of deriving prices for agricultural inputs and outputs for economic analysis of experiments were presented in the preceding sections. Certain prices are derived with some difficulty and perhaps reflect erroneously the situation faced by farmers. It is useful to know how seriously an error may affect the outcome of an analysis.

Table 10. Example table of seasonal prices of agricultural outputs in local markets.

Month	Prices of agricultural products (₦)			
	Chicken (kg)	Eggs (doz)	Rice (kg)	Maize (kg)
Jan	20	9	1.40	1.40
Feb	19	9	1.25	1.50
Mar	18	9	1.10	1.50
Apr	17	10	1.10	1.50
May	17	10	1.20	1.40
Jun	19	9	1.35	1.35
Jul	19	9	1.50	1.35
Aug	19	9	1.60	1.10
Sep	19	8	1.60	1.20
Oct	21	8	1.55	1.25
Nov	22	8	1.50	1.30
Dec	23	9	1.45	1.35

Researchers may examine the sensitivity of conclusions by computing different results for prices above and below the levels originally assumed. A reasonable range of price variation should be chosen. For example, the seasonal extremes of labor wages and product prices are a reasonable range for those items. Varying prices within a standard percentage range, plus or minus 20% for example, has also been suggested (Perrin et al 1976).

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CHAPTER 5

ANALYSIS OF INVESTMENTS AND RETURNS OVER TIME

J. A. WICKS

Chapter 3 introduced the concept of partial budgeting. This is relatively simple when applied to annual crops because all costs and returns are incurred during 1 year and limited data need to be considered. As soon as partial budgeting is extended to perennial crops or capital investments, budgeting becomes more complex. These frequently require inputs and provide output for many years. Therefore, the volume of data to be analyzed is large.

Long-term capital investments can range from the purchase of machinery to construction of large-scale irrigation systems. To illustrate the main principles involved in investment appraisal, two examples are used.

Before examining specific analytical methods which might be used, we need to clarify the relevance of inflation and the discount rate for money. Inflation has reached high levels in most countries and it is almost impossible to predict 1 year in the future, much less 5 or 6 years in advance. Therefore, specification of future costs and returns in actual money is almost impossible, so the only way values can be obtained is by using current prices. These should include any anticipated changes in *real* prices, such as a change in the price of rice relative to other items.

The value of cash is dependent on the time of receipt. A unit of money (₦1) today is usually worth more than ₦1 at year end. Money available today can earn a rate of return — interest — and will yield more money at year end.

When capital markets operate efficiently and borrowing/lending programs are well developed, a specific interest rate paid for money lent or borrowed can be identified. Knowing this interest rate enables us to compute the present amount of money that will yield a specified amount at a future date.

Therefore, a common base for comparing money earned or spent at different time periods can be developed. To do so, all future cash flows are discounted to present values. The concept of present value is central to this analysis.

If r is the interest rate, the present value (Pr) of ₦1 100 earned (or spent) at the end of a year's time is:

$$₦1\,100 \cdot \frac{1}{(1+r)}$$

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If M 100 is earned (or spent) at the end of 2 years time, its present value is

$$M\ 100 \cdot \frac{1}{(1+r)^2}$$

The present value of a sum of money S earned (or spent) in t years' time is

$$S \cdot \frac{1}{(1+r)^t}$$

One of the most important limitations of this type of analysis is that capital markets are not perfectly competitive. Borrowing rates do not generally equal lending rates and many different interest rates can be observed in an economy. Therefore, it is impossible to identify a unique discount rate. However, an appropriate rate must be chosen.

Usually the interest charged on loans for investments in long-term crops or machinery purchased is used. (These commonly range from 10 to 20% per annum.) If an investment is considered risky, a higher figure may be selected (perhaps 30%). The latter rate also applies when borrowing from institutional sources is difficult and interest rates in informal credit markets are high.

Sometimes, for personal decisions, the appropriate discount rate can be obtained by finding the decision maker's *subjective rate of time preference* (SRTP). Ignoring the effects of inflation, most people would prefer to receive M 1 today, compared with M 1 a year in the future. By increasing the amount to be received in 1 year, a point of indifference will be reached. The rate at which the future amount must be discounted to equal M 1 received today is known as the subjective rate of time preference.

It is usually best to analyze a situation with more than one interest rate to ensure that major conclusions are sufficiently robust.

To simplify such calculation, tables have been developed showing the present value of M 1 for any number of years in the future. Some pocket calculators also enable direct computation of present value. To assist you in your calculations, the values for four of the most frequently used discount rates (5, 10, 15, and 20%) are produced as Table 1, Discounted Cash Flows (irregular flows).

SOME ALTERNATIVE APPROACHES TO THE ANALYSIS OF INVESTMENT OVER TIME

There are many ways of analyzing investments that have an extended payback period. In this section we review several of these methods and illustrate their potential drawbacks. A simple example, where a decision maker must select one of four possible projects, is shown in Table 2. These projects are analyzed and ranked by various methods in Table 3.

Ranking by inspection

It is sometimes possible to rank projects by inspecting the returns from an equal investment level. This is possible under two conditions. First, if two alternative

Table 1. Discounted cash flows (irregular flows), 40 years.

Year	5%	10%	15%	20%
1	0.952381	0.909091	0.869565	0.833333
2	0.907029	0.826446	0.756144	0.694444
3	0.863838	0.751315	0.657516	0.578704
4	0.822702	0.683013	0.571753	0.482253
5	0.783526	0.620921	0.497177	0.401878
6	0.746215	0.564474	0.432328	0.334898
7	0.710681	0.513158	0.375937	0.279082
8	0.676839	0.466507	0.326902	0.232568
9	0.644609	0.424098	0.284262	0.193807
10	0.613913	0.385543	0.247185	0.161506
11	0.584679	0.350494	0.214943	0.134588
12	0.556837	0.318631	0.186907	0.112157
13	0.530321	0.289664	0.162528	0.093464
14	0.505068	0.263331	0.141329	0.077887
15	0.481017	0.239392	0.122894	0.064905
16	0.458112	0.217629	0.106865	0.054088
17	0.436297	0.197845	0.092926	0.045073
18	0.415521	0.179859	0.030805	0.037561
19	0.395734	0.163508	0.070265	0.031301
20	0.376890	0.148644	0.061100	0.026084
21	0.358942	0.135131	0.053131	0.021737
22	0.341850	0.122846	0.046201	0.018114
23	0.325571	0.111678	0.040174	0.015095
24	0.310068	0.101526	0.034934	0.012579
25	0.295303	0.092296	0.030378	0.010483
26	0.281241	0.083905	0.026415	0.008735
27	0.267848	0.076278	0.022970	0.007280
28	0.255094	0.069343	0.019974	0.006066
29	0.242946	0.063039	0.017369	0.005055
30	0.231377	0.057309	0.015103	0.004213
31	0.220360	0.052099	0.013133	0.003511
32	0.209866	0.047362	0.011420	0.002925
33	0.199873	0.043057	0.009931	0.002438
34	0.190355	0.039143	0.008635	0.002032
35	0.181290	0.035584	0.007509	0.001693
36	0.172657	0.032349	0.006529	0.001411
37	0.164436	0.029408	0.005678	0.001176
38	0.156605	0.026735	0.004937	0.000980
39	0.149148	0.024304	0.004293	0.000816
40	0.142046	0.022095	0.003733	0.000680

Table 2. Description of four hypothetical investments.

Investment	Initial cost (M)	Net cash proceeds per year (M)	
		Year 1	Year 2
A	1000	1000	
B	1000	1000	100
C	1000	376	776
D	1000	576	576

Table 3. Some alternative analyses of the four hypothetical investments.

Analysis	Investment			
	A	B	C	D
Inspection ranking	B preferred to A, D preferred to C No further comparisons possible			
Payback period (yrs)	1	1	1.8	1.7
ranking	1	1	4	3
Net present value 10% discount (M)	-90.9	-7.4	-16.9	-0.3
ranking	4	2	3	1
Rate of return on total capital – 10% discount rate (M)	100	57.2	56.6	57.6
ranking	1	3	4	2
Internal rate of return (%)	0	9	9	10
ranking	4	2	2	1

investments have equal cash flows through to the final year of the first, but the second investment continues to show returns for more years, the latter is more desirable. Second, consider the case of two investments with the same initial outlay and the same earning life. If at the end of every year net earnings from the first investment are at least as high as net earnings from the second investment, but are higher in at least 1 year, then the first investment is preferred to the second. In Table 2 we can determine, as shown in Table 3, that B is preferred to A and D preferred to C. No further ordering of preferences is possible.

Payback period

One of the simplest, and most frequently used, methods of investment appraisal is to determine the payback period, that is, the number of years over which the original investment is repaid. In Table 3 investments A and B have a 1-year payback period, D 1.8 years, and C 1.7 years. All four can be ranked, which could not be done by inspection. Note, however, that the rankings of C and D are switched and that A and B are equally preferred. Ranking by payback period takes no account of income derived after the initial investment has been repaid. For investments A and B this is a serious deficiency because only one provides a payback over the investment. Also, no account is taken of time preference.

Net present value

Net present value (NPV) is a technique for discounting a stream of future incomes and expenses to a fixed point in time, usually to present time. The rate discount is assessed as the appropriate rate of time preference for money. For a simple illustration, consider proposals A and B in Table 2. Initial costs are assumed to be incurred in year 0, so present value of the investment is M 1,000. Assuming a discount rate of 10%, refer to Table 1 and look down the column marked 10% to the row for year 1. This tells you that M 1 in year 1 discounted by 10% will be equivalent to M 0.909091 in year 0. Hence M 1,000 received in year 1 will have a present value of M 1,000 × 0.909091 or M 909.09. NPV, the current value of costs, in investment A is M 909.09

− 1000 = −₥ 90.91, rounded to −₥ 90.9 in Table 3. In investment B, there is an additional return of ₥ 100 in year 2. This time look down the 10% discount column until you find the row marked year 2. This shows present value of ₥ 1 in year 2 to be ₥ 0.826446. The present value of ₥ 100 is ₥ 82.64.

Therefore, NPV of investment B = −₥ 1000 +909.91 + 82.64 = −₥ 7.45, rounded to −₥ 7.4. Now, try estimating net present values for investments C and D.

Section 5 of Table 3 shows investment D to be best, followed by B, C, and A.

Rate of return on total capital

Rate of return on total capital (RR) is measured as an annual percentage rate of return, using the following formula:

$$RR = (A/PV) \times 100$$

A is the annuity of the stream of cash benefits expected from the investment. PV is the present value of all capital expenditures required to obtain the benefits. An annuity is a flow of equal returns over a number of years. If the expected flow is unequal, the present value of returns must be estimated, then converted to an annuity.

For investment B in Table 2, returns to the investment are ₥ 1,000 in year 1 and ₥ 100 in year 2 which, given a 10% discount rate, has a present value of ₥ 992.55. To determine the value of a 2-year annuity, which at a discount rate of 10% will have a net present value of ₥ 992.55, use Table 4. Look down the column marked 10% to the row for year 2. The value shown at that point, 1.7355, is the present value of a ₥ 1 2-year annuity discounted 10%. The value of a 2-year annuity that satisfies the requirements is ₥ (992.55/1.7355), or ₥ 571.91, using the formula:

$$RR = (571.91/1000) \times 100 = 57.2\%.$$

Repeat the calculations for investments C and D to ensure that you understand the use of the tables. Note that this method ranks the projects differently.

Computing RR requires one more step than calculating NPV. RR has the same conceptual problems as NPV — the need to differentiate between fixed costs and variable costs so cost and return components can be correctly assessed. For many situations this is not easy.

Internal rate of return

The internal rate of return (IRR) (sometimes called discounted yield or discounted cash flow rate of interest) is the discount rate at which the NPV of an investment is 0. Computations used to estimate internal rate of return are the same as for the NPV, but they must be repeated until a discount rate that produces a NPV of zero is located. A programmable calculator or computer helps to calculate IRR fairly rapidly. Computation with a nonprogrammable machine is much more complex and requires detailed discounted cash flow tables. The main advantage of IRR is it does not require determination of an appropriate discount rate. Despite this advantage, and although the results of the calculation are shown in Table 3, we suggest it should not be used.

Table 4. Discounted cash flows (regular flows), 40 years.

Year	5%	10%	15%	20%
1	0.9524	0.9091	0.8696	0.8333
2	1.8594	1.7355	1.6257	1.5278
3	2.7232	2.4869	2.2832	2.1065
4	3.5460	3.1699	2.8550	2.5887
5	4.3295	3.7908	3.3522	2.9906
6	5.0757	4.3553	3.7845	3.3255
7	5.7864	4.8684	4.1604	3.6046
8	6.4632	5.3349	4.4873	3.8372
9	7.1078	5.7590	4.7716	4.0310
10	7.7217	6.1446	5.0188	4.1925
11	8.3064	6.4951	5.2337	4.3271
12	8.8633	6.8137	5.4206	4.4392
13	9.3936	7.1034	5.5831	4.5327
14	9.8986	7.3667	5.7245	4.6106
15	10.3797	7.6061	5.8474	4.6755
16	10.8378	7.8237	5.9542	4.7296
17	11.2741	8.0216	6.0472	4.7746
18	11.6896	8.2014	6.1280	4.8122
19	12.0853	8.3649	6.1982	4.8435
20	12.4622	8.5136	6.2593	4.8696
21	12.8212	8.6487	6.3125	4.8913
22	13.1630	8.7715	6.3587	4.9094
23	13.4886	8.8832	6.3988	4.9245
24	13.7986	8.9847	6.4338	4.9371
25	14.0939	9.0770	6.4641	4.9476
26	14.3752	9.1609	6.4906	4.9563
27	14.6430	9.2372	6.5135	4.9636
28	14.8981	9.3066	6.5335	4.9697
29	15.1411	9.3696	6.5509	4.9747
30	15.3725	9.4269	6.5660	4.9789
31	15.5928	9.4790	6.5791	4.9824
32	15.8027	9.5264	6.5905	4.9854
33	16.0025	9.5694	6.6005	4.9878
34	16.1929	9.6086	6.6091	4.9898
35	16.3742	9.6442	6.6166	4.9915
36	16.5469	9.6765	6.6231	4.9929
37	16.7113	9.7059	6.6288	4.9941
38	16.8679	9.7327	6.6338	4.9951
39	17.0170	9.7570	6.6380	4.9959
40	17.1591	9.7791	6.6418	4.9966

We, and many other people, favor using NPV to evaluate alternative investments. However, NPV is not required when inspection is adequate to evaluate the alternatives.

AN ILLUSTRATIVE PROBLEM OF INVESTING IN A TWO-WHEEL TRACTOR

The easiest way to explain many problems of investment appraisal is to work through a substantial example. The following example illustrates many problems involved in evaluating machinery investments.

A farmer, who grows 5 ha of rice in wet season and 5 ha in dry season, must replace his carabaos. He is willing to consider two alternative sources of power. He can purchase a 10-hp, 2-wheel tractor, including implements, for ₱ 11,700; or hire a custom operator for ₱ 250/ha. If he buys the tractor he can do up to 15 ha of custom work in wet season and 15 ha in dry season to offset costs. Expected life of the tractor is 8 years and expected salvage value (value at which it can be sold) is 10% of the initial cost. He has funds to purchase the tractor outright. Should the farmer purchase or hire? (Refer to Table 5.)

We do not have sufficient information to answer the question. First we need to determine some engineering standards. Then we will discuss the investment with the farmer to assess how much these values should be modified, and what other variables should be included.

Costs

Checking machine specifications shows repair/maintenance costs should be 45-65% of initial costs over the life of the investment. The higher value is 8%/annum. Because the farmer is inexperienced with machines we suggest a higher repair cost for years 1 and 2, 10% and 9% respectively, and higher costs in years 6 and 7 because the machine is aging. We suggest that only essential repairs be made the final year; therefore, apply one half the normal rate. We agree to review these assumptions later. Information also shows that an insurance cost of 2% of the purchase price must be paid at the beginning of each year.

The tractor will need 10 hours to cultivate 1 ha. It will use ₱ 122.67 of fuel, at ₱ 4.60/liter, and ₱ 2.20 of oil at ₱ 9.50/liter. During the first two seasons cultivation will take longer because the farmer is inexperienced. Allow 12 h/ha and fuel costs at ₱ 147.70/ha.

Using these data the costs of operating the tractor, over its 8-year life, are calculated in Table 5, Section A. Note that half of the annual variable costs and the whole annual insurance are included in year 0. These costs are incurred at the beginning of the year and should not be discounted. The costs at year 8 also are only for half a year.

Returns

Now, estimate expected returns from the investment. These are salvage value at the end of the machine's useful life and the increased production from more timely land preparation. The farmer believes he is suffering yield loss because he cannot make maximum use of available water. By the second year of his investment he believes he will have enough experience to produce an additional disposable 100 kg/ha per crop, followed by 200 kg/ha the next year and peaking at 400 kg/ha in year 4. If he does contract work these benefits will be lost at a rate of 50% for 5 ha of contract work per season and 100% for 10 ha. Additional production is priced at ₱ 1/kg (the price received from a private dealer most recently).

If the alternative option were more complex a separate table of costs and returns would be developed. However, for the current problem the alternative is so simple that it can be treated as partial budgeting. Costs avoided by not having to custom hire will be used as the return to tractor purchase. Values of additional yield, salvage

Table 5. Analysis of tractor investment over 8 years.

Item	0	1	2	3	4	5	6	7	8	
Costs										
Purchase of machine (10-hp tiller)	11,700									
Fixed costs										
Repair/maintenance		1170	1053	936	936	936	1170	1170	468	
Insurance (2%)	234	234	234	234	234	234	234	234		
Variable costs										
Gasoline (₱4.60/1)	736	1472	1343	1213	1213	1213	1213	1213	606	
Lubrication oil (₱9.50/1)	11	22	22	22	22	22	22	22	11	
A Total Costs	12,681	2898	2652	2405	2405	2405	2639	2639	1085	
Returns with no custom work										
Increase production at ₱1/kg			1000	2000	4000	4000	4000	4000	4000	
Salvage value of year 8 (10%)									1170	
Cost avoided										
Hire cost of custom operator (₱250/ha)	1250	2500	2500	2500	2500	2500	2500	2500	1250	
B Total Returns	1250	2500	3500	4500	6500	6500	6500	6500	6420	ΣNPV
C Net Returns (B–A)	−11431	−398	848	2095	4095	4095	3861	3861	5335	12361
discounted at 10%/year	−11431	−361.8	700.8	1574.0	2796.9	2542.7	2179.4	1981.5	2488.8	2471.1
15%/year	−11431	−346.1	641.2	1377.5	2341.3	2035.9	1669.2	1451.5	1744.0	516.6
20%/year	−11431	−331.6	588.9	1212.4	1974.8	1645.7	1293.0	1077.5	1240.8	−2729.5
Returns with 10 ha/year contract work										
Increase production at ₱1/kg			500	1000	2000	2000	2000	2000	2000	
Salvage value at year 8 (10%)									1170	
Net income from contract work	294	718	848	848	848	848	848	848	424	
Cost avoided										
Hire cost of custom operator (₱250/ha)	1250	2500	2500	2500	2500	2500	2500	2500	1250	

Continued on opposite page

Table continued

Item	0	1	2	3	4	5	6	7	8	
Savings from experience gained		129	130							
D Total Returns	1544	3347	3978	4348	5348	5348	5348	5348	4844	*ΣNPV*
E Net Returns (D–A)	–11137	449	1326	1943	2943	2943	2709	2709	3759	7220.0
discounted at 10%/year	–11137	408.2	1095.9	1459.8	2010.1	1827.4	1529.2	1390.1	1753.6	337.3
15%/year	–11137	390.4	1002.6	1277.6	1682.7	1463.2	1171.2	1018.4	1228.8	1902.0
20%/year	–11137	374.2	920.1	1124.4	1419.3	1182.7	907.2	756.0	874.2	–3578.2
Return with 20 ha/year contract work										
Increased production			0	0	0	0	0	0	0	
Salvage value at yr 8 (10%)									1170	
Net income from contract work	588	1436	1696	1696	1696	1696	1696	1696	848	
Cost avoided										
Hire cost of custom operator (₦250/ha)	1250	2500	2500	2500	2500	2500	2500	2500	1250	
Savings from experience gained		129	130							
F Total Returns	1838	4065	4326	4196	4196	4196	4196	4196	3263	*ΣNPV*
G Net Returns (F–A)	–10843	1167	1674	1791	1791	1791	1557	1557	2183	2668
discounted at 10%/year	–10843	1060.9	1383.4	1345.6	1223.3	1112.1	878.9	799.0	1018.4	–2021.4
15%/year	–10843	1014.8	[illegible]	1177.6	1024.0	890.4	673.1	585.3	713.6	–3698.4
20%/year	–10843	972.5	[illegible]	1036.5	863.7	719.7	521.4	434.5	507.7	–4624.5
H Net income from additional 10 ha/year (i.e. 30 ha/year)	294	718	848	848	848	848	848	848	424	*ΣNPV*
I Net Returns (G+H)	–10549	1885	2522	2639	2639	2639	2405	2405	2607	9192
discounted at 10%/year	–10549	1713.7	2084.3	1982.7	1802.5	1638.6	1357.6	1234.1	1216.2	2480.7
15%/year	–10549	1639.2	1907.0	1735.2	1508.9	1312.1	1039.7	904.1	852.2	349.2
20%/year	–10549	1570.8	1751.4	1527.2	1272.7	1060.6	805.4	671.2	606.3	–1283.4

value, and costs avoided are listed in section B in Table 5 and summed to give total returns. The hiring cost avoided for cultivation in the first season of year 1 is credited to year 0 because it must be paid immediately. Additional income from rice grown the first season of year 2 is credited to year 2 because harvest cannot be sold until the crop has been grown.

We can now compute net returns (B-A) for each year as shown in section C. Determine NPV of this investment. NPV are in the final column, marked ΣNPV. They are computed as follows. Relevant discount rates are selected (based on earlier discussion we have chosen 10, 15, and 20%). The NPV of income received in year 0 is that income, and can be written in each row. Locate net returns for year 1, namely −₥ 398, and discount by relevant factors. For a 10% discount rate look down the column marked 10%, in Table 1, to the row marked year 1. This shows the present value of ₥ 1 to be ₥ 0.909091. Multiplying −₥ 398 by 0.909091 generates a present value of −₥ 361.8. Repeat the procedure using the columns marked 15 and 20%. Find the present value of ₥ 1 received in year 2 at a 10% discount rate. The value is ₥ 0.826446 and multiplying by 848 yields a present value of ₥ 700.8. Repeat the process for all years and all discount rates. Add the product value across the rows to get the various total NPVs. The undiscounted values have been added in this calculation to yield NPV at 0% discount.

At a discount rate of 10%/year, buying the tractor is preferable to hiring a custom operator. At a 15% discount rate the farmer should hire a custom operator and use his money for other purposes.

Now examine the possibility of the farmer undertaking 10 ha/year (5 ha in wet season and 5 ha in dry season) of custom work. Details of the estimated returns are in section D of Table 5. Increase in returns from additional production is reduced to 50%, according to earlier estimates. Tractor salvage value and savings from not having to hire a custom operator, as previously estimated, are included.

We also recognize two additional returns: income from custom work and savings in cultivation costs shown in section A because the farmer gets additional operating experience in year 1. These are estimated to be ₥ 129 in year 1 and ₥ 130 in year 2.

The farmer estimates he will employ a casual worker at ₥ 30.00/ha which they jointly cultivate. Expected net returns for the first year of operation are:

Returns from 10 ha cultivation (₥ 250/ha)		₥ 2500
Cost of fuel (₥ 4.60/liter)	₥ 1472	
Cost of lubrication (₥ 9.50/liter)	22	
Cost of additional repairs	117	
Cost of casual workers (₥ 30.00/ha)	300	1911
Net returns ₥ 589	1911	₥ 589

Additional income is distributed evenly between years 0 and 1 to allow for 50% being received at the beginning of year 1 and 50% being received in the middle. The calculations are repeated for each year.

Total the returns for the option with 10 ha/year. In section E net returns are computed as D-A. By comparing net returns in E with net returns in C we see that the custom operation option has increased returns in earlier years at the cost of

returns from increased production in later years. Now, determine NPV of incomes at 10, 15, and 20% discount as described for section C. Check to see if you obtained the correct answer.

Continue the analysis to compute corresponding NPVs for custom hire at 20 and 30 ha/year. The NPVs of these options are summarized in Table 6. It is clear that the farmer must do custom work on 30 ha/year before returns will equal those obtained by improving his own production.

INVESTING IN A COCONUT PLANTATION

This example illustrates a much longer-term investment. For simplicity assume there are no alternative land uses. Before describing the problem it is worth repeating that farmers often have a lower subjective rate of time preference for investments involving perennial crops.

A farmer requires more information about the economics of long-term investment in coconuts. The field he wants to develop is 2.17 ha. When planted it will contain 300 coconut trees. Operations and costs involved in production are:

1. Field preparation for coconut seedlings requires one mound for each seedling at ₥ 2/mound.
2. Digging shallow canals between coconut rows costs ₥ 1,800/ha.
3. When coconuts are 3 years old building up the mounds and deepening the canals will cost ₥ 1,200/ha.
4. Maintaining canals every second year costs ₥ 1,200/ha.
5. Seed nuts will be planted by the farm family but will cost ₥ 0.50 each to purchase.
6. Harvesting by hired labor will cost ₥ 0.08/nut.

Coconuts are expected to begin bearing in year 8. We will assume a yield of:

10 nuts/tree in year 8
20 nuts/tree in year 9
40 nuts/tree in year 10
60 nuts/tree in year 11
74 nuts/tree in year 12.

Table 6. Summary of results of tractor investment analysis.

Investment proposal	Plan no.	Net present value at discount rate of			
		0%	10%	15%	20%
C Own farm, no custom work	1	12,361.0	2,471.1	-516.5	-2,729.5
E Own farm plus 10 ha custom work per year	2	7,220.0	337.3	-1,902.0	-3,578.2
G Own farm plus 20 ha custom work per year	3	2,668.0	-2,021.4	-3,698.4	-4,624.5
I Own farm plus 30 ha custom work per year	4	9,192.0	2,480.7	349.2	1,283.4

Yields after year 12 will be 74 nuts/tree per year. Nuts are expected to sell for ₱ 0.45/nut.

During the first 3 years of the coconut crop the farmer will intercrop 0.57 ha of rice per ha of coconut. Family labor will be used. Net returns will be ₱ 1,070, 1,400, and 1,070/ha respectively. After the third year the coconut trees will be too large for rice to be grown.

Costs and returns for the first 14 years are shown in Table 7. The ₱ 8,214 annual return and ₱ 2,604 biennial cost will continue for the lifetime of the investment. This flow pattern begins in year 12 and continues until year 51. Net returns for each year could be calculated, discounted to year 0, and summed to get NPV. However, this approach is tedious. We know that it is simpler to discount a set of equal cash flows than a set of unequal flows. Therefore, let us try to adjust figures from year 12 forward. The following possibilities exist.

1. Treat costs as one set of cash flows, to be discounted biennially at twice the annual discount rate, and returns as a second set of cash flows to be discounted annually. This would involve a slight approximation error and would require two sets of discounting, although the annuities would be simpler.
2. Because the investment runs to an odd year number, and maintenance cost is incurred in even years, cost could be spread equally over the year in which it occurs and the next year. The ₱ 2,604 cost in year 12 would be ₱ 1,302 in year 12 and ₱ 1,302 in year 13. If costs are likely to be incurred in pattern the approach is acceptable, otherwise errors will be introduced.
3. The most accurate approach is to determine the amount of equal costs in years 12 and 13 that will, when discounted, equal the actual cost in year 12. The same relationship will hold for costs in year 14, year 16, etc. Therefore, a constant flow of costs, total returns, and net returns can be produced. Present value of these may be determined as an annuity.

To follow the methodology refer to Table 8, which lists the revised set of costs and returns. Costs to year 11 are in the first row. The second to fourth rows show annuitized values, at three discount rates, of biennial costs for years 12-51. These are computed as follows: A ₱ 1/year annuity for years 0 and 1 has a present value of $(1 \times 1 + 1 \times 0.952381)$ if discounted at 5%. The ₱ 2,604 return has an annual value of ₱ 2,604/1.952381 or ₱ 1,333.75. This is the annual annuitized cost for years 12-51. Similar calculations are required for 10 and 15% discount rates.

The fifth row shows total returns for all years. Row 6 shows net returns for the first 11 years. Annuitized net returns for three discount rates are shown in successive rows. By this stage there is a single annuity for each discount rate, net present value of which must now be estimated.

The easiest approach is to estimate the 40-year annuity in year 11, which is equivalent to estimating present value of an annuity received in years 1-40. Turn to Table 4 and look down 5% column to year 40. Present value of ₱ 1/year for 40 years is ₱ 17.1591. Present value of ₱ 6,880.25/year for 40 years is ₱ 6,880.25 × 17.1591 or ₱ 118,058.90. This value is in parentheses under year 11. Now, discount the flow of net returns to obtain net present values. For year 11 add net return for year 11 to 11-year annuity value and discount the total to year 0. Annual values are summed to obtain NPV of the total investment. This analysis shows coconuts are a profitable

Table 7. Costs and returns for coconut investment problem, 14 years.
Costs/Returns

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Costs															
Prepare field for seedlings (300 mounds at ₱2/mound)	600														
Seed nuts (at ₱0.50/nuts)	150														
Initial digging of shallow canals (₱800/ha)		3906													
Deepen canals and build up mounds after coconuts are 3 years old and every 2 years (₱1200/ha)					2604		2604		2604		2604		2604		2604
Total costs	750	3906			2604		2604		2604		2604		2604		2604
Returns															
Rice (2.17 ha., 57% cropped)		1323	1732	1323											
Coconuts (₱0.45/nut less ₱0.08 for harvesting)									1110	2220	4440	6660	8214	8214	8214
Total returns		1323	1732	1323					1110	2220	4440	6660	8214	8214	8214

Table 8. Restructured flow of annual costs and returns.

Item	0	1	2	3	4	5	6	7	8	9	10	11	12 —	51
Costs to year 11	750	3906	0	0	2604	0	2604	0	2604	0	2604	0		
Annuitized costs from year 12 to year 51 at 5%													1334 —	1334
10%													1364 —	1364
15%													1393 —	1393
Total returns	0	1323	1732	1323	0	0	0	0	1110	2220	4440	6660	8214 —	8214
Net returns to year 11	−750	−2583	1732	1323	−2604	0	−2604	0	−1494	2220	1836	6660		
Annuitized net returns from year 12 to year 51 and value at year 11[a] at 5%												(118059)	6880 —	6880
10%												(64931)	6850 —	6850
15%												(45307)	6821 —	6821
													ΣNPV	
NPV at 5% discount	−750	−2450	1571	1143	−2142	0	−1943	0	−1011	1431	1127	72921	69886	
10% discount	−750	−2348	1431	994	−1779	0	−1470	0	− 697	942	708	2509	22123	
and 15% discount rates	−750	−2246	1310	870	−1489	0	−1126	0	− 488	631	454	11169	8335	

[a]The values at year 11 for each of the annuities are shown in parentheses.

long-term investment, although returns are not realized for several years.

Let us include one refinement. The investment has been appraised only to year 51. A coconut plantation will be productive well beyond year 51, although the exact number of years may not be known. We can account for this by summing returns to an infinite (∞) number of years. This will provide an upper limit to the present value of the investment.

First, an example of ₥ 10 invested at 10% interest. Annual earnings will be ₥ 1 for as long as the ₥ 10 is intact. Therefore, current value of an annuity to infinity at 10% discount rate is:

$$₥\ 1/0.10 = ₥\ 10$$

Similarly, the year 11 value of the ₥ 6,850 annuity, if summed to infinity, is:

$$₥\ 6{,}850/0.10 = ₥\ 68{,}500$$

which is ₥ 3,568.85 more than the value shown in Table 8. These values can be discounted to yield NPV. However, when investments do not produce income immediately farmers may experience cash flow, or liquidity, problems. They may have insufficient income to meet essential expenses and be forced to borrow, often at excessively high interest rates. For projects that show negative net returns for more than 2 or 3 years, it is wise to also produce a cash flow. If the farmer needs to borrow money he may be more sympathetically treated if he can provide such information well in advance.

Cash flow for the coconut plantation is shown in Table 9. To construct the table, costs and returns from the coconuts were added to additional income values from a second field just opened to rice production, and to a household expenditure amount. Because inflation is likely to be high we inflated all costs and returns. Annual

Table 9. Cash flow for coconut plantation.

Year	Net income from other activities A	Household expenditures B	Total costs for coconuts C	Returns from coconuts D	Cumulative cash flow (each savings) E
0	2,480	1,000	750		730
1	3,480	1,200	4,300	1,450	160
2	2,970	1,400	0	2,100	3,790
3	3,250	1,730	0	1,760	7,070
4	3,550	2,070	3,810	0	4,740
5	2,480	2,480	0	0	4,740
6	1,160	2,980	4,610	0	-1,690
7	0	3,580	0	0	-5,270
8		4,300	5,580	2,380	-12,770
9		5,160	0	5,230	-12,700
10		6,190	6,750	11,520	-14,120
11		7,430	0	19,000	-2,550
12		8,910	8,170	25,780	6,150
13		10,700	0	28,360	23,810
14		12,840	9,880	31,190	32,280
15		15,400	0	34,310	51,190
16		18,480	11,970	37,740	58,480

Table 10. Compound interest, 40 years.

Year	5%	10%	15%	20%
1	1.0500	1.1000	1.1500	1.2000
2	1.1025	1.2100	1.3225	1.4400
3	1.1576	1.3310	1.5209	1.7280
4	1.2155	1.4641	1.7490	2.0736
5	1.2763	1.6105	2.0114	2.4883
6	1.3401	1.7716	2.3131	2.9860
7	1.4071	1.9487	2.6600	3.5832
8	1.4775	2.1436	3.0590	4.2998
9	1.5513	2.3579	3.5179	5.1598
10	1.6289	2.5937	4.0456	6.1917
11	1.7103	2.8531	4.6524	7.4301
12	1.7959	3.1384	5.3502	8.9161
13	1.8856	3.4523	6.1528	10.699
14	1.9799	3.7975	7.0757	13.839
15	2.0789	4.1772	8.1371	15.407
16	2.1829	4.5950	9.3576	18.488
17	2.2920	5.0545	10.761	22.186
18	2.4066	5.5599	12.375	26.623
19	2.5269	6.1159	14.232	31.948
20	2.6533	6.7275	16.367	38.338
21	2.7860	7.4002	18.822	46.005
22	2.9253	8.1403	21.645	55.206
23	3.0715	8.9543	24.891	66.247
24	3.2251	9.8497	28.625	79.497
25	3.3864	10.835	32.919	95.396
26	3.5557	11.918	37.857	114.48
27	3.7335	13.110	43.535	137.37
28	3.9201	14.421	50.066	164.84
29	4.1161	15.863	57.575	197.81
30	4.3219	17.449	66.212	237.38
31	4.5380	19.194	76.144	284.85
32	4.7649	21.114	87.565	341.82
33	5.0032	23.225	100.70	410.19
34	5.2533	25.548	115.80	492.22
35	5.5160	28.102	133.18	590.67
36	5.7918	30.913	153.15	708.80
37	6.0814	34.004	176.12	850.56
38	6.3855	37.404	202.54	1020.7
39	6.7048	41.145	232.92	1224.8
40	7.0400	45.259	267.86	1469.8

inflation rates selected were 20% for inputs and 10% for outputs. Inflated values can be computed using Table 10 which shows the inflated value of 1 unit up to 40 years into the future. Cash available at the beginning of the plan was ignored but results can easily be adjusted. Cumulative cash flows (E) at the end of period t are:

$$E_t = E_{t-1} + A + D - B - C$$

This is not precise, but merely a rough method to highlight likely problems. In this example cumulative cash flow declines as rice production from the new field declines. This is a critical phase, lasting up to year 12. The farmer should know he

may be short of money during this period, and will need to look for other income, particularly if additional costs arise. Once coconut production begins the surplus will grow rapidly. However, remember this is in future ₦, so the real value of money will be less. Compare it to cost of living which is constant in real terms.

You should now be prepared to evaluate investments over time. However, when you go to the field much of the data required will not be obtained from the specific farmer. Alternative data sources are:

1. engineering and other standards for inputs, and
2. survey results from similar areas.

Adjust the data if you feel the farmer is much worse or better than average and investigate the problem fully and be prepared to do additional sensitivity analyses.

ADDITIONAL PROBLEMS

For each of the following cash flows, compute the net present value at discount rates of 10 and 15%.

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
A	1000	100	100	100	100	1100
B	1000	264	264	264	264	264
C	1000					1611

Which investment would you recommend?

The ABC company is considering the purchase of a piece of equipment costing ₦7,500 and having expected returns at the end of each year, at:

Year	*Return*
1	₦5,000
2	3,000
3	2,000
4	1,000
5	500

From your knowledge of the company you anticipate a reasonable discount rate to be 15 or 20%. Would you recommend they make the investment?

Which of the three following mutually exclusive investments should be chosen, given a discount rate of 10%/year?

Investment	Year 0	Year 1	Year 2	Year 3
A	−1,000	505	505	505
B	−10,000	2,000	2,000	12,000
C	−11,000	5,304	5,304	5,304

A farmer is considering two alternative investments with the following returns:

Year	Investment	
	A	B
0	−1,000	−2,000
1	0	−2,000
2	−1,000	0
3	0	0
4	0	100
5	0	500
6	0	750
7	100	750
8	300	750
9	500	750
10	500	750
11	500	750
12	500	750
⋮	⋮	⋮
50	500	750

Using discount rates of 5 and 10%, which, if any, would you recommend?

CHAPTER 6

FACTOR SHARE IN AGRICULTURAL PRODUCTION: DEFINITION, ESTIMATION, AND APPLICATION

M. KIKUCHI

Factor share is a fundamental concept in economics that plays a critical role in research concerning production structure, costs and returns analysis, income distribution, and technology choice. Because the factor share concept often is a starting point in these types of economic analysis, it is important that researchers who study these issues fully understand the concept.

This chapter defines factor shares, gives procedures for using farm survey data to estimate factor shares in agriculture, and shows how estimates of factor shares are used in economic analyses.

FACTOR SHARES AND FUNCTIONAL DISTRIBUTION OF INCOME

Factor shares are the ratio of costs of factor inputs used in a production process to the total value of output, i.e. total revenue.

Consider a production process in which a firm uses four inputs, current input (C), capital (K), labor (L), and land (A), to produce a single output, paddy (Q). All variables are defined in terms of flow. If the firm purchases inputs and sells output at constant unit prices (p, i, w, r, and P, respectively), factor shares of the firm's input are:

$$\begin{aligned} \text{Factor share of current input} &= \frac{pC}{PQ}, \\ \text{Factor share of capital} &= \frac{iK}{PQ}, \\ \text{Factor share of labor} &= \frac{wL}{PQ}, \\ \text{Factor share of land} &= \frac{rA}{PQ}. \end{aligned} \tag{1}$$

where C, K, L, and A are the physical quantities of each input factor used in production, and Q is the physical quantity of output produced. The numerators are the firm's factor costs and the common denominator is total revenue (paddy price × output quantity). Factor costs are payments for inputs purchased and are also called *factor payments.*

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Functional distribution of income[1]

A firm's production process is generally expressed by a production function that gives the quantity of output as a function of the quantities of its inputs:

$$Q = F(C, K, L, A). \tag{2}$$

The firm seeks to maximize profit in the production process. Profit (π) is the difference between total revenue and total costs:

$$\pi = PQ - (pC + iK + wL + rA).$$

Substituting equation 2 for Q,

$$\pi = P \cdot F(C, K, L, A) - (pC + iK + wL + rA).$$

Profit is a function of inputs and is maximized with respect to these variables.

Standard economic theory states that profit is maximized when each input is utilized to the point where its value of marginal productivity equals its market price. Mathematically, it is expressed as:

$$\begin{gathered} P \cdot F_1 = p,\ P \cdot F_2 = i, \\ P \cdot F_3 = w, \text{ and } P \cdot F_4 = r, \end{gathered} \tag{3}$$

where F_j ($j = 1, \ldots, 4$) is the partial derivative of the production function with respect to the j-th input, i.e. the marginal productivity (MP) of j-th input. It is assumed that the production function of equation 2 satisfies all conventional requirements for a production function.

The value of MP of an input ($P \cdot F_j$) is the rate at which the firm's revenue would increase when one unit of the j-th input is added to the production process, if other input levels are held constant. The conditions of profit maximization, equation 3, show the firm can increase profit as long as an addition to the total revenue earned from using an additional input unit exceeds its input cost.

Substituting equation 3 for equation 1, the factor share of labor is written as:

$$\text{Factor share of labor} = \frac{wL}{PQ} = \frac{F_3 \cdot L}{Q}, \tag{4}$$

or rewriting F_3,

$$\frac{F_3 \cdot L}{Q} = \frac{\alpha Q}{\alpha L} \cdot \frac{L}{Q} = \frac{MP}{AP},$$

where AP is the average productivity of labor. If profit maximization is satisfied, the factor share of an input equals its production elasticity — the proportionate rate of change of output Q with respect to input. The factor share, which is equivalent to the production elasticity of an input, can be expressed as a ratio of the marginal and average productivities of the input at profit maximizing level.

[1] Readers who are interested only in the technical procedure of estimating factor shares may skip this section. Readers who want to grasp the issue to its full extent should consult the chapter on the "The Theory of the Firm" in any microeconomics textbook.

If the product market is perfectly competitive in the sense that free entry and exit of competing firms are assured, the maximum long-run profit of the representative firm in the industry (in this case, rice farming) would be expected to be zero. If maximum profit is positive, additional firms will enter the industry and lower the profit. If it is negative, some firms will leave the industry and profits will rise. Therefore, long-run profit of the representative firm (π^*) is:

$$\pi^* = PQ - (pC + iK + wL + rA) = 0$$

Substituting equation 3 and rearranging the terms, we obtain:

$$Q = F_1 \cdot C + F_2 \cdot K + F_3 \cdot L + F_4 \cdot A. \qquad (5)$$

Total output would be exactly exhausted if the firm paid the supplier of each input its marginal product.

To an input owner a factor payment, for instance $F_4 \cdot A$, is their production income earned in return to their supply of the production factor. It is through factor payments that income earned in a production process is distributed among those who contributed resources. In other words, distribution of income from a production process among production factors is determined first by production function and market prices after profit maximization, then the income is distributed among resource owners. Personal distribution of income comes after the income is generated.

Income distribution determined in this way is called functional distribution of income. It is this link in basic economic theory that makes factor share an important concept in analyzing economic issues such as resource allocation efficiency and income distribution. The marginal-productivity theory of distribution states that the functional distribution of income is determined according to marginal contributions of factor inputs to the output: each input is paid its marginal product and total product is exactly exhausted at the equilibrium.

Dividing by Q through equation 5, the following relationship is obtained:

$$1 = \frac{F_1 \cdot C}{Q} + \frac{F_2 \cdot K}{Q} + \frac{F_3 \cdot L}{Q} + \frac{F_4 \cdot A}{Q}$$

or,

$$1 = \frac{pC}{PQ} + \frac{iK}{PQ} + \frac{wL}{PQ} + \frac{rA}{PQ}$$

The summation of factor shares over all inputs becomes unity at the equilibrium.

ESTIMATING FACTOR SHARES

Functional distribution and mixed income

Let us consider a farm where a farmer hires land, labor, and capital to produce an agricultural commodity. Assume further that these resources are owned by landowners, laborers, and capital investors (e.g. banks, lenders). Functional distribution of income equals personal distribution of income. In this case, factor income of land

is land rent paid to landowners, factor income of labor is wages paid to laborers, and factor income of capital is interest and rental paid to capital owners. Therefore, factor costs for a firm are equal to income earned by the factors. Factor income also is personal income for factor owners.

This kind of farm is unusual if it exists at all. The typical production unit is a family farm which contributes several production resources and also hires some outside resources. A family farm might own farmland, labor, and some capital equipment, perhaps a tractor. The farmer might also hire a capital item like a threshing machine, or employ other farmers or landless workers as laborers during busy seasons.

In this case functional distribution of income does not equal personal distribution of income. Personal income from a family farm consists of returns to various factor inputs owned by the farmer. Farm income is the *mixed income* from these owned factors.

If a farm has a mixed income some production factors do not pass through the markets and do not receive a market return or do not have a market determined price. This makes it difficult to estimate factor shares. Therefore, it is necessary to break down mixed income into individual factor contributions. Income from owned resources can be divided along functional lines if some assumptions about the value of family owned resources are set.

Figure 1 relates functional income distribution to personal income distribution for rice farming. I illustrates factor shares or functional distribution of income. The production function is the same as in the previous section:

$$Q = F(C, K, L, A).$$

Capital inputs (K) include services of fixed capital (production assets that are usable beyond a production period, such as a draft animal, tractor, hoe, or sickle) and capital funds used in the production process.

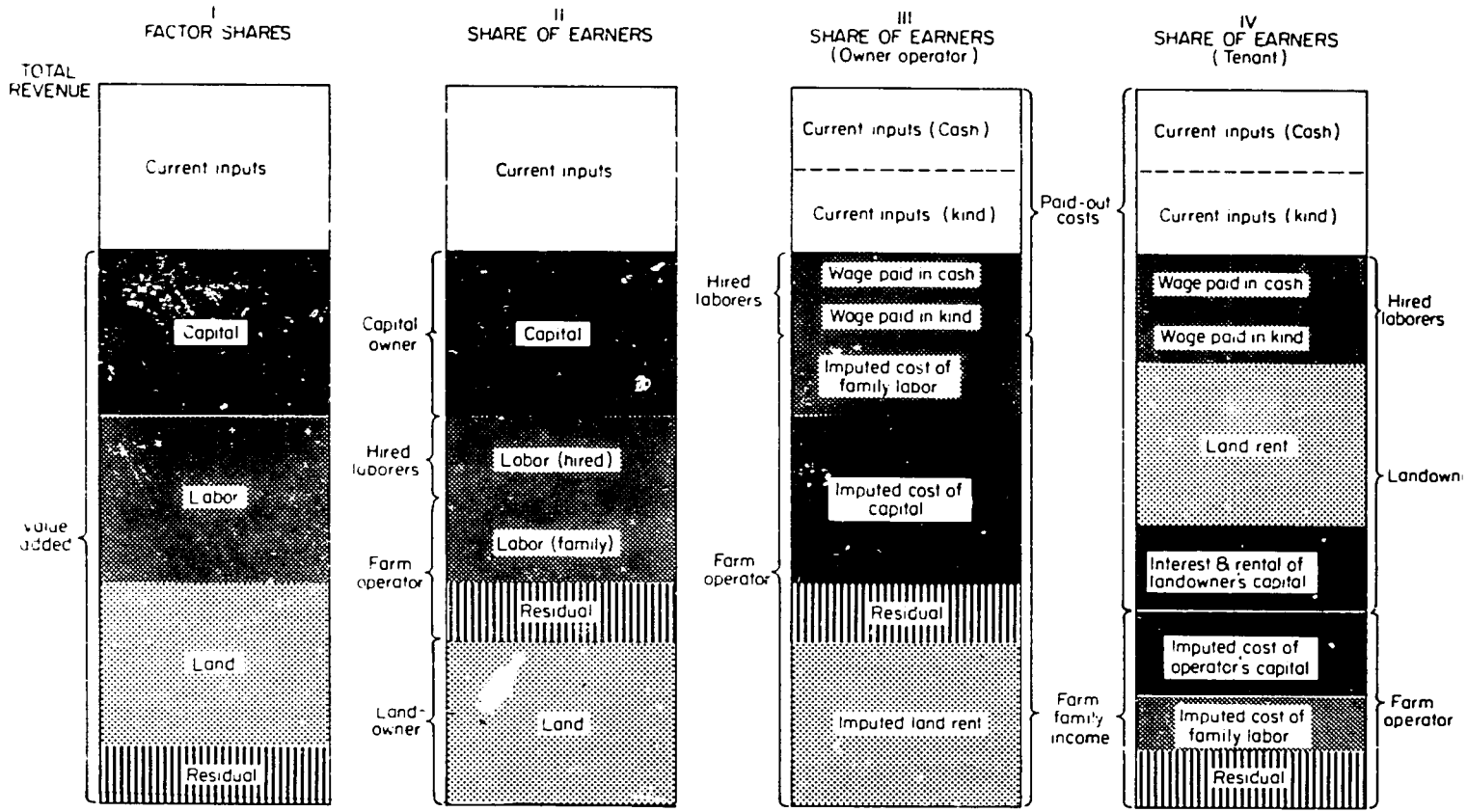
Each input category can consist of several different resources. Current inputs might include seeds, fertilizer, chemicals, and gasoline for the tractor. Labor input might be used for farm tasks like land preparation and transplanting, for which different wage rates may be paid. Some factors are not purchased through markets so money is not actually paid out.

Total revenue is expressed as:

$$PQ = pC + iK + wL + rA + e \qquad (6)$$

where e is a residual. Unlike the explanation in the previous section, total output is not exhausted in equation 6. If long-run perfect competition does not prevail or if we are dealing with individual farms, there will be a residual left after total factor costs are subtracted from total revenue. The residual term, e, is a balance term showing farm profit if it is positive (Fig. 1) or farm loss if it is negative. If some production resources, such as management skill, are not included in the production function, returns to those resources will be included in the residual.

The difference between total revenue and current input cost ($PQ - pC$) is the value that is added to an economy by a production process, and is called *value added*.



1. Distribution among factors and among earners. Adapted from Herdt (1978).

Value added is income distribution among resource contributors in a production process.

Factor income (value added) accrued to capital, labor, and land is distributed to the resource owners (II). III and IV give definite examples of resource ownership. III illustrates income distribution among factors and resource owners for an owner-operated farm. The farmer owns land and capital and hires laborers for some farming tasks. Farm operator or farm family income is mixed income consisting of returns to family labor, capital, and land, and the residual. Personal income of hired laborers is wages paid and is part of the factor cost of labor.

IV shows the income distribution for a tenant farmer who rents land, owns part of the capital used, and hires labor for some farming tasks. The landowner supplies some capital to the tenant. Farm family income is returns to family labor and capital owned by the farmer, and the residual. The landowner's personal income includes land rent and returns to his capital. Hired laborers' share is the same as III.

The difference between total revenue and farm family income is paid-out costs, in cash or in kind, by the farmer.

As already mentioned, a major problem in estimating factor share is how to impute prices of inputs not acquired from markets. As a general principle, the value of unpaid factor inputs is determined by their *opportunity costs*. If a farmer does not use an owned resource, but sells it, how much is he paid? Market prices, if they exist, can be good values for unpaid factor inputs. If a market price is not available, farmer evaluations can be used although they are less reliable than objective market rate. Remember that market prices of factor inputs must equal their marginal productivities at the competitive equilibrium.

If no suitable price for an input can be found, you may estimate factor share of the input as a residual. If it is difficult to calculate capital input costs, the factor cost of capital may be estimated as:

$$(iK + e) = PQ - pC - wL - rA.$$

Use the same process to estimate factor cost of land, if there is no land rental rate (r) available. Note that factor costs(s) of input(s) thus estimated almost always include the residual in the real sense.

An illustration of factor share estimation

Factor shares can be estimated for an economy as a whole, for an industry, for all rice farms in a country or region, or for an individual firm. It is sometimes meaningful to estimate factor shares by farm category; by crop — rice or vegatables; by land condition — irrigated or rainfed; by size — small or large; or by tenure status — owner-operator, leaseholder, or share-tenant. The type and level of aggregation used for factor share estimation depend on the purpose of the research. The following factor share calculation uses farm records from *a* Philippine sharecropping rice farm (Table 1). For collection of cost data from surveys, see chapters 11, 12, and 13.

Output

This tenant harvested 4.5 t of rice in a crop season from 1.5 ha. Market price of rice was ₱ 1.30/kg. Gross revenue was ₱ 5,850. Some produce was saved for home

Table 1. Factor share estimation for a sharecropping rice farm.

Output	Quantity	Price	Total value
	4,500 kg	₱1.30/kg	₱5,850 (PQ)

Factor payment	Purchased Quantity	Purchased Price (₱)	Purchased Total value (₱)	Self-supplied Quantity	Self-supplied Price (₱)	Self-supplied Total value (₱)	Total value (₱)
Current inputs							
1) Seeds				111 kg	(1.30/kg)[a]	144	144
2) Fertilizer	300 kg	1.80/kg	540				540
3) Chemicals			250				250
4) Gasoline	50 l	4.00/l	200				200
Total			990 (C_1)			144 (C_2)	*1134* (C)
Capital							
1) Carabao				12 carabao-days	(15/day)	180	180
2) Tractor	5 tractor-days	80/day	400				400
3) Sprayer				4 days	(5/day)	20	20
4) Thresher							
Total			400 (K_1)			200 (K_2)	*600* (K)
Labor							
1) Land preparation	5 man-days	15/day[b]	75	12 man-days	(15/day)	180	255
2) Transplanting	15 man-days	15/day	180	1 man-day	(12/day)	12	192
3) Weeding	20 man-days	12/day	240	24 man-days	(12/day)	288	528
4) Harvesting and threshing	55 man-days	1/8[c]	731				731

Continued on next page

Table continued.

Output		Quantity	Price			Total value	
		4,500 kg	M1.30/kg			M5,850 (PQ)	
(others)[d]	2 man-days	12/day	24	20 man-days	(12/day)	240	264
Total			1250 (L_1)			720 (L_2)	*1970* (L)
Land	1.50 ha	Sharing[e] 50:50	2003 (A_1)				*2003* (A)
Residual							*143* (e)
Total (C + K + L + A + e)							*5850*

Value added = PQ − C = K + L + A + e = M4715

Value added ratio = (PQ − C)/PQ = 0.806

Farm family income (mixed income) = PQ − C − K_1 − L_1 − A_1 = K_2 + L_2 + e = M1063

Paid out costs = C + K_1 + L_1 + A_1 = PQ − K_2 − L_2 − e = M4787[f]

[a]Prices in parentheses are market prices. [b]Wage rates include both cash wage and the value of meals, if served. [c]Harvesters are paid in kind, 1/8 of total harvest. [d]Other tasks such as seedbed preparation, fertilizer and chemical applications and irrigation control. [e]Sharing arrangement between landowner and tenant. Some cost items also are shared equally: 1) seeds, 2) fertilizer, 3) chemicals, 4) hired labor cost for transplanting, and 5) hired labor cost for harvesting and threshing. [f]Costs actually paid by the farm are M3,864 because of the cost sharing.

consumption. Although this did not go through the market, it is valued at the market price.

The market price of rice varies. It is lower during the harvest season than in lean season. The farmer may sell his rice at different times for different prices. Usually, a typical price at which the majority of rice is sold or a weighted average price is used as market price for computing output value.

For factor share calculation, output(s) must be carefully defined. In this example, output is the (paddy) rice after threshing. Output price and other costs are defined accordingly. Output price is the farm gate price of rice after threshing. All costs are incurred from land preparation through delivering threshed rice to the farm gate.

Rice output is defined as milled rice; the production process includes land preparation through milling. Output price is price of milled rice at the mill and input factors used to transport rice to the mill and for milling must be included in the total production cost. If a farmer sells his produce as standing crop before harvest, output is standing crop before harvest. The output *price* is at the field and the total cost does not include harvesting and threshing *costs*.

Outputs at different levels must not be mixed in a factor share calculation, unless adjustments are made to allow for the differences. This does not mean that the factor shares cannot be calculated for multiple outputs, however. For instance, some farmers grow rice and maize during the same year. To estimate factor shares for annual production, combine factor share estimates for both crops, being careful to uniquely define each production process.

Current inputs

Some current inputs were self-supplied. This farmer used 111 kg of rice seeds from previous production. It was valued, like output, at opportunity cost, the market price of rice. Other current inputs were bought at the market and there is no imputational problem.

Although the example shows only four items as current inputs, there can be more. All material inputs used in production, for which total value transfers to output and is exhausted during the production period, are defined as current inputs.

Although 50% of seed, fertilizer, and chemical costs were shared by the landowner in this illustration, all current inputs must be included in the calculation, regardless of who bears the cost.

Capital

Capital is usually defined as physical inputs usable for multiple production periods. Draft animals, capital equipment (a tractor), and farming tools (hoes and sickles) are in this category.

Estimation of capital services derived from capital assets during a production period might be difficult if capital is owned by farm operators. For capital equipment with established rental market, the rental rate can be considered as the marginal contribution of services from farm equipment. However, rental markets often do not exist for some farm capital assets.

There are two ways to estimate capital services costs. Value of capital services can be calculated using capital depreciation, or by calculating total value of capital assets

and applying an interest rate to the value. Estimating costs by depreciating capital is difficult because rate of capital depreciation depends on depreciation method and on usable lifetime of capital assets. Determining a reasonable interest rate is also difficult.

Rental rates are used to evaluate services of owned capital in the illustration. Small tools like sickles and hoes are not considered. Returns to them, if any, are included in the residual. This is done because cost of these tools is a fraction, often less than 1% of total costs.

Rental rates and operator wages, although sometimes reported together, should be separated. Wages for operator, even if they are not paid explicitly, must be included in return to labor and rental rate must be pure rentals. In the example, tractor rental is obtained by subtracting ₱ 15/day of operator wages from ₱ 95/day gross rental. Draft animal rental is obtained using ₱ 30/day gross rental. Pure rental rates are multiplied by days of equipment use to estimate the value of capital services derived from equipment.

Because it is difficult to obtain a reasonable interest rate for capital funds used in the production process, it is not included in the example. If a 10% interest rate per crop season is used, capital interest for this farm would be ₱ 205 if all funds were used at the beginning of the crop season [$(C + K_1 + L_1 -$ wage for harvesters$) \times 0.10 =$ ₱ 205]. If the capital interest payment is borne by the farmer regardless of the cost sharing arrangement with the landowner, the residual, −₱ 62, is negative.

Labor

In South and Southeast Asia even small rice farmers depend on hired labor for farm operations. Labor markets are well developed, so market wage rates are available to impute family labor costs. Market wage rates are often not established for non-standard, specialized tasks requiring careful management — pest and disease control, and irrigation and drainage management. Opportunity costs of labor for these tasks may be obtained by asking farmers what they would pay a person to do this job.

Wage rates should include cash and kind. The value of all meals provided to hired laborers should be added to the cash wage.

Land

Return to land, if the land is owned by a farmer, is difficult to determine. These methods can be used:

1. Obtain the average (or typical) ratio of land rent to total output for tenants in study areas. Multiply the ratio by the owner-operator's output.
2. Compute the average (or typical) ratio of land rent to land price and multiply it by the value of the land owned by the operator.
3. Apply a reasonable interest rate to the owner-operator's land value.

These methods are useful only when land and capital markets are well developed. Where land and land rental markets do not exist, returns to land can be estimated only as a residual.

In the example the farmer and the landowner share the output 50:50. Some current inputs and hired labor costs are also shared equally between tenant and

owner. Costs shared by the owner must be deducted from his output share to determine the amount actually received by him as land rent.

If there is a leasehold arrangement and a fixed land rent (cash or kind) is paid to the landowner, all production costs are usually borne by the leasehold tenant. Fixed rent is a factor payment for land in this case.

Irrigation fee. An irrigation cost is not in this example. It was omitted to simplify the illustration. Unless land is rainfed, irrigation water or service of irrigation system must be included as a production input.

If a farmer pays irrigation fees in cash or kind, the payment is for services. Irrigation fees can be considered in two ways. Irrigation water can be considered as a current input, or as services from capital (dams, canals, ditches).

If irrigation water is supplied by a pump owned by the farmer, determine costs by the method used to evaluate fixed capital.

Tax and rate. Land and income taxes, and rates such as a village contribution where amount is determined in proportion to rice output or land area, must not be included in the factor share calculation. They are not production factors. Factor shares are defined in relation to a production function. Taxes and rates are levied on the results of a production process after it is over.

Sometimes taxes and rates affect farmers' production decisions and therefore, the functional distribution of income. Taxes and rates (or subsidies) that affect output and/or input price are examples.

Taxes and rates affect personal distribution of income, but usually not the functional distribution of income. Distribution of disposable income among landlords, farmers, and hired laborers varies according to what taxes and rates are levied and how they are determined.

Presentation of factor shares

Factor and income shares from Table 1 are reported per hectare in Table 2. Factor payments can be presented many ways. For crop farming, they can be expressed per hectare or per farm. To simplify comparison, it is sometimes convenient to present them per unit of land.

It is also convenient to discuss factor payments for interregion, intercountry, and over time comparisons in terms of relative input and output prices.

Application

Effects of any change which affects an existing production function and a relative price structure of outputs and inputs can be observed through associated changes in factor shares. Factor share is a powerful tool in analyses when dealing with economic growth, technological changes, and income distribution.

Although the factor share concept can be widely used, it is better when applied to aggregate data.

Factor shares can be estimated for a single farm. Used in this way, the estimates serve as accounting or documenting tools for farm management. If estimates are compared cross-sectionally over time, insights similar to those obtained by other types of farm budgeting or accounting analyses can be derived. (See Chapter 4 for a description of farm budget analysis.)

Table 2. Factor and income shares (per hectare).[a]

Factor share	Factor payment		
	Value (₱)	Paddy equivalent[b] (kg)	Factor share (%)
Output	3,900	3,000	100.0
Current inputs	756	581	19.4
Capital	400	308	10.2
Labor	1,313	1,010	33.7
Land	1,335	1,027	34.2
Residual	96	74	2.5

Income share	Income		
	Value (₱)	Paddy equivalent (kg)	Income share (%)
Value added	3,144	2,418	100.0
Landowner	1,335	1,027	42.5
Hired laborers	833	641	26.5
Farm operator	709	545	22.5
(Capital)	(133)	(102)	(4.2)
(Family labor)	(480)	(369)	(15.3)
(Residual)	(96)	(74)	(3.0)
Capital owner	267	205	8.5

[a]Based on Table 1. [b]Value terms are divided by the price of rice (₱1.30/kg).

Because market equilibrium plays a critical role in the concept of factor share, data that have been collected from microlevel farm (or village) surveys may need to be aggregated to reduce variation of individuals from equilibra. Factor share analysis, however, is not limited to studies using data from microlevel surveys. It is most often employed in studies, such as nationwide agricultural census, in which macrodata are used.

A factor share analysis example

To illustrate how factor share estimates are used in economic analyses, results of a Philippine rice village study are discussed (Kikuchi and Hayami 1980).

Population around the study village was growing rapidly, but land resources were limited. There were an increasing number of subtenancy arrangements, where leaseholders subleased land on a 50:50 share contract. Government land reform regulations controlled leasehold rental rates.

The hypothesis

Economists hypothesized that the gap between economic (or functional) rent accruing to the service of land and the actual rent paid to landlords widened in relation to population pressure under the institutional rigidity of the land rental market. This gap induced leasehold tenants to become intermediate landlords.

Table 3. Factor payments and factor shares in rice per hectare production in a Philippine village, 1976 wet season.

	Leasehold tenancy	Share tenancy	Sub-tenancy
		Factor payments (kg/ha)[a]	
Rice output	2889	2749	3447
Factor payments:			
Current inputs	657	697	803
Capital[b]	337	288	346
Labor	918	850	1008
Land	567	698	1305
(Paid to sublessor)	(0)	(0)	(801)
(Paid to landlord)	(567)	(698)	(504)
Operator surplus[c]	410	216	-13
		Factor shares (%)	
Rice output	100.0	100.0	100.0
Factor payments:			
Current inputs	22.7	25.3	23.2
Capital[b]	11.7	10.5	10.1
Labor	31.8	30.9	29.3
Land	19.6	25.4	37.8
(Paid to sublessor)	(0)	(0)	(23.2)
(Paid to landlord)	(19.6)	(25.4)	(14.6)
Operator surplus[c]	14.2	7.9	-0.4

[a]Factor payments are converted to paddy equivalents by the factor-output price ratios. [b]Sum of irrigation fee and paid and/or calculated rentals of carabao, tractor, and other machines. [c]Residual.

A test of hypothesis

To test the hypothesis, the factor shares of rice output were estimated for the 1976 wet season for different tenure types by imputing unpaid factor inputs at market prices. Self-supplied current inputs were valued at market prices. Costs of family labor and family-owned capital such as carabao and tractors were imputed by market wage and rental rates. Land rents to sublessors under the pledging arrangement are imputed by applying the interest rate of 40% per crop season, the most common rate in the village.

Results show the share of land was lowest and the operators' surplus highest for the land under leasehold tenancy, in both absolute and relative terms (Table 3). In contrast, share of land was highest and no surplus was left for farm operators contracting under subtenancy. Land share for subtenants was close to the sum of land share and operators' surplus for other tenure classes. These observations indicate that a substantial portion of economic rent was captured by leasehold tenants in the form of operators' surplus.

To provide further information, the production function for rice was estimated using the same set of data used to calculate factor shares. The functional form used is the unrestricted Cobb-Douglas (linear in logarithms) relating quantity of rice output per farm to the following independent variables:

Land = hectares harvested per farm;

Labor = man-days used per farm;

Table 4. Cobb-Douglas production function estimates for rice using farm survey data in a Philippine village, 1976 wet season.

Regression number	(1)	(2)	(3)	(4)
Coefficients of				
Land	0.343	0.343	0.333	0.352
	(0.203)[a]	(0.207)	(0.206)	(0.215)
Labor	0.299	0.299	0.300	0.292
	(0.200)	(0.204)	(0.203)	(0.210)
Capital	0.135	0.135	0.130	0.139
	(0.099)	(0.101)	(0.101)	(0.104)
Current inputs	0.240	0.241	0.248	0.242
	(0.094)	(0.096)	(0.096)	(0.096)
Subtenancy dummy		−0.005		
		(0.147)		
Share-tenancy dummy			−0.058	
			(0.099)	
Scale dummy				−0.019
				(0.129)
Sum of conventional coefficients	1.018	1.017	1.011	1.024
	(0.055)	(0.061)	(0.057)	(0.072)
R^2 (adjusted)	0.931	0.928	0.929	0.928
Standard error of estimate	0.248	0.253	0.291	0.253
Intercept	1.019	1.038	0.994	1.041

[a]Standard errors of regression coefficients are enclosed in parentheses.

Capital — sum of irrigation fee and paid and/or imputed rentals for carabao, tractor, and other machines per farm ($\dot{M}$);

Current inputs — sum of paid and/or imputed costs of current inputs per farm ($\dot{M}$);

Subtenancy dummy — subtenancy = 1, and others = 0;

Share-tenancy dummy — share tenancy = 1, and others = 0;

Scale dummy — farms larger than 2 ha = 1, and others = 0.

Results of the estimation by ordinary least-squares method are summarized in Table 4. All estimates of the production elasticities of inputs have positive signs, as was expected. Although these estimates are not significant at conventional levels of significance, except for current inputs, they are at least larger than their standard errors. In contrast, the coefficients of dummy variables are smaller than their standard errors.

Assuming market equilibrium, the production elasticities equal the functional shares of factors. Estimates of production elasticities in Table 4 are similar to the values of relative factor shares in Table 3. Estimates of land production elasticity are surprisingly close to the estimate of relative share of land for subtenants. Results support the hypothesis that subtenants pay rent equal to the marginal value product of the land.

Leasehold tenants can preserve the marginal return to the service of land over the actual land rent paid out to the landowners in the form of operators' surplus by

cultivating the land themselves. Alternatively, they can capture the surplus by subleasing the land. The population pressure that has produced the surplus can be identified as the force creating multistage landlordism, despite land reform laws.

A brief list of literature in which one finds factor shares applied in some ways to economic analyses is found in the Appendix.

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CHAPTER 7

CROPPING SYSTEMS RESEARCH METHODOLOGY: AN OUTLINE

S. K. JAYASURIYA

In most Asian countries farmers have limited resources, small farms, and depend on crop cultivation for their primary livelihood. Specific biophysical and socioeconomic farming environments are diverse in the region and even within individual countries. Recognition of this diversity led to the development of site-specific research which recognizes that farm-level environment varies significantly from conditions at experimental stations. These realizations helped scientists develop the concept of on-farm experimentation.

Scientists have also come to understand that farming systems are often complex, involve multiple cropping and noncropping activities, and that new technology adoption and consequences are conditioned by these system considerations. It has even been suggested that the limited success crop or commodity-oriented agricultural research has had in reaching the majority of small farmers is because such technologies were inappropriate for local farming systems.

Increased population pressures on land and the crop intensification potential of short-duration modern varieties (particularly rice) have helped draw attention to the value of developing new technologies and cropping systems tailored to specific farming environments.

Cropping systems research at the International Rice Research Institute (IRRI) began with intensive multiple cropping work initiated by Dr. R. Bradfield in the 1960s. In 1972 multiple cropping research was broadened to cropping systems research. During 1974-75 a major expansion took place. An interdisciplinary team, which included a full-time economist, was formed to conduct cropping research using systems research concepts and methods.

The Asian Cropping Systems Network (ACSN) was formed in 1974 to encourage collaboration between national research programs conducting cropping systems research in Asia. Bangladesh, Burma, China, India, Indonesia, the Republic of Korea, Nepal, the Philippines, and Thailand participate in ACSN. Malaysia collaborates to a limited degree. Vietnam will initiate collaborative research in 1982, and Pakistan has expressed interest in participating. In 1981 there were 100 cropping research sites in the cooperating countries. To ensure close and continuous interaction between national programs and IRRI, a working group of program leaders

from member programs was formed. They meet twice a year, rotating between participating countries. In addition to regular meetings, two major international conferences have been held, in 1976 and 1980. Regular study tours of participating country research sites are organized so network scientists can evaluate accomplishments, problems, and methods, exchange ideas, and interact. ACSN also facilitates exchange of scientific literature and materials. Although IRRI research is on rice-based cropping systems, other collaborators do research in other areas, depending on national and regional requirements.

The IRRI program has worked collaboratively with national programs to successfully develop a methodology for conducting site-specific, on-farm research to generate more productive cropping systems. IRRI scientists realized that for such a methodology to be useful and viable in a national program setting, it must be designed for institutional conditions and resource availabilities in national programs. The methodology used in the ACSN, with modifications needed for specific situations, has been tested in national programs and discussed at each working group meeting, where modifications are made.

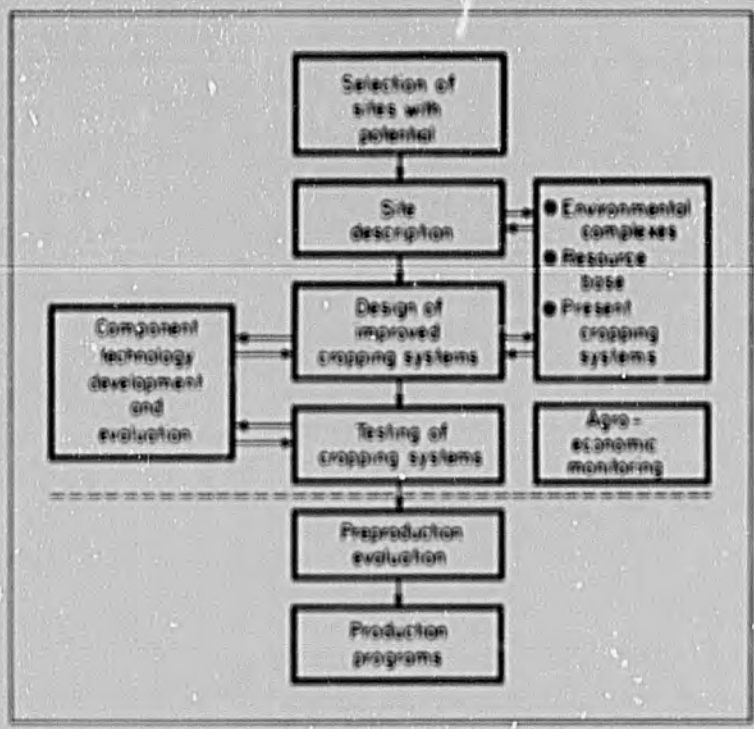
Modified methodology is taken back to the field sites for further testing. A review team that evaluated International Agricultural Research Centers (IARCs) research programs in 1978 wrote: "In the opinion of the review team, the formation of the Asian Cropping Systems Network has been the most significant development in cooperative programs between an IARC and its constituent countries. The collegial, collaborative mode of the ACSN — especially as regards program planning, development of methodology, and program evaluation — is a key factor in the success of the Network."

A major component of ACSN collaboration has been the definition of data collection requirements at each stage of the research process and the development of methods and procedures for collecting, processing, managing, and analyzing data for specific research objectives, always recognizing the time and resource limitations prevailing in national programs.

RESEARCH METHODOLOGY

The research methodology used by the IRRI cropping systems program and in the ACSN is based on the systems approach where "agriculture is recognized for what it is I/M a hierarchy of systems with a purposeful nature" (Dillon 1976). The holistic nature of agricultural systems makes such research intrinsically multidisciplinary. Figure 1 shows major components of this methodology, as described in detail by Zandstra et al (1981).

The research process comprises five phases once a cropping systems research site has been selected. The first phase — site description — may start before final selection of a site. Often, site-specific research is necessary to generate suitable technology for a particular environmental complex. More and more major rural development projects have a built-in research component designed to provide appropriate new technology for target area farmers. A specific research site is chosen because it represents major biophysical and socioeconomic environmental parameters of the target area.



1. Components of the site-related cropping systems research, IRRI, 1977.

Objectives of site description are to identify and describe major regional farming systems and understand the dynamic and interactive relationships of those systems with wider regional systems and overall environment. This understanding is the basis for the design phase.

In the design phase, researchers attempt to assemble component technologies into new cropping patterns and systems that have potential for successful farmer adoption and will improve farm productivity and welfare. Research output from experimental stations (often commodity oriented) in the form of new varieties, agronomic practices, agricultural equipment and tools are component technologies. Cropping systems researchers must assemble these in combinations appropriate for the target environment. In this sense, the research is site or environment specific. Such combinations form new cropping patterns and systems. Although the objective of research is to develop better cropping systems, the design, and subsequent testing/evaluation, is within the framework of wider farming systems. In other words, the cropping systems researcher works on a specific subsystem of the farming system, understanding that its relationships with higher- and lower-level systems determine its performance. (For a discussion of the relationship of cropping systems research to farming systems research see Appendix)

Products of the design phase are cropping patterns with all production techniques specified, a list of data to be collected, and a set of alternatives based on anticipated weather or other environmental conditions. New patterns are usually land type

specific. Sometimes, researchers may decide to concentrate on selected components of current systems, particularly when farmers already operate intensive and complex systems. In either case, components will be tested as part of patterns. The design phase may also suggest component technology experiments for finding answers to a specific problem or problems expected in a pattern.

Patterns are tested on farmers' fields under farmer management with researcher supervision. Component technology experiments may be superimposed on pattern trials (i.e. a number of rice varieties may be tested in a pattern trial where rice is the component crop) or may be done by researchers (e.g. an NPK trial). Patterns are tested on large plots (at least 1,000 m^2) so farm-level constraints can be identified in a realistic setting. Tests are replicated across farms; each farm is a replicate. Performance of experimental patterns is closely monitored by biological scientists and economists and evaluated at the end of each crop season and crop year. Based on results of this evaluation, patterns may be tested further in their present form, modified, or dropped. Pattern testing is done for 3-4 years, then the most promising patterns are selected for preproduction evaluation.

Preproduction evaluation is the final major testing phase before new cropping patterns are extended to many farmers through a production program. Preproduction testing may be part of a pilot production program which evaluates patterns on a wider basis. It tests community-level impact of large-scale adoption, market capacity, and extension services and other institutions, and attempts to identify constraints that must be corrected at the production program stage. If new systems are to be extended to wide areas with similar environments, multilocation tests are conducted to fine-tune technologies to minor environmental variations. Ideally, new systems should be packaged for extension officers to take to farmers at the end of the preproduction evaluation phase. Major infrastructural requirements should have been identified and an assessment of the consequences of large-scale adoption made. During a production program, studies may need to assess level of adoption and constraints to better technology performance or adoption if adoption is not satisfactory.

DATA REQUIREMENTS

Data requirements vary for each stage of the research process. At any given stage, because of the systems research approach and associated nature of multidisciplinary research, data needs are substantially larger than are usually required when a single discipline is involved. Some data can be obtained from secondary sources, some from surveys, and some from close field experiment monitoring.

At the site selection/description stage researchers attempt to build an agroeconomic profile of the site that provides a framework to understand the farming systems, and their linkages and dynamic interaction. Biophysical and socioeconomic data for the farmers' environment as well as for the farm and its subsystems (crops, livestock) are required. Data must be integrated in a holistic framework so researchers can use the information to design better cropping systems. Researchers also need information on available component technologies and their performance in similar agroecosystems.

To evaluate new systems, biological and economic performance data are needed. Similar data are required from component technology trials. In the ACSN new systems are not evaluated in isolation. Performance of new systems is always compared with existing farmer systems. For such comparisons, data on farmers' systems are needed.

Data are needed for all major inputs and outputs of crops and cropping patterns grown on specified land types. Since new systems may change levels and patterns of resource use and outputs over time, dated input-output data must be obtained. Information for all levels of the regional agricultural system can be gathered during the testing period. During on-farm experimentation researchers are close to the situation and can increase their understanding of the systems and system dynamics. Important changes that can modify the systems in operation during the site description phase can also be monitored. Generally, it is true to say that site description is a continuous activity throughout research at a site.

Data on farmers' reactions to new systems are of particular importance. In village communities, reactions can come not only from the farmers who are trying new systems but also from other farmers. Valuable information on farm-level constraints, on managerial complexity of particular technologies, and on environmental factors affecting farming can be learned from farmers during the testing period. Such data are essential to a realistic evaluation of new systems.

At the preproduction evaluation stage, more emphasis is placed on the macro situation. Data on markets, storage and transportation capacities, credit availability, credit sources and arrangements, number and quality of extension staff, and community-level labor availability are required to assess the consequences of wider adoption of new systems.

Data on key component adoption, whole system adoption, farm-level performance of new systems, and farm-level and community-level impact on several welfare indicators (production, income, income distribution, nutrition) are required to evaluate the consequences of a new system.

At this stage, emphasis shifts to factors that facilitate/limit adoption and to farm-level performance of new technologies. Constraints research and yield gap analysis address these issues. Such research measures farm-level performance of new technologies, comparing it with potential performance and identifying factors that result in divergence between farm-level performance and agronomic potential of new technologies.

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Appendix. Committee report of cropping systems research in farming systems projects, *A. Gomez, S. Jayasuriya, and Inu Ismail.* (From "Proceedings of the 10th Working Group Meeting of the Asian Cropping Systems Network," IRRI, Los Baños, 1981.)

The committee considered the following:

1. Crops and animals are the two major farm enterprises.
2. Although livestock raising is important to most farms in the region, recent cropping systems research dominated most farm-oriented research activities.
3. Crop and animal production compete for limited farm resources. Advances in cropping systems techniques will be enhanced by progress in animal production where animals produced are important crop production inputs.

A production technology can be evaluated for feasibility at several levels:

1. The component technology level — A component technology corresponds to the specific practice required for a specific operation for a given crop. Some examples are seedling establishment method, fertilizer application level, and pest management practices.
2. A crop-level package uses technology required for the culture of a single crop. It maximizes that crop's productivity and does not consider other crops on the same land.
3. A cropping pattern level technology package specifies management for crops to be grown in a particular cropping pattern. The goal of a cropping pattern level package is to maximize productivity in a field for a specified time. Components of all crops of the pattern must be evaluated as a package, because each crop is expected to influence the productivity of all other crops.
4. A farm-level technology package specifies management for a group of cropping patterns (or farming systems if animals are included) to be implemented on one farm. This level of packaging collapses to the cropping pattern level if only one pattern is implemented for the farm.

Cropping systems research methodology advocates that the biological feasibility test be conducted at the cropping pattern level because the interaction among component crops in a pattern is expected to be large. Crop performance depends on the position of a crop in the cropping pattern. For example, in a sequential cropping of rice - rice - mungbean, yield of the first rice crop is not expected to equal that of the second rice crop because management practices and physical environment for the crops are different.

A legitimate question is: do cropping patterns or crop-animal patterns on different parts of a farm interact biologically? If this interaction is negligible, the cropping pattern level of evaluating the biological feasibility of a technology package is adequate. If biological interactions are large, evaluation should be at the farm level. Biological interaction among cropping patterns used in different farm parcels is usually small and the cropping pattern level is adequate for evaluating biological feasibility. An integrated approach may be necessary where crop-livestock interactions are large.

For economic feasibility evaluations, however, the interaction among farm parcels is almost always large because farm resources come from a common pool, and what is used in one parcel is usually not available for other parcels. Therefore, management decisions for one farm parcel affect the others. Economic evaluation must be done at the farm level.

The role of cropping systems research in farming systems activities can be summarized as:

- Cropping systems research is adequate and can serve farming system activities as far as biological evaluation of productivity is concerned.

- Animal or crop-animal systems must be evaluated just as crops are.
- Economic evaluation of crop and crop-animal systems must be conducted to design and select the best farm-level production package.

CHAPTER 8

FARM HOUSEHOLD SYSTEMS

S. K. JAYASURIYA AND L. CASTILLO

Farms are the basic economic units engaged in agricultural production. In most less developed Asian countries, farmers have low resources and relatively small farms, and depend primarily on crop products for their livelihood. Because both production and consumption activities take place within these farms they are better described as farm households.

A *farming system* (or farm system or whole-farm system) is not just a collection of crops and animals to which one can apply an input and expect immediate results. It is a complex of soils, plants, animals, implements, workers, other inputs, and environmental influences that is manipulated by a farmer who attempts to produce output from the inputs and technology available to him, based on personal preferences and aspirations. It is the farmer's unique understanding of his immediate natural and socioeconomic environment that determines his farming system (TAC Review 1978).

To design, test, and evaluate new farm technologies, scientists must understand the dynamic, interactive relationships of a farm with its environment. Researchers are increasing their use of the systems approach to study the farm, the related agricultural sector, and to evaluate procedures used to develop suitable new farming technology.

THE SYSTEMS APPROACH IN AGRICULTURE

The systems approach was first developed and applied in biology and is probably most associated with ecology. A system is an arrangement of components that function as a unit (Hart 1979) or as a set of related elements (Ruthenberg 1976).

"Any farm is part of a hierarchy of systems belonging first to the larger system of the rural area and consisting, secondly, of various activities, which are systems themselves" (Ruthenberg 1976). This concept of a series of hierarchically interacting systems provides the integrating framework within which individual units are studied. Each unit is evaluated as an integral part of a larger whole and not as an isolated, self-contained entity.

"Each hierarchical level is conceptualized as a system composed of a set of subsystems. Interaction between two subsystems of the same system can be defined as

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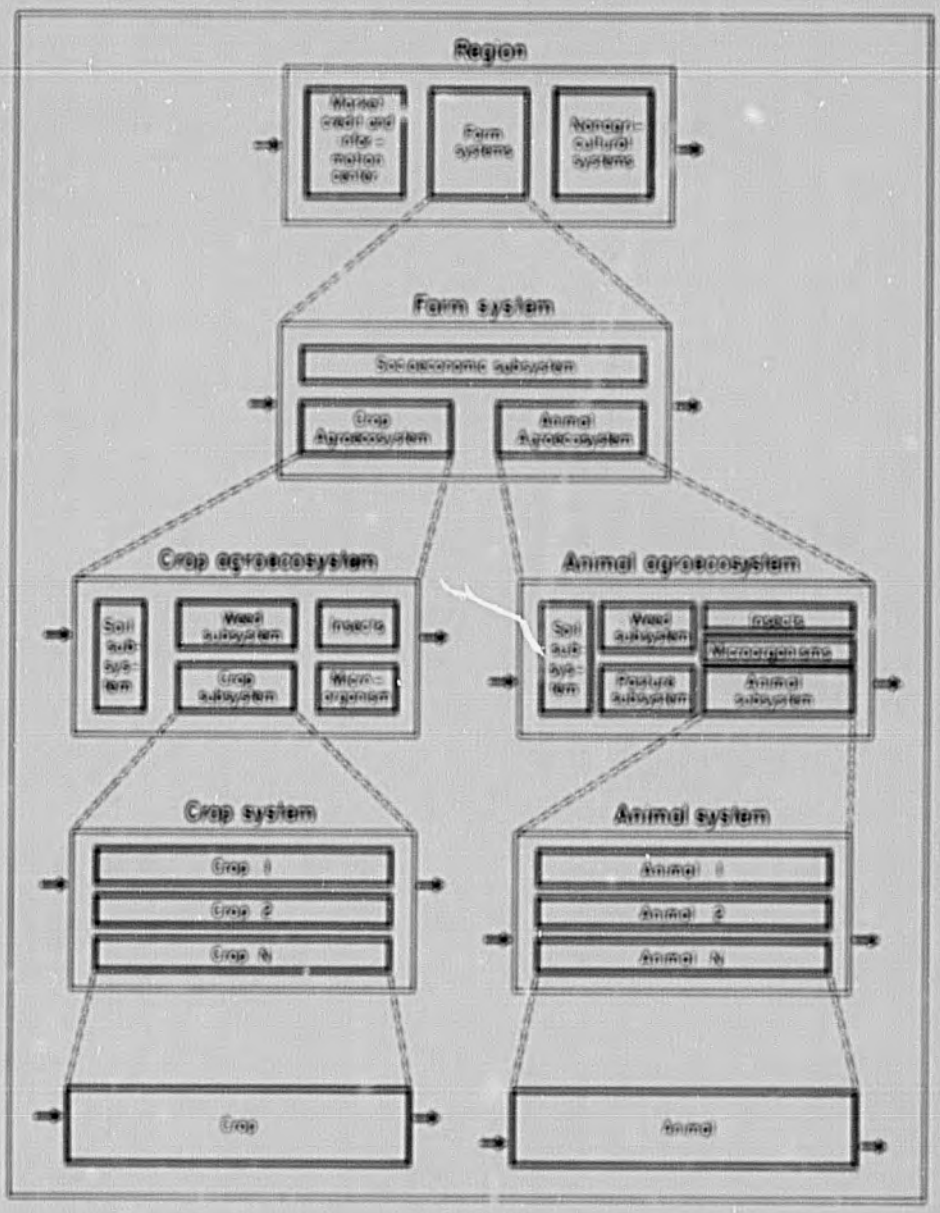
horizontal system integration" (Hart 1979). By applying this approach to agricultural production processes, we can identify a set of hierarchically related agricultural systems (Fig. 1). Some subsystem outputs of each system are inputs to others.

In most of Asia the typical small farm consists of a number of subsystems. The cropping system is often most important. Pure subsistence farms that have negligible



1. Hierarchical relationships between agricultural systems. Hart 1979.

linkages with markets are virtually nonexistent. Most farms are semisubsistence farms with significant market interactions.

The farm supplies a substantial proportion of the inputs (labor, animal power, manure) and a similar proportion of outputs are consumed within the farm (food, milk, animal feed). Hired labor use is common, particularly during periods of peak labor needs (crop establishment and harvesting, threshing). Purchased inputs (inorganic fertilizer, agrochemicals) are becoming important, and a variety of food stuffs, clothes, and fuel are purchased from markets. Credit transactions are frequent. Purchases imply cash outflows to markets that are balanced by revenues from crop and livestock sales, off- and nonfarm employment, and other market-related activities.

Thus, the typical farm household system (farm system) is bound to larger, higher agricultural systems in many ways. It is influenced by them and can influence them.

A farm's crop production activities determine its cropping system. A system may be composed of several cropping patterns and involve the production of several crops. All components required to produce a particular crop and their environmental relationships are part of a cropping system. Individual crops within a cropping system comprise a lower level subsystem and these subsystems comprise physiological systems.

Animal production systems are at the same level as cropping systems. Although animal production systems on small Asian farms are often of secondary importance to the cropping system, they also constitute a major subsystem within the farm and have a high degree of interaction with the cropping system. According to McDowell and Hildebrand (1980), "Animals utilize many of the by- and subproducts of the crops and provide fertilizer, power, and transportation for them."

Farms are goal-oriented systems and farmers usually have many goals. Usually farmers seek to increase income, avoid risks, and provide minimum subsistence levels of food and other essentials. Although this is an oversimplification of farmer goals, which vary within and across sociocultural and income groups, it is a working hypothesis that reasonably approximates farmer behavior in many farming situations.

Farm households are complex systems. They are hybrid systems that combine biological and social systems (sometimes even machine [tractor] systems) that are more difficult to study than purely biological and mechanical systems (Ruthenberg 1976).

In agricultural research we often concentrate attention on one level of a hierarchy of systems. In cropping systems research emphasis is on the cropping system. Focus may be further limited to cropping systems on a particular land type (lowland paddies) or to a single crop (rice). "In principal, however, it will always be necessary to study at least three levels: the unit of interest, and the next higher and next lower levels. The next higher system must be studied to measure the inputs into the system, and the next lower level must be studied to understand how the system functions" (Harr 1979).

In cropping systems research, site, farm, and parcel (plot) - level data are required. Site-level data provide information on the major environmental parameters and are common to farms at a given site. Farm- and plot-level data may show considerable diversity.

Data needed for a farming systems study would include information about:

a) rainfall, temperature, solar radiation, soils, topography, water resources, flooding, droughts, typhoons;

b) common crops and varieties grown during different seasons on different land types, their biological performance, common disease and insect pests, and weeds;

c) farm size, tenure, farm composition, farm equipment, power sources, technical knowledge, resource flows within the farm, market linkages, animals, crops and cropping patterns, input use and productivity levels; and

d) labor, material inputs (fertilizer, chemicals), credit, power and other input markets, product markets and transport facilities, and extension services.

Hart suggests that the first step in studying a system is the construction of a qualitative model that identifies system inputs and outputs, subsystems, and the circuitry connecting these systems. This qualitative model then becomes the basis for a quantitative model.

When site (location)-specific research begins, the first activity is site description. This procedure develops an initial qualitative model of the farming system and its environment and then quantifies the most important relationships and interactions necessary to design potentially useful technologies. Secondary data sources can usually be used to develop a systems model that can be refined and quantified during site visits and farm surveys.

Site description also provides a framework for seeking answers to the questions that enable a farming system to be understood (Collinson 1979).

1. *What* are the farmers doing?
2. *How* is it being done?
3. *Why* are they doing it in that way?

The biophysical environment determines farming activities, but the effects of environmental factors do not dictate the types of crops grown, their performance, etc. Irrigation, bunds, and terraces modify the effects of rainfall pattern on soil moisture. Fertilizer changes soil nutrient balance.

The socioeconomic environment within which farmers operate is also continually changing. Markets and social institutions are being changed by a variety of internal and external influences. Governments build roads and change the structure of markets, land reform activities change tenure institutions, and some changes are caused by farmers. National and international economic changes cause prices of major farming inputs and outputs to change. New farming technology also changes the external socioeconomic environment.

Farmers continually interact with and adapt to their environment. What, how, and why questions do not relate to a static situation but to a dynamic one. Answers must be sought by methods that recognize these dynamic dimensions.

Traditional farming systems have evolved over long periods, changing slowly. In less developed countries in Asia and other areas, transformations have resulted in a significant degree of farming commercialization. Commercialization affects the nature of farming practices.

The environment, known technology, farmer resources, and goals answer the what, why, and how questions. Our goal is to improve the welfare of the farmer and

society by changing technology used in farming operations. The analytical approach is holistic because it examines the entire system while seeking to directly change only one component. Without understanding the farm, we cannot understand what is happening on one part of it, perhaps the cropping system, and we cannot understand the farm without understanding something about the village, its markets, institutions, etc.

We also must recognize that we do research with limited resources and time. We cannot wait to analyze and understand everything about higher level systems before beginning to develop technology for a particular subsystem. Therefore, we must understand enough about the wider context to develop useful technology. The analysis should focus on general features of the system and on the most important interactions and links that will affect and will be affected by changes in the technology of the subsystem. If we do research to develop technology for a lowland paddy system, livestock or upland systems need to be studied only to the extent that there are significant interactions. Tenure institutions should be studied to the extent that they influence farmer decisions, practices, and results of new technology adoption.

The initial qualitative model is quantified with these considerations in mind. Quantification is more precise and detailed where interactions with target systems are strongest.

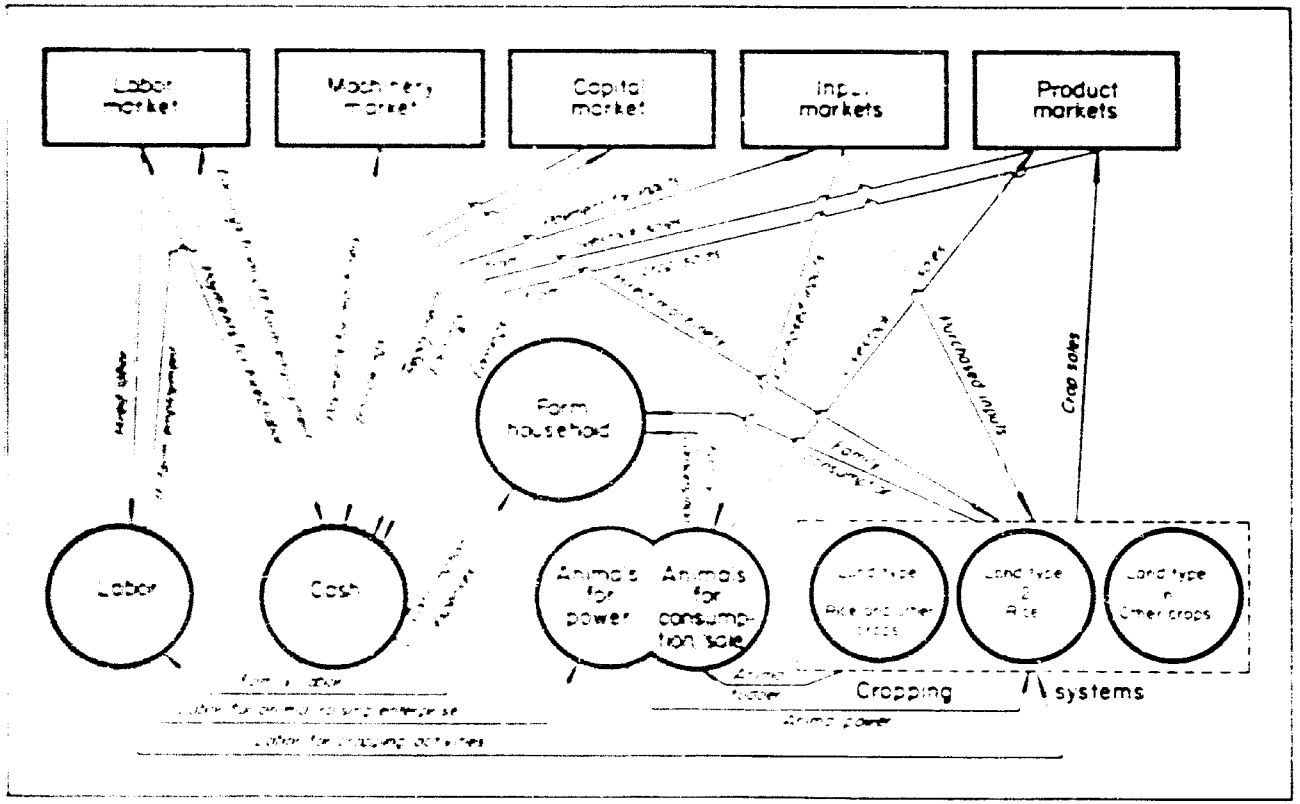
A general qualitative model of a small farm household is shown in Figure 2. It shows some outside market linkages, important resource flows, and potentially competitive demands on farm resources. Strong and weak linkages resource flows can be identified at an early stage in the analysis. Greater precision and better quantification is possible as more data are collected, but even at an early stage, the wider context within which particular farm activities take place can be recognized. Where crop-livestock interaction is high, we must be sensitive to the potential impact of changes in one of the systems. For instance, if crop residues are an important source of animal fodder, replacing a traditional tall rice variety with a modern short variety can adversely affect livestock production.

If a farm has a large upland area, technology changes in lowland areas may be hampered by competition for resources in the upland. Some technologies that might appear promising when evaluated in isolation may not be attractive when the total situation is considered. Such interactions may explain why farmers follow practices that appear to be irrational at first glance.

The following discussion shows how a holistic approach was used to develop a systems model for a site in the Philippines.

Capiz is a settlement area on Panay Island in the Philippines that has a rainfed farming system. Capiz has lowland and upland (knoll) areas. Lowland includes plateau and sideslope regions. Rice is the major crop. Most rice is grown on the lowland plains. Upland crops are grown at low management levels in scattered knoll areas. Farmers produce two rice crops annually, helped by a relatively long rainy season, which begins in May and ends in January. Farmers also raise livestock, mainly carabaos. They are used for draft power and sold in other provinces. Grazing land is abundant.

Average farm size is 3 ha. Land preparation is largely by carabao. Power tillers



2. Resource flows in the farming system

and mechanical threshers are not common. Most threshing is manual. Labor is commonly hired for specific farm operations like land preparation and harvesting. Farm households are the source of hired labor in the community.

In Figure 3, the system is quantitatively presented in a matrix of rows and columns. Rows record input and output figures of a particular activity. Inputs are classified into land, labor, and power. They are expected to generate cash, paddy, upland crops, and livestock. (The presentation in Figure 3 is not the same as that commonly used in optimizing whole-farm models.)

In this illustration the year is divided into two periods corresponding to the first crop and the second crop. Other periods may be selected depending on the level of detail desired.

Family resources are entered in the first column. The example represents a 3-ha farm with 1 ha plateau, 1 ha sideslope, and 1 ha of knoll area. Activity columns are separated into activities that occur within and outside (markets) the farm. Because paddy and livestock production play major roles in the farming system, two production activities are listed: crop raising (classified into rice and upland crops), and livestock raising (generally carabaos, used in crop production or sold).

In addition to generating output through production activities, the household consumes its produce and purchased items. Household consumption of crops and other items is recorded in the within-farm consumption section.

Activities that involve markets or the external sector are located in the second section. In the example labor, power, inputs, capital, and products are active markets relevant to the system. There is not an active land market because the farmers in the settlement area own their land.

The figure should be read from right to left, beginning with within-farm activities. For example, rice production requires 1 ha of plateau and 1 ha of sideslope land in the first crop period. To farm these 2 ha, the farmer needs 79 working days of labor and 26 working days of carabao power. For this activity he would require ₱2338 which in turn would give him a 7.17 t/ha yield from both land types.

Of the paddy output, a percentage is consumed by the household. It is recorded in the paddy consumption column as a negative figure in the paddy balance row. The minus sign indicates a deduction from the existing paddy balance. The same occurs in the nonpaddy crop balance and livestock balance rows when the household consumes some of the output from these activities.

To produce the rice crop, the farmer must purchase necessary inputs from the external sector. If available family labor is inadequate for total labor requirements, labor must be hired from the labor market. The table separates labor hiring into preharvest (PH) and harvest (H) labor. For example, the farmer had to hire 18 man-days of PH labor and 32 man-days of H labor in the first crop period. If the farmer and members of his household work as hired labor during their slack periods, these activities are recorded in the labor hiring-out column. Entries in these columns show that an active labor market is present in the area.

Because the farmer has enough carabaos for land preparation activities, there is no entry in the carabao hiring-in column. The farmer might hire out carabaos to other farmers.

	Family resources	Within farm																
		Production						Consumption						Lal				
		Crop raising				Animal raising		Crops				Animal	Other	In				
		Rice		Others		Power	Sale	Rice		Others				1		2		
		1	2	1	2			1	2	1	2			PH	H	PH	H
Land (plateau, 1st crop/period)	1 ha	1																
Land (plateau, 2d crop period)	"		1															
Land (side slope, 1st crop period)	"	1																
Land (side slope, 2d crop period)	"		1															
Land (knoll, 1st crop period)	"			.25		.25	.25											
Land (knoll, 2d crop period)	"				.25	.25	.25											
Labor (1st crop period) (man days)	Z	29		x										18	32			
Labor (2d crop period) (man days)	Z		21		x											14	2	
Power (1st crop period) (man days)	SO	26		x														
Power (2d crop period) (man days)	SO		25		x													
Cash (1st crop period)		2438		x		x	x	x		x		x	x	x				
Cash (2d crop period)			1026		x	x	x		x		x	x	x			x		
Rice balance (1st crop period) (cavans)		163						x							x			
Rice balance (2d crop period) (cavans)			150						x									x
O[illegible] balance (1st crop period) (cavans)		x								x								
O[illegible] balance (2d crop period) (cavans)			x								x							
Livestock balance (1st crop period)						x	x					x						
Livestock balance (2d crop period)						x	x					x						
Crop residues						x	x											

3. Matrix of farm household activities in the farming system. This represents a 3 ha farm: 1 ha plateau, 1 ha lowland side slope, 1 ha upland. x denotes data are not available, minus x refers to subtractions from the system. Land rentals are not included because farmers are all landowners within the settlement area.

Material inputs, recorded in value terms, required for production are entered in the input purchase column as a deduction from the cash balance row. In the example, MAO was spent on material inputs in the first period.

Borrowings from the capital market are entered in the loans column. Amount borrowed is entered as a positive figure to show additions to the system. Payments at the end of the season are entered with negative figures under the payments column because they are outflows. The capital market is also divided into formal and nonformal sectors. Most farmers in the area use nonformal credit and the borrowed amounts are usually small. The substantially higher level of payments shows that interest rates are high.

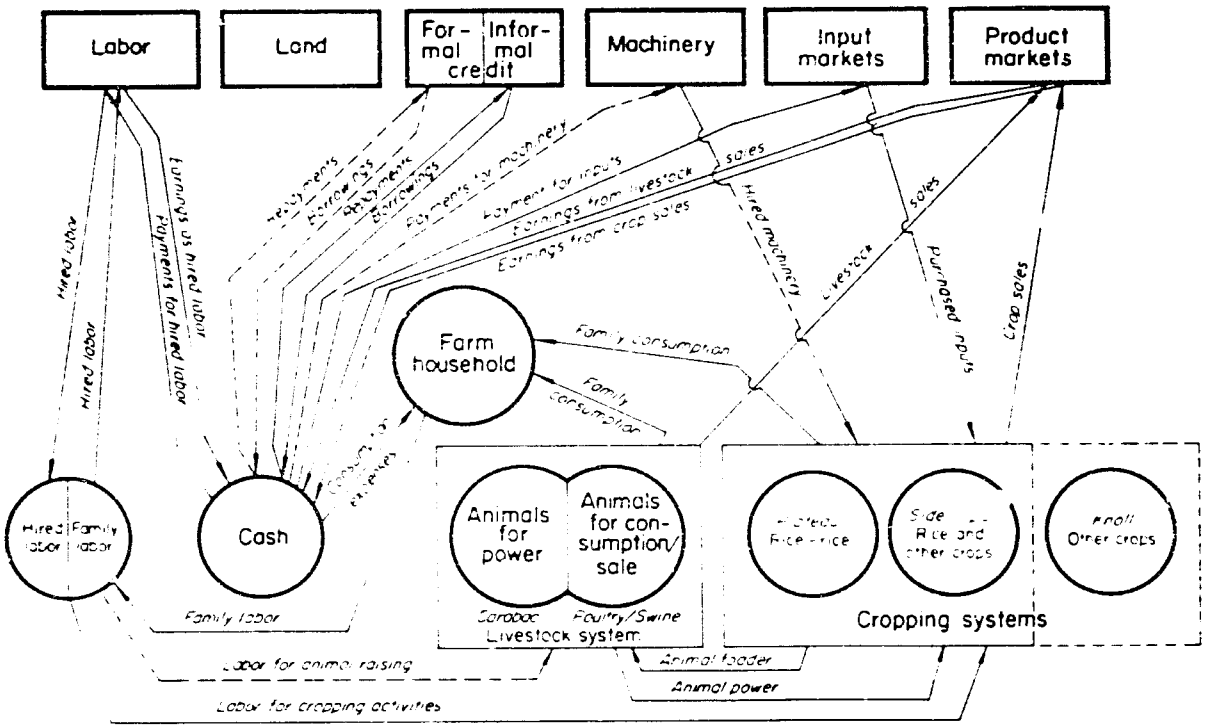
Markets																						
…ring			Carabao						Capital								Product					
Out			hiring				Input		Loans				Payments				Crop sales				Livestock	
1	2		In		Out		purcha.		F		II		F		II		Rice		Others		Buy	Sell
II	PH	II	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2		
−x																						
	−x	−x																				
	x						605		1350		467		−x		−x		x		x		−x	x
								516		1350		346		x		x		x		x	−x	x
x																	−x					
		x																x				
																			x			
																				x		
																					x	−x
																					x	−x

Sales are recorded in the cash row, depending on whether they fall under rice, other crops, or livestock. These values are entered in their respective columns. Product sales constitute an inflow to the system and are denoted by positive figures.

The paddy balance row shows the amount left after consumption and paddy sales each season. Similar data are entered in rows for other crops and livestock.

The model describes the farming system in a tabular manner. The right side shows where the farm household acquires its inputs and disposes of its output. The figure shows the system basically depends on paddy production. Paddy production uses the most land, labor, and power. It also provides the biggest share of cash generated by sale activities, and is the farm household's major source of income. Although subsistence farming activities are dominant, market exchanges also play an important role in the system.

Figure [illegible] also shows the interaction of subsystems within the whole farm framework. Crop residues generated by the crop subsystem provide the livestock subsystem with fodder. Similarly, carabao raising provides draft power for crop pro-



4. Resource flows in farming system in Capiz.

duction. Because they are substantial crop-livestock interactions, changes in one subsystem's technology could cause substantial changes in the other subsystem. For example, if power tillers were to become popular, the importance of carabao raising would probably diminish.

Using the tabular presentation, weak and strong flows in the system can be reformulated to provide the graphical representation in Figure 4. By using solid lines to show strong linkages and flows and broken lines to show weaker ones, researchers can illustrate specific resources and activities relevant to the technology design and testing process.

In this figure, land markets are eliminated because tillage rights are not bought and sold. The machinery market is linked with a broken line because of its minor role in the production process. The link with the nonformal credit sector is shown by a solid line. The formal sector link is shown as a weak relationship. The livestock subsystem is connected to the crop subsystem with a solid line to denote strong interaction. The labor resource is divided into family and hired. Hired labor is used only in the crop subsystem. Livestock is raised using family labor only.

This kind of presentation helps researchers understand what is happening on the farms and helps them make better decisions about kinds of research to be conducted. It is a method to study effects of changes in farming technologies within a whole-farm framework and to develop technologies best suited to a farming system.

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CHAPTER 9

DETERMINING OPTIMUM FERTILIZER RECOMMENDATIONS

R. A. MORRIS

The determination of optimum crop fertilizer rates is one of the most common research areas that use agronomic and economic analytical tools. Fertilizer is one of many components in a technology package, but in terms of its impact on productivity, and because of modern fertilizer-responsive high-yielding crop cultivars, it plays a crucial role in modern agricultural technology.

Different crops and crop cultivars at the same site respond differently to fertilizers. Responses are markedly different across sites. Even when fields with similar soils and water regimes are selected, different field-to-field fertilizer responses are expected. Variations occur because of differences in soils, pest management, local weather, and crop history. In some fields, large amounts of fertilizer may have been applied, leaving residual fertility. In other fields, nutrient availability to a following crop may be high because drought caused only small quantities of nutrients to be used by the preceding crop.

Despite these differences, it is common to have nationwide fertilizer recommendations for major crops such as rice. Recently, however, many countries have made progress toward developing recommendations for land with similar characteristics, hereafter referred to as *recommended domains*, following the terminology used by Zandstra et al (1982). In many Asian countries the spread of cropping systems research activities has led to extensive on-farm research. In these situations agronomists and economists are challenged to develop appropriate fertilizer recommendations for a given land type.

In this chapter we discuss methods for determining optimum fertilizer recommendations for several land types within a cropping systems research site. Field-to-field variability, of course, prevents any rate from being exactly optimal for a large number of fields. Economists may not be involved during every experimental stage that will generate data for economic analysis. However, economists who interact with agronomists in the final economic analysis of experiments should be aware of and appreciate procedures used in earlier stages. Therefore, all major steps used in fertilizer rate research at a site will be discussed in this chapter.

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PRELIMINARY QUESTIONS

To determine fertilizer rates for cropping patterns, ask some of the following questions:

- What is the crop and what is its nutrient requirement for high yields?
- What is known about nutrient uptake patterns during crop growth?
- What is the soil and how much of each required nutrient can it supply?
- What are the current fertilizer recommendations for each soil mapping unit or region? Is it easy to obtain a soil analysis and are the test data for the soils reliable? (Has the soil test been calibrated for the soils and crops?) Early in the project it may be sufficient to know if an element is deficient. Later it may be necessary to determine optimum levels for several recognized land types. Ultimately, researchers may need to determine carry-over or residual effects and to compare practical methods of improving fertilizer efficiency.

Other questions relate to the capacity to do research:

- How diverse is the study area?
- How large is the research staff and how familiar are they with soil fertility research, experimental design, and data analysis methods?
- What are the immediate and long-range objectives of the project?

The analysis and interpretation of data — a fertilizer study is not complete until data are properly interpreted — ask the following questions.

- What are fertilizer and product prices?
- Will farmers use government-sponsored production loans to buy fertilizers?
- Will fertilizers be subsidized or will a current subsidy be reduced?
- How specific must fertilizer recommendations be? Can a specific recommendation be justified?

The research method will be affected by background information such as past fertilizer response experiments, soil test results, soil maps, and related information. The size and experience of research staff, and the complexity of the site also will affect research.

Recommendations are often made in bags of fertilizer materials or increments of 10 or 20 kg/ha. Data that permit greater precision in estimates are unnecessary and costly.

ALTERNATIVE METHODS

At the start of fertilizer rate research, examine each land type selected for cropping systems research at the site (see chapter 3, Selection of land types). Soil types, textural classes, predominant mineralogy, and hydrological conditions should be noted. Soil maps and previous research should be examined and soil scientists consulted to determine what mineral deficiencies to expect. The cropping pattern design process will determine the crops and their growing periods for which fertilizer recommendations must be determined. For these crops the approximate requirements for nitrogen, phosphorus, and potassium are generally known and will provide a starting point for initial cropping pattern design and fertilizer recommendation trials.

Two methods are described. They differ in design and analysis complexity and in conceptual intricacy.

- Example 1. Assume, based on previous studies in the area, that the crop responds to 50 kg N/ha. Phosphorus and potassium responses are uncertain. Your interest is to test the response to higher nitrogen rates and for phosphorus and potassium deficiencies. You have personnel to conduct a moderately large conventional experiment and six small superimposed N-P-K trials and you have a staff member who understands computation of basic statistical analysis with a pocket calculator.

The method in this example evaluates several treatment combinations in which fertilizer response may occur. An example of a test for treatment interactions with fields is also explained.

Analysis of variance procedures are the most widely used statistical tool in many agronomic experiments, including fertilizer trials. Economists with a multidisciplinary team should become familiar with this technique. Analysis of variance procedures for rice research are described by Gomez and Gomez (1976). In subsequent discussions we shall assume that readers have this basic familiarity.

Twelve selected treatment combinations for conventional experiments are shown in Table 1. A subset of six treatment combinations was chosen for superimposed trials (Table 2). It will permit you to examine response to phosphorus, potassium, the phosphorus-potassium interaction at 70 kg N/ha, and nitrogen response without phosphorus or potassium fertilizer. The analyses of variance are also presented in Tables 1 and 2.

In addition to the routine analysis of variance on the superimposed trial, the Error Sum of Squares (Error SS), which is computationally equivalent to a Block X Treatment interaction SS, was partitioned into a Block (linear) X Treatment interaction SS ($B_l \times T$). If there is a Block X Treatment interaction, which is apt to occur when there are major field effects, the interaction will likely be most strongly expressed in the Block (linear) X Treatment component. By subtracting the $B_l \times T$ SS from the Error SS, the remainder (Block [deviation] $\times$ Treatment SS) is expected to be a more correct estimate of the Error SS. An F-test on $B_l \times T$ will suggest whether the $B_l \times T$ and the $B_{dev} \times T$ should be considered part of the Error SS. When the $B_l \times T$ SS is large, treatment responses are not uniform over fields. Depending on the interaction term, some treatment responses will increase or decrease as field means increase.

In this analysis of superimposed trial data, treatments did not strongly interact with block means. Therefore, the appropriate analysis of variance is that without error partitioned, i.e. the original analysis of variance of superimposed trial data.

The analyses of variance on the conventional experiment and the superimposed trials show that treatment differences occurred. Phosphorus and potassium did not influence yield, but nitrogen did. The results (yield levels, treatment responses, and error) of the two experiments are in approximate agreement, suggesting that similar response to fertilizer applications would occur in many area fields.

Economic analysis of nitrogen response data can be done, but it appears that response over the range tested was linear. Therefore, using a simple profit-maximizing assumption, the highest nitrogen rate would be more profitable than the

Table 1. An example of a conventional 12-treatment nitrogen-phosphorus-potassium fertilizer experiment.

Treatment no.	Treatment designation			Grain yield (t/ha) by farm				
	N	P	K	R_1	R_2	R_3	R_4	X
1	50	0	0	3.54	4.11	3.47	3.39	3.62
2	50	0	30	4.05	3.83	4.12	3.16	3.79
3	50	30	0	4.15	4.12	3.59	3.52	3.84
4	50	30	30	3.50	4.18	4.00	4.02	3.92
5	70	0	0	3.90	3.85	4.17	3.94	3.97
6	70	0	30	4.30	3.87	3.96	3.43	3.89
7	70	30	0	4.10	3.68	4.22	3.91	3.98
8	70	30	30	3.91	4.30	4.07	4.16	4.11
9	90	0	0	4.09	4.31	4.59	4.32	4.33
10	90	0	30	3.94	3.87	4.07	4.63	3.88
11	90	30	0	3.92	4.10	4.07	4.03	3.03
12	90	30	30	4.08	4.07	4.49	3.93	4.14

Source	DF	ANOVA		
		SS	*MS*	*F*
BLOCKS	3	0.265	0.088	
N	2	1.036	0.518	6.55
P	1	0.266	0.266	3.36
K	1	0.252	0.252	3.18
N × P	2	–	–	
N × K	2	0.00	–	
P × K	1	0.00	–	
N × P × K	2	0.00	–	
Error	33	2.611	0.0791	
		P-	P+	
Yield (t/ha)	K-	3.97	3.95	
	K+	3.85	4.06	
		. . . . .	. . . . .	
		N_{50}	3.52	
		N_{70}	3.86	
		N_{90}	4.23	

middle rate, provided the cost of an increment of nitrogen is less than the value of additional yield. If responses are similar to nitrogen responses in this example, input availabilities, cost constraints, and risk factors should be considered jointly by agronomists and economists.

If farmers in the area have adequate funds to invest in high fertilizer levels, researchers can test fertilizer response at even higher nitrogen levels to discover the level at which additional yields begin diminishing. If farmers' resources are low and/or the risk levels are high (with high probabilities of crop failure due to drought, floods, etc), the optimal rate can be decided by using a specified expenditure limit which is likely to be an upper limit of what most farmers can spend on fertilizer.

- Example 2. This example shows a more complete definition of the yield response to fertilizer. It allows optimum rates of two nutrients for different cost-price relationships to be calculated. This example also includes a complete analysis and economic interpretation. In a site where five or more crops are managed in cropping patterns, this more complete approach should be confined to the most important and most responsive crops.

Assume that you know the upper limits of fertilizer response for both nitrogen and phosphorus, and that potassium is not limiting in the research area. Furthermore, you strongly suspect that nitrogen is more limiting than phosphorus and you have personnel to conduct 6-10 experiments using 9-12 treatment combinations replicated twice in each field.

To decide the rates, use the five-step method shown schematically in Figure 1.

1. Determine experimental fertilizer ranges and select test levels based on soil tests, previous experiments, or both, on similar soils.
2. Determine rational treatment combinations based on fertilizer prices and crop nutrient requirements, eliminating treatment combinations that will be uneconomic.
3. Allocate experiments to fields within recognized land types, using 2 replications/field in at least 6 fields to sample for yield variability.
4. Review the data statistically by computing analyses of variance on each experiment, and inspecting treatment and error mean squares and treatment means for extreme behavior.
5. Determine economically dominant fertilizer rates by plotting benefits against costs.

In the first step, collect information about general soil fertility in the research area. Logical sources of information are reports on fertilizer experiments and soil test results. Identify nutrient application limits that are thought to satisfy the needs of the crop being studied.

To determine reasonable fertilizer rates for crops in patterns being tested in the first year, the same fertilizer response information should be available as that required to determine the limits for the fertilizer experiments. Generally the levels used in the first year are between 50 and 75% of the limiting level used in the fertilizer-rate experiments. In the second year cropping pattern fertilizer levels are adjusted using results of fertilizer trials and after consultation with the site economists. It is impractical, however, to refine rates more precisely than 10-20 kg N/ha and 5-10 kg P_2O_5/ha for recommendations targeted at major land types.

In the example, fertilizer limits were 135 kg N/ha and 60 kg P_2O_5/ha. Nitrogen was the primary limiting element, and all treatments, except the nonfertilized control, contained some level of nitrogen. Nitrogen-phosphorus treatment combinations roughly bracketed the expected expansion path. Note that resources are not wasted by including high phosphorus rates limited by low nitrogen levels, or high nitrogen rates limited by low phosphorus levels.

Remember that the objective is to determine fertilizer recommendations for a crop in a cropping pattern, not to show nitrogen-phosphorus interactions.

Following the procedure, treatment combinations were formed at constant intervals (0, 45, 90, and 135 kg for nitrogen, and 0, 20, 40, and 60 kg for P_2O_5). The

Table 2. An example of a superimposed 6-treatment nitrogen-phosphorus potassium trial in tons per hectare × 100.

Treatment no	Treatment	Grain yield (t/ha × 100) by farm						
		1	2	3	4	5	6	$\bar{X}$
1	50-0-0	3.36	4.34	4.51	4.11	4.02	3.75	4.02
2	90-0-0	4.39	4.16	5.06	4.59	4.82	4.31	4.56
3	70-0-0	4.43	3.66	4.57	3.70	4.54	3.50	4.12
4	70-30-0	4.12	4.19	4.12	3.98	4.99	3.84	4.21
5	70-30-30	4.16	3.66	4.82	3.20	3.97	4.02	4.06
6	70-0-30	4.17	3.77	4.93	3.64	4.90	3.87	4.21
$\bar{X}$		4.10	4.02	4.67	3.95	4.54	3.88	

Analysis of variance

Source	df	SS	MS	F
Total	34	69,071		
Farms	5	32,178		
Treatments	5	11,212	2,242	
N	2	9,837	4,918	4.79
Remainder	3	1,375	458	< 1
Error	25	25,683	1,027	

Treatment no	S_{xx}	S_{xy}	S_{yy}	Reg SS	Res SS
1	5.445	3.011	8.589	1,665	6,924
2	5.445	4.822	5.697	4,327	1,369
3	5.445	6.457	10.554	7,760	2,794
4	5.445	4.015	8.004	3,000	5,004
5	5.445	4.973	8.712	4,420	4,292
6	5.445	9.042	16.501	15,216	1,085
Totals	32.672	32.220		32,389	

Analysis of variance

Source	df	SS	MS	F
Farms	5	32,178	6,436	
Treatments	5	11,212	2,242	
$B_i \times T$	5	4,615	923	< 1
$B_{dev} \times T$	20	21,066	1,053	

At 70 kg N/ha		− K	+ K
Yield, t/ha	− P	4.12	4.21
	+ P	4.21	4.06

At 0 P and 0 K		
Yield, t/ha	N_{50}	4.02
	N_{70}	4.12
	N_{90}	4.56

$$\Sigma \text{ Reg } SS \quad \frac{(\Sigma S_{xy})^2}{\Sigma S_{xx}} = B_i \times T$$

$$16,389 \quad \frac{(32,220)^2}{32,672} = 4,615$$

Continued on opposite page

Table continued

Terms and computations

Sxx is sum of squares of block (farm) means. The value is the same for all treatments.

$$Sxx = 4.10^2 + \ldots 3.88^2 - 6\,(4.19)^2$$
$$= 5.44$$

Sxy is sum of cross-products between block means and treatments. For Treatment 1

$$Sxy = 3.36 \times 4.10 + 4.34 \times 4.02 + \ldots + 3.75 \times 3.88 - 6\,(4.02)\,(4.20)$$
$$= 3{,}011$$

Syy is sum of squares of treatments. For Treatment 1

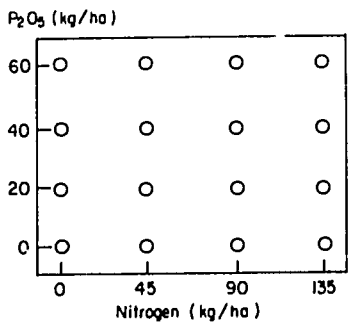
$$Syy = 3.36^2 + 4.34^2 + \ldots + 3.75^2 - 6\,(4.02)^2$$
$$= 8{,}589$$

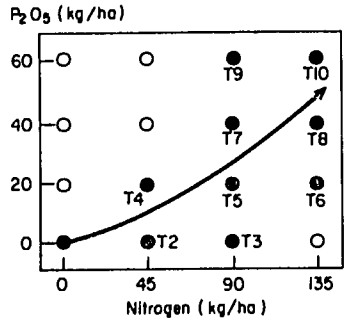
Reg SS is sum of squares of regression. For Treatment 1

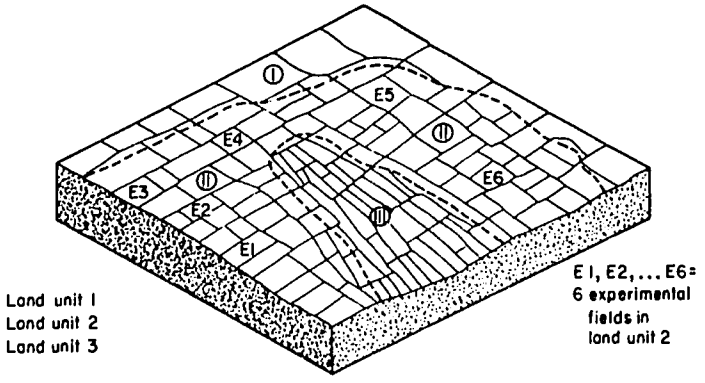
$$\text{Reg SS} = (Sxy)^2/Sxx = (3011)^2/5{,}445 = 1{,}665$$

$B_L \times T$ is Block (linear) $\times$ Treatment interaction.

$$B_{Ldev} \times T = \text{Error SS} - B_L \times T = 25{,}681 - 4{,}615 = 21{,}066$$

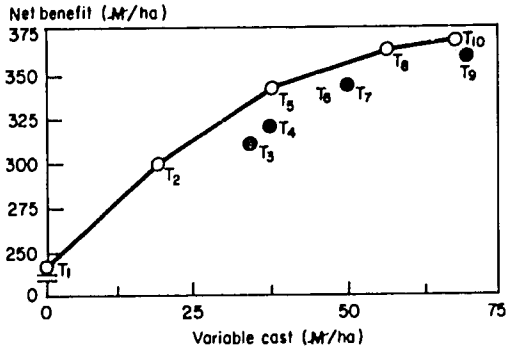






Analysis of variance

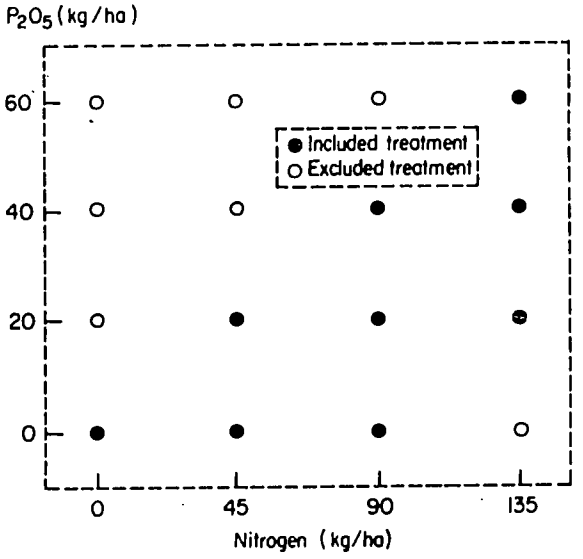
Source	*df*	*F*
Replications	1	
Treatments	9	**
A. T2-T5		
N	1	**
P	1	**
NP	1	*
B. T5-T10		
N	1	**
P	2	*
NP	2	ns
Error	9	



1. Five steps to determine economical fertilizer rates by field experimentation.

treatment design is shown in Figure 2. The most appropriate number of treatments for these kinds of studies is 9, 10, or 12.

Following the field phase of the study, review data for reliability. Inspect data for missing values (which may be estimated in most cases) and values that are obviously erroneous (extremely high or low). When a value is suspect, it should be recalculated from raw data to determine if computation errors were made. Staff members who frequently observe the experiment in the field should be asked about suspect



2. Included and excluded treatment combination.

numbers. If no valid cause of value error can be found, and the value is within biological possibilities, it should be assumed correct and part of the natural variability in the population.

Statistical partitioning of the Total SS into Rep SS, Treatment SS, and Error SS will aid the data review process by calling attention to two types of errors:

1. Obviously erroneous data, usually from one or two plots with very high or low values that cause inflation of experimental error, and
2. Treatment behavior that is clearly different from other fields, such as no yield response to any treatment, despite a low coefficient of variation.

In the statistical analysis, the coefficient of variation (CV) should be from 10 to 12% for good sensitivity in the tests. CVs exceeding 25% indicate major yield differences within the same treatment, even after the effect of replications is removed. Experiments with such high CVs seldom will generate a feeling of satisfaction, even if treatment differences are large enough to be detected.

Further partitioning of Treatment SS can be used to isolate the contributions of nutrients to yield increases. Where data on other attributes such as plant height, straw weight, stand or tiller counts are recorded, statistical analysis of these attributes can strengthen the convergence of evidence of the yield response to nutrients.

Convergence of evidence is important when analyzing low sensitivity data (i.e. the CVs are greater than 15%) or when yield differences between treatments are not substantial (below 1 or 5% significance level). By applying statistical tests to many attributes a pattern consistent with underlying basic principles (e.g. phosphorus fertilizer promotes tillering; both nitrogen and phosphorus increase plant height) can be shown. In such a case, there is strong evidence that statistically significant yield differences at the 10 or 15% level are due to true responses to applied nutrients, and not to chance variability.

Table 3. Summary of frequency of treatment significances obtained in 9 experiments.

Source	df	Frequency
First factorial set[a]		
N	1	7
P	1	4
N x P	1	0
Second factorial set[b]		
N	1	4
P	1	1
N x P	1	0

[a]N = 45 and 90 kg/ha, and P_2O_5 = 0 and 20 kg/ha. [b]N = 90 and 135 kg/ha, and P_2O_5 = 20 and 40 kg/ha.

Table 4. Degrees of freedom and mean squares of analysis of variance on grain yield as affected by nitrogen and phosphorus fertilization in 4 of the 9 farm fields.

Source of variance	DF	Analysis of variance on grain yield (t/ha) in field[a]			
		1	2	3	4
Replication	1	427.49**	276.83ns	287.28*	0.53
Treatment	8	3,255.28**	3,422.50**	2,051.11**	2,423.50**
Error	9	15.49	84.07	40.44	37.22
		Planned comparisons based on 2 x 2 factorial N (45 and 90 kg/ha) and P_2O_5 (0 and 20 kg/ha)			
N	1	606.65**	521.73*	243.60*	203.52*
P	1	239.78**	472.88*	165.31ns	68.12ns
N x P	1	47.28ns	169.07ns	1.92ns	39.76ns
		Planned comparisons based on 2 x 2 factorial N (90 and 135 kg/ha) and P_2O_5 (20 and 40 kg/ha)			
N	1	414.96**	179.70ns	90.95ns	615.50**
P	1	54.45ns	59.00ns	77.82ns	105.57ns
N x P	1	17.11ns	1.17ns	5.25ns	0.33ns

[a]*significant at the 5% level. **significant at the 1% level. ns, not significant.

In this example (Ali 1980), the nine treatment combinations (kg N/ha and kg P_2O_5/ha) were:

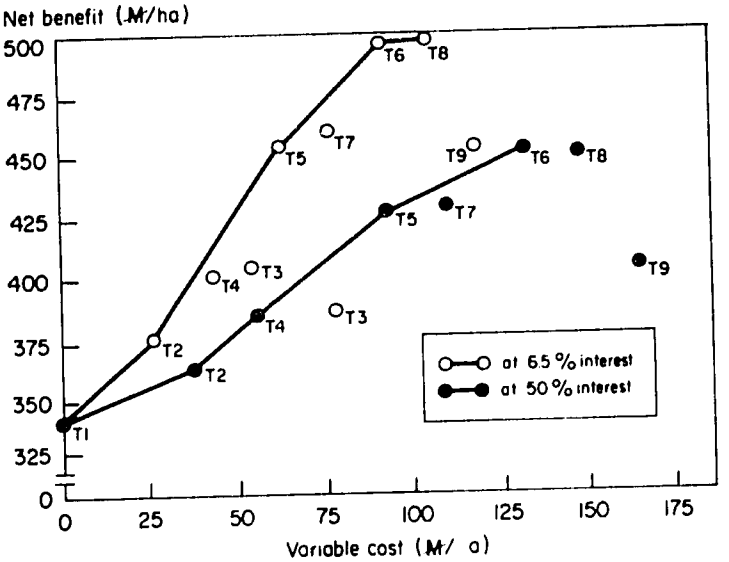
T1 — 0-0	T4 — 45-20	T7 — 90-40
T2 — 45-0	T5 — 90-20	T8 — 135-40
T3 — 90-0	T6 — 135-20	T9 — 135-60

Treatment effects were significant in each experiment analyzed separately. Two 2 X 2 factorial sets of treatment combinations from within the full set were examined separately. Frequencies of significant effects and interactions are summarized in Table 3. Examples of analysis of variance are shown for four fields in Table 4. The summary table shows that nitrogen and phosphorus produced additive effects at

Table 5. Partial budget for grain yields, variable costs, and net benefits of 9 fertilizer treatments, at 2 interest rates.

Treatment no.	T1	T2	T3	T4	T5	T6	T7	T8	T9
Fertilizer rates (N-P_2O_5)	0–0	45–0	90–0	45–20	90–20	135–20	90–40	135–40	135–60
Av grain yield (t/ha)	3.67	4.37	5.03	4.78	5.65	6.33	5.84	6.48	6.16
Net yield (t/ha[a])	2.91	3.46	3.98	3.78	4.47	5.01	4.47	5.13	4.87
Gross field benefit[b] (₥/ha)	339	403	463	440	520	583	538	597	568
Fertilizer cash cost[c] (₥/ha)	0	25	51	36	62	87	73	98	109
Other variable cost and interest at 6.5%	0	3	4	4	4	6	5	7	8
Other variable cost and interest at 50%	0	14	26	20	32	45	37	50	56
Net benefit, 6.5% interest	339	375	408	400	454	490	460	492	451
Net benefit, 50% interest	339	364	386	384	426	451	428	449	403

[a]Assuming one-sixth share goes to harvesters, and field losses are 5% for a total reduction of 20%. [b]At ₥116/t of net yield. [c]At ₥0.55/kg N and ₥0.56/kg P_2O_5.



3. Net benefits and variable costs of 10 fertilizer treatment combinations, at 2 interest rates.

intermediate (first factorial set) and high fertilizer rates (second factorial set). Significant nitrogen and phosphorus effects were frequent at intermediate levels, but only nitrogen effects were common at high levels.

To the farmer the most important question is "Will fertilizer be profitable?" You can examine profitability more realistically by using marginal analysis than by comparing net profits from the treatments tested (see discussion on researcher-managed trials in Chapter 5). Marginal analysis involves estimations of net yields, gross field benefits, and total variable costs, and calculation of the marginal benefit-cost ratio (MBCR) to each increment of variable cost. (A comprehensive discussion of the economic concepts and their application in analysis is given in Perrin et al 1976.)

Using results from this example, net yield was calculated as the measured yield per hectare in the field, less a 5% harvest loss and a one-sixth harvester share. Gross field benefit equals net yield multiplied by field price. Total variable costs equal the sum of the fertilizer cost, the cost of fertilizer topdressing applications, and interest on variable costs. Costs and prices assumed are in Table 5. Two cases were examined; one where interest was computed as 6.5% (institutional credit rate) and the other at 50% per half year (village moneylender's rate). Net benefit was computed as gross field benefit less total variable cost. Partial budgets of the 9 treatments, using mean yields over the 10 experiments, are presented in Table 5.

Net benefit curves were constructed by plotting the variable costs of the alternative fertilizer rates against their net benefits (Fig. 3). Only treatments that form the upper boundary (efficient frontier) of the net benefit relationship to available cost should be considered. T9 and T3 were inferior to other alternatives. For the treatments that

form the efficient frontier, Table 5 can be used to calculate MBCR for each cost increment:

Treatment increment	Added gross benefit (₱/ha)	Added cost[a] (₱/ha)	MBCR
T1-T2	64	28	2.3
T2-T5	117	38	3.1
T5-T6	63	26	2.4
T6-T8	14	12	1.2

[a]At 6.5% interest.

The MBCRs were high where fertilizer applications were low but relieved limiting nutrient supplies. The MBCR obtained by shifting 90-20 (T5) to 135-20 (T6) was 2.4 at the 6.5% interest and 1.7 at the 50% interest. Beyond 135-20 returns decreased rapidly.

Although 90-20 produced a MBCR near or greater than 2 for both interest rates, fertilizer cost of ₱62/ha was required. This was high in relation to most farmers' fertilizer expenditures in the research area. A 70-15 rate, determined by interpolating rates used in the experiments, would provide a high rate of return under a ₱50/ha fertilizer material restriction.

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CHAPTER 10

ECONOMIC ANALYSIS OF NEW TECHNOLOGIES

G. R. BANTA AND S. K. JAYASURIYA

The need for economic evaluation of new technologies — new cropping practices and cropping patterns, new farm implements and machinery — is now widely accepted by agricultural researchers.

Economic evaluation can be done before technologies are released to farmers or after they are released, when farmers have had the opportunity to accept or reject them. Evaluation done before a technology is released is ex ante evaluation; done afterward it is ex post evaluation.

Ex ante evaluation is usually used to determine if new farming technologies (cropping patterns or component technologies) developed for a particular farming site using site research are acceptable to farmers and if they will improve farmer welfare. The assessment is made before recommending any new technology.

A new technology can be evaluated from many points of view. The most common economic evaluations are done using the individual farmer's point of view or society's point of view.

Technology that benefits individual farmers may not be desirable from society's point of view. For instance, using tractors may increase farmer profit but may not be beneficial for society if landlessness and unemployment are widespread.

Methods for analyzing the economic dimensions of a new technology likely to be desired by farmers will be discussed in this chapter. There can be other factors, such as the managerial complexity of a new technology or social barriers, that affect farmer adoption. In each situation researchers must be sensitive to these factors to thoroughly evaluate a new technology. The innovation being evaluated can be a component technology (a new fertilizer treatment for a crop), a new crop (with associated component technologies), or a new cropping pattern. Although the level of complexity increases as the process grows from evaluation of a simple treatment, to a crop, to a cropping pattern, the underlying principles are the same.

ANALYTICAL METHODS

A researcher in a crop research program must evaluate a new technology that will directly affect the cropping system or a component of the cropping system. Changing the rice crop establishment method from transplanting to direct seeding

only affects the rice enterprise directly; however, due to farm household interactions, such a change may cause major changes in other farm activities. Farmer adoption will depend on the whole-farm effect of adopting the new technology. The evaluation should consider direct and indirect effects of the new technology on the whole farm.

Rigorous, quantitative evaluation of new technologies in a whole farm setting can be conducted using mathematical programming methods. Of these, linear programming is the best known (Dillon and Hardaker 1980, Throsby 1970). However, such methods need volumes of data, substantial time and skilled personnel, and adequate computer facilities. Program planning or simplified programing is a simple procedure (Dillon and Hardaker 1980, Banta 1980, Jayasuriya and Chiew 1980). In many situations, particularly at site-level research, this technique is also difficult.

In site-level research the same results can be rapidly obtained using simpler methods. The following sections describe these methods. However, we want to stress that, irrespective of the method used, the quality of the evaluation depends on the researchers' understanding of the real farming situation.

The simple evaluation methods are based on budgeting techniques discussed in Chapter 3. Budgeting principles and procedures must be understood before continuing. We discuss new crop evaluation, but the principles are applicable to other new technologies.

Returns above variable costs (RAVC) gross margin criterion

New cropping patterns are designed for particular land types and are expected to replace present cropping patterns on that land type.

The simplest evaluation compares the economic performance of new technology to the dominant technology. This is plot level analysis because the activities in the land area (plot) are abstracted from the rest of the farm household.

In the first step of the evaluation procedure we compare the returns above variable costs (RAVC) (gross margin) expected from the new (or experimental) technology and farmer technology.

Figure 1 gives a set of decision points for evaluating the problem areas of a new technology. If the RAVC is higher further tests should be made to judge technology acceptability to the typical farmer. The RAVC of a new technology should be at least 30% higher than the farmers' technology or chances for farmer adoption will be low. This margin allows for farmer adjustment costs and the higher yields usually obtained from research plots which get better than average cultivation.

If new technologies give lower RAVC than farmer technology no further analysis of likely acceptance is needed. However, the 30% higher rule may not be an adequate guide to farmer adoption, and analysis should not stop at this point if agronomic research into new technologies is ongoing.

Analysis of new technology with RAVC less than 30% higher than farmer technology

If the RAVC is not acceptable, we should find out why it is low, then decide if more research is needed on what problem. Ask the following questions:

- If yield was lower than expected, why?

Steps	Decision points		Problem	Possible research areas
1.	Is RAVC acceptable	Yes		Test if technology is acceptable for farm resource base
	No			
2	Is yield acceptable	No	What is the cause?	Nutrients Pests Disease Timeliness Rainfall Management
3.	Is product price acceptable	No	Why?	Marketing Product quality
	Yes			
4.	Are input costs acceptable	No	Can quantity, type, or price be reduced?	Labor Power Fertilizer Chemicals
	Yes			
	Probably reject			

1. Decision analysis procedure for evaluation of new technology.

- If yield is acceptable, is the RAVC low because the product price was lower than expected?
- Is it a marketing or product quality problem?
- If the product price is acceptable, is one or more of the input costs unacceptably high?

If farmer resources are adequate to incur input costs, the new technology should probably be dropped from the research program if the RAVC is not acceptable. While working through this analysis several problem areas may be identified. They will help the researcher set priorities for future research.

Suppose a farmer's crop returns ₦ 1000/ha over variable costs. The new 4-month crop has the following levels and values:

Item	*Unit*	*Level/ha*	*Unit price (₦)*
Yield (Y)	kg	1000	2
Nitrogen (N)	kg	40	10
Phosphorus (P)	kg	10	30
Insecticide (I)	kg	1	100
Labor			
land preparation (Lp)	day	8	20
crop care (Lcc)	day	3	20
harvest (Lh)	day	7	20
Total cash cost (TCC)		₦ with 50% annual interest	

The equation for RAVC is
Gross return − total variable cost = RAVC
Gross return = Yield × Product price (+ by-product yield × price, if applicable)
Total variable cost = Σ Quantity of input × Input price
In this example,
Gross return = 1000 × 2 = 2000
Total variable costs =

Nitrogen 10 × 40	= 400
Phosphorus 30 × 10	= 300
Insecticide 100 × 1	= 100
TCC interest 800 × 50/100 × 4/12	= 133
Labor (Lp) 20 × 8	= 160
Labor (Lcc) 20 × 3	= 60
Labor (Lh) 20 × 7	= 140
Total	= 1323

RAVC = 2000 − 1323 = 677

The new technology RAVC is lower than the farmers' and not acceptable.

The next step in the analysis considers yield. Is the yield of 1,000 acceptable? In this example assume that it is. Assume that the price of the product is also acceptable. The decision on what is acceptable is subjective; however, members of the research team know what the input and output levels in previous research were. The final step considers input costs. The entomologist notes that an expensive insecticide was used and one that costs only ₦ 10/ha should work just as well. Should this be studied in the coming year? Probably not, as the savings on insecticide cost and interest charges would only increase the RAVC by 90+ (90 × 50/100 × 4/12) = 105. The new RAVC is 677 + 105 = 782, still less than the farmers' RAVC of 1,000. Nitrogen and phosphorus are the major costs. If nitrogen (N) was reduced from 40 to 25 and phosphorus (P) from 10 to 7 and the new cheaper insecticide used what yield would give the same RAVC as the farmer? The new variable costs would be:

N 10 × 25	= 250
P 30 × 7	= 210
I 10 × 1	= 10
TCC int 470 × 50/100 × 4/12	= 78
Labor Lp 20 × 8	= 160
Lcc 20 × 3	= 60
Lh 20 × 7	= 210
Total	978

Use the RAVC equation to find yield.

$$2 \times \text{Yield} - 978 = 1000$$
$$2 \times \text{Yield} = 1978$$
$$\text{Yield} = \frac{1978}{2}$$
$$\text{Yield} = 989$$

To compete with the farmers' crop the new crop would have to get the same yield using lower N and P levels. Therefore, the new crop seems to have little potential and research on it should be stopped.

An exercise such as this can prevent conducting research trials that have little hope of success. It allows the researcher to explore technology with potential.

If the new crop had been more profitable than the current crop, more analysis would be needed to decide if it is likely to be adopted.

Graphs

New technologies require greater resources, particularly cash and labor and often power, than traditional farming patterns. Some of these resources may be more scarce than others. An idea of how the new technology adoption can affect overall labor and power use can be obtained using graphical methods.

Table 1 shows a 1-year labor use pattern for a typical farm in a certain region that grows several crops on two land types. The farmer has 2 ha of lowland rice land where he traditionally grows a single long-duration variety and 1 ha of upland.

Researchers have developed a new rice - rice cropping pattern with the labor requirements shown in Table 2.

The change in labor requirements, if the farmer adopts the new pattern on his entire 2 ha lowland paddy, is shown in Table 3.

The new labor use pattern on the entire farm is shown in Figure 2.

Table 1. Present labor use.

Month	Lowland		Upland	Total
	Man-days/ha	Man-days/2 ha	Man-days/ha	Man-days
May	0	0	15	15
June	15	30	5	35
July	30	60	0	60
August	5	10	30	40
September	2	4	0	4
October	5	10	0	10
November	–	–	0	0
December	40	80	0	80
Total	97	224	50	274

Table 2. Labor requirement of new pattern.

Month	Man-days/ha	Man-days/2 ha
May	15	30
June	25	50
July	5	10
August	5	10
September	70	140
October	5	10
November	5	10
December	40	80
Total		340

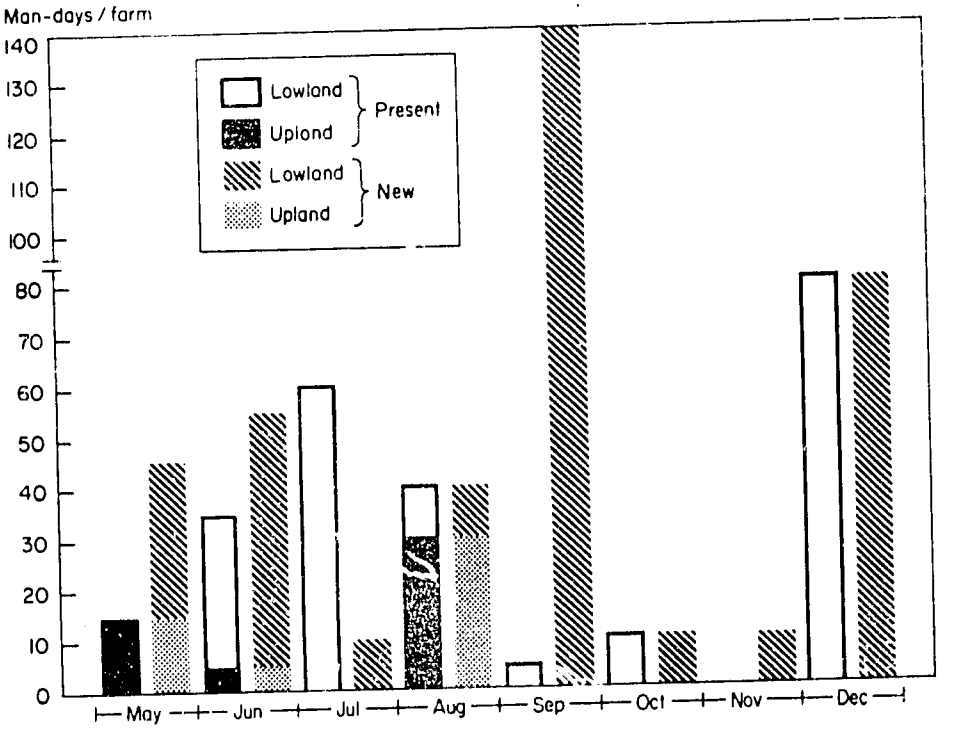
Table 3. New labor use pattern.

Month	Lowland man-days/2 ha	Upland man-days/ha	Total
May	30	15	45
June	50	5	55
July	10	0	10
August	10	30	40
September	140	0	140
October	10	0	10
November	10	0	10
December	80	0	80
Total	340	50	390

A major labor peak requiring an additional 136 man-days has developed in September because harvesting and postharvest operations for the first rice crop and land preparation and crop establishment of the second rice crop must be accomplished.

Can the farmer obtain this labor during September?

When asking such a question, bear in mind that if this pattern is widely adopted many farmers will need labor on this scale. The question can be answered only by studying labor supply in the area and the potential for labor migration from surrounding areas. This kind of analysis and questioning is particularly important



2. Present versus new labor use patterns.

when large-scale farmer adoption of a technology can significantly increase total demand for factors such as labor and power.

In cropping systems research the rates of return on costs incurred by new technologies can be used to predict new technology acceptance. The rate of return obtained from current technology reflects some of the resource constraints and other factors operating at farm level.

Experience at cropping systems research sites has shown that farmers will adopt cropping patterns that have a higher rate of return on total variable costs than patterns if resources are available (Price et al 1982). The rate of return on total variable costs is computed as gross returns/total variable costs, often called the benefit-cost ratio.

If a new technology requires high inputs (labor and cash) it is helpful to compute the rate of return to these factors for new and current technologies.

Ideally, the new technology should have equal or higher rates of return, but in practice the rate of return for cash often is lower than that from present technology because present technology uses little cash, causing the rate of return to cash to be high. In such a case examine the RAVC level and local interest rates to determine if farmers will find it attractive to invest their limited cash. The RAVC must be substantially higher than in the present system and the rate of return to cash must be higher than the interest rate paid during the crop growing period.

Return to labor should be higher than in the farmers' pattern. If an active labor market exists with opportunities for off-farm employment, it must equal the wage rate. If the return to labor is lower than the wage rate it implies that it is better for the farmer to do off-farm work. However, sometimes the return to labor from current farmer technology is lower than the off-farm wage rate. When this happens check to see that the assumed wage rate is not too high and whether farmers can always find outside work at this wage rate. If the new pattern is likely to produce peaks in labor use then it is useful to compute the return to labor during peak periods and compare it with the expected wage rate.

A further simple analytical step is to examine the *marginal benefit cost ratio* (MBCR), where

$$\text{MBCR} = \frac{\text{Added returns obtained by shifting to new technology (NT) from farmers' technology (FT)}}{\text{Added costs incurred by shifting to NT}}$$

$$= \frac{\text{Gross return of NT} - \text{Gross return of FT}}{\text{Total variable costs of NT} - \text{Total variable costs of FT}}$$

The MBCR should be equal to or greater than 2:1 for the new technology to be acceptable.

As emphasized in Chapter 3, all computations should be based on the real costs and returns to the farmer. Farm-gate prices should be used and appropriate adjustments should be made for the particular tenurial arrangements in the area.

It is also useful to examine total added costs, which shows the total increase in expenditure the farmer needs to incur to fully adopt the new technology. If the

researcher knows the typical farmer situation, credit facilities available, etc he may be able to judge the extent to which new technology adoption is feasible. Of course, if the innovation can be adopted on a small part of the land type, a relatively high added cost may not deter farmers from adopting the technology in stages.

Of the performance criteria discussed above, the most important criterion (or criteria) in evaluating a new technology depends on the specific site conditions. Researchers should follow the general rule that the returns to the constraining resource or resources are most important.

Performance variability and the associated risk can be an important determinant of farmer adoption. Mean values are a fair guide provided failures are included in analysis. Means and standard deviations (SD) can be used in comparisons. If means are similar the technology with a smaller SD is preferred. If the SDs are similar, the technology with higher mean is preferred.

In this discussion we have assumed that it is possible to identify a unique, dominant farmer technology on the relevant land type. Procedures for evaluating technologies where many important technologies with different resource productivities are found on the same land type are discussed by Zandstra et al (1981).

In these situations compare the less intensive farmer technology with more intensive experimental patterns and with more intensive farmer technologies on the same land type. Usually, the more intensive farmer technologies are intermediate between low intensive technologies and researcher technologies. We should examine why farmers do not use the more intensive farmer technology on all of the particular land area.

Certain physical factors may limit adoption of the new pattern. In an area broadly classified into a certain land type, it is sometimes possible to find important differences that affect cropping performance. If this is the case, then there is no need to compare low intensive and more intensive systems in economic terms.

On the other hand, some resource limitations may prevent farmers from adopting the more intensive farmer system on the whole area. In this situation compare the added net benefits of shifting from the present system to any alternative, including the farmers' more intensive system, using the methods discussed in the preceding sections.

FARM-LEVEL CONSIDERATIONS

Performance criteria based on budgeting procedures can be useful for evaluating a new technology, but they may be inadequate to provide a sound assessment by themselves, particularly if changes in the component being studied significantly influence other farming activities. Although techniques that allow rigorous quantitative whole-farm level assessments are difficult to use in many situations and almost impossible in site-level analysis, we are not forced to ignore whole-farm considerations when using simple analytical tools.

What is most important is to think about the whole-farm impact of a change in one component.

Consider, for example, a situation where cattle are important to the farmer. They may be important sources of power, nutrients, and/or fuel (for example, cattle dung is one of the most important sources of fuel in many parts of the Indian sub-

continent). Much of the fodder may come from crop residues. If we are evaluating the effects of introducing a dwarf rice variety to replace a traditional tall variety, it is important to realize that the supply of fodder will be reduced.

If we remember this when we construct our budgets we should include the value of straw in our calculations. When doing that, remember it is possible that the present price of straw in the region is lower than the cost the farmer may have to pay if he is forced to buy straw to feed his animals in the future. If many farmers adopt the new rice variety, the total straw supply in the region will diminish and straw prices will rise.

For another example, early land preparation and crop establishment in lowland paddies permit a profitable two-crop system to be established in certain areas of the Philippines. However, the change in timing of operations requires that farmers allocate labor away from the dryland components of their farm during this period, causing lower returns from dryland areas.

If we understand the farming system and carefully examine the effects of a change in one component on other components, we can adjust budget analysis to reflect all costs and returns. Even if precise quantification of some costs is difficult, estimates can be made that will result in a better evaluation.

Another source of valuable information for evaluating a technology are farmers who have used the technology. Researchers at cropping systems research sites should tap the experiences of the farmers who are cooperating in testing new technologies. Farmer adoption of a new technology is the real test. If farmers who have seen and experienced the new technology do not adopt it, it is usually a clear sign, irrespective of all calculations, that there are problems. A study of reasons for nonadoption can identify the problems and help modify the technology to better suit the farmers' situation. It may also provide policy makers useful information about farm-level constraints to the adoption of better technologies.

All these procedures help us tell if a new technology will be more productive for and acceptable to farmers. However, farmers are not the only people involved in agricultural production. Landless laborers are an important group that performs agricultural tasks and derives livelihood from agriculture. Farmer adoption of new technologies can affect them, sometimes positively, and sometimes negatively.

In Chapter 6 the procedures for computing factor share were discussed. These can be computed for the new technology to obtain an assessment of the likely impact on employment and incomes of landless laborers. The new technology should be analyzed as a package when evaluating impact. Consider the following case.

In a new cropping pattern labor-saving techniques reduce labor use in the first crop, as compared with the existing farmer technology. However, by using this labor-saving technique in the first crop the farmer can grow two crops instead of the present single crop, and total hired labor use in both crops is higher. On the whole, landless laborers may be better off.

Before a new technology is finally released for widescale adoption, an evaluation that takes these wider considerations into account should be conducted to ensure that the new technology will improve overall social welfare. This is important if the new technology differs substantially from present farmer technology in the levels and proportions of factor use.

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CHAPTER 11

STUDYING MARKETING SYSTEMS

N. F. C. RANAWEERA

New agricultural technologies change the demand for inputs and the agricultural product supply levels. These changes can affect the prices of inputs and products and the profitability of cultivation of these products. The major reason for conducting market studies is to assess the potential impact of new technology on profitability levels.

BASIC CONCEPTS

Supply and demand are the most basic economic concepts.

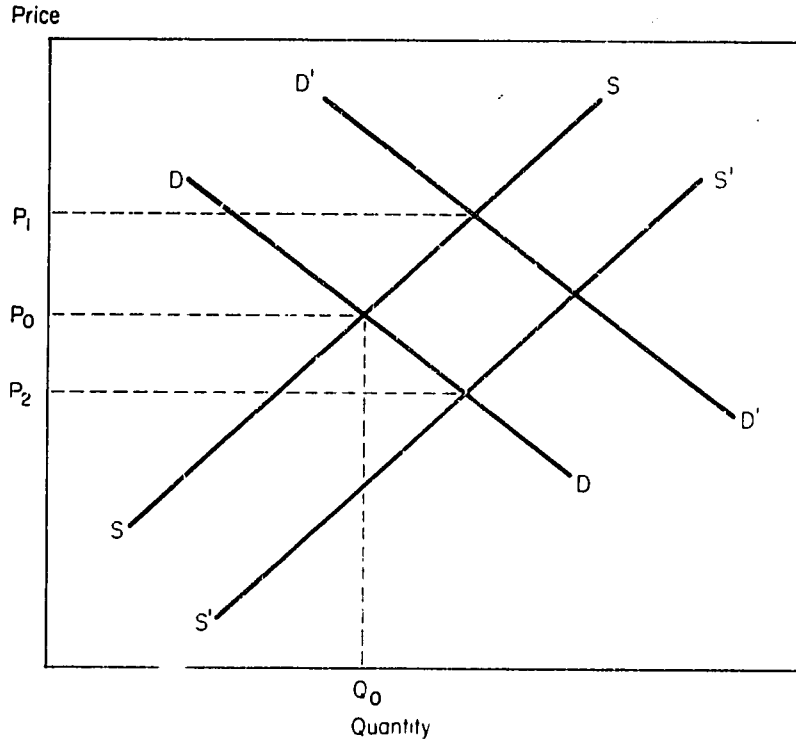
A market is an institution that enables commodity exchanges to take place. Barter (where one commodity is exchanged for another) was common in the past but is usually unimportant today, because most transactions are conducted using money. In money markets a *price* is a sum of money for which a commodity can be bought or sold. A market comprises all potential buyers and sellers of a commodity.

Generally the quantity supplied (or made available for sale) is greater when its price is high and smaller when its price is low. The demand relationship is opposite. Demand is greater at lower prices and smaller at higher prices because people are inclined to buy when prices are low.

These relationships are expressed graphically in Figure 1. SS is a supply curve and shows quantities that will be supplied to the market at different prices. DD is a demand curve and shows quantities that will be demanded (bought) at different prices. When supply equals demand there is an equilibrium. In Figure 1 this is achieved at the intersection of the two curves. At this point the quantity q_0 will be supplied and bought. The price at which this occurs, P_0, is the equilibrium price.

For different types of commodities, at different times and / or sites, these curves are different. Supply, for example, is affected by the production costs. If inputs become cheaper more production will be offered at the same price and the supply curve will shift to the right (S'S'). This can also happen if a new technology produces a greater output at any specified cost level causing per unit production cost to decrease.

Shifts in demand can be caused by changes in population, taxes, incomes, prices of substitutes, etc. For example, if rice becomes expensive more wheat flour may be



1. Supply and demand curves.

demanded, even at the same wheat price. An increase in demand at a given price will shift the demand curve to the right (D'D'). When such shifts occur equilibrium prices change. If only demand rises, this price will go up; at intersection of SS and D'D' the price P1 is higher than P0. If supply increases and demand does not change (intersection of S'S' and DD), the price (P2) will be lower. When demand and supply change, the price will go up or down depending on the relative magnitudes of the shifts and the shapes of the curves.

The shapes of the demand and supply curves describe quantity-price relationships. A steeply rising S1S1 curve implies that the change in quantity of supplies caused by a price change is less than in a flatter curve. Steeper curves are said to be less elastic or inelastic with respect to price changes and flatter curves are said to be elastic. When a supply curve is flat it is called perfectly elastic. When vertical it is called perfectly (or completely) inelastic.

If prices are fixed the market may not reach an equilibrium. For example, at a fixed price more of a commodity will be demanded than is supplied if the price is fixed below equilibrium price. There is *excess demand* in this situation. *Excess supply* situations can also exist. Sometimes supply may be determined by an agency that also fixes price below equilibrium price. Excess demand can lead to a black market in this situation.

Many agricultural commodities do not pass directly from the producer to the consumer. A commodity may be bought and sold several times before it reaches the

consumer. This chain of buyers and sellers or *middlemen* sometimes store, transport, grade, and process the product. The chain that connects the producer to the consumer is the *marketing channel*. The difference between the price at which a trader buys a product and the price at which he sells the product is called the *marketing margin*. Note that the marketing margin is not a measure of the level of profits made by middlemen, although it includes their profits.

MARKET STUDIES AT RESEARCH SITES

In this chapter we will discuss methods and procedures for assessing the potential impact of new cropping technologies in areas and regions within a country. New technology can be a new variety, a single-crop technology package, or a new cropping pattern. Crop(s) may be already locally grown or may be new.

Marketing aspects that must be evaluated in a market study are:

a) input supplies,
b) expected output increases,
c) market potential,
d) capacity of the marketing system to handle increased output, and
e) anticipated government interventions.

C, d, and e are closely related.

Input supplies

Large-scale farmer adoption of new technologies usually increases demand for inputs: seeds, fertilizer and chemicals, power and labor, etc. Labor and power markets will not be discussed because they are discussed in other chapters. Availability of seeds, fertilizers, and chemicals often is a prerequisite for successful large-scale adoption of new technologies. If farmers can multiply and retain seeds from a crop for subsequent plantings (rice), seed supply is not likely to be a major problem. However, if new seeds need to be bought regularly (hybrid maize) then the marketing system must be evaluated to ensure that a functioning marketing channel for transferring seeds from the producers to the farmers exists in the area or will develop soon. Crop production programs have failed because a marketing channel for seed supply did not exist. Similar considerations apply to fertilizer and other chemicals. However, in most parts of Asia the infrastructure for import supplies is developing and, provided the attractiveness of the technology can be demonstrated, input supply problems are easier to solve than product marketing problems.

In many marketing systems credit and crop sales are linked. Traders often extend credit for inputs and sometimes even for personal consumption that must be repaid by selling the produce to them. If market prospects for the crop are good, this type of informal lending can facilitate farmer adoption of the crop and the necessary inputs.

Expected increases in marketed output

Expected marketed output increases can be estimated using expected farm yields, the potential area that is likely to come under the new technology, and the proportion of output that farmers are likely to sell in the market. In our projection we must be careful not to use yield figures from plots that have been managed by researchers

or from those that have had substantial researcher input. If a crop can be consumed by the farm-household, it is necessary to assess the proportion of output that will actually enter the market.

The proportion of output that will be marketed varies depending on the price of the crop, price and availability of substitutes, etc. A rough approximation can be made using a reasonable estimate of expected average per capita consumption of the particular commodity. For a staple food crop this level may be much higher than the present level of consumption if present production levels are low. For subsidiary food crops, consumption level is not likely to rise. Asking farmers about expected consumption *if* they had adequate supplies may give some idea of this figure. Another method is to assume that consumption level will equal the present consumption level of a farmer with adequate supplies.

Market potential, capacity of marketing system, and government policies

The crucial factor in determining market potential is the level of demand. For level of demand it is important to distinguish between different types of crops.

Traditional staple crops, particularly cereal grains that can be stored relatively well, usually have established marketing channels. Although problems such as lack of storage and transportation facilities can develop, experience with rice, wheat, and maize during the last 15 years shows that these are temporary problems. Local marketing systems already have been established for these grains and they are traded nationally and internationally, therefore local or regional demand is not of primary importance. Similar considerations apply to export crops.

Serious marketing problems develop when new crops or perishables are introduced. Perishable crops (vegetables, fruits, etc) require either a large enough local market or a good marketing channel with adequate transport facilities to carry produce to a market quickly at reasonable cost. If either of these conditions is lacking it is wise not to advocate such crops on a large scale. The situation can change, of course, if a canning or processing factory is set up in the locality.

Even for nonperishable new crops, future marketing facilities must be examined closely. If there is demand elsewhere in the country and if marketing channels for other crops are already well developed, traders and dealers may respond well to the availability of the new crop and diversify their marketing operations. Government plans also may exist for establishing processing facilities or government purchasing centers.

Estimating consumer demand for many crops is difficult if adequate demand studies have not been done. This is likely to be the case in most sites. If a large increase in a new crop (which is expected to be consumed in the region) is to be implemented through a major production program, it is worth investing time and resources to conduct a demand study so that the impact on prices can be ascertained. If a demand study is not feasible, a survey in the area will provide some useful information.

It is best if economists try to evaluate the potential marketability of a crop once its agronomic feasibility has been established at an experimental station and before it is tested widely in farmer fields. If this has not been done and the crop is being tested at the research site, the economist should not wait until trials are conducted for many

years to establish agronomic possibilities before conducting a market study.

A survey to obtain market information can be done at three levels:

1. at the farm,
2. at the local market, and
3. among local traders.

At the farm

The initial site description survey should have provided some basic information on farmer tastes, preferences, and food habits. Farmers must be surveyed (quickly and informally) to assess their reactions to the new crop. If the reactions are strongly negative, the research team should deliberate carefully and decide whether they should proceed further, because it is likely that attempts to introduce the crop may not be successful in the short run.

Information on crops that farmers would like to grow can be obtained during the site description survey. If this was not done, a somewhat larger number of farmers than the farmer cooperators who indicated they would like to grow a new crop should be surveyed.

At the local market

The site economist should conduct simple surveys with 5-10 questions to identify tastes and preferences of the consumers in terms of present consumption patterns and potential consumption of a new crop.

Information should be collected about:

a) food crop preferences;
b) prices paid by consumers for preferred crops;
c) the highest price consumers will pay for preferred crops;
d) distaste for crops locally grown and marketed crops and reasons;
e) preferences, if any, for a particular grading system (for example, will farmers pay more for quality chilis, rice, tomatoes, etc? This can be important in the case of cereals and pulses as well as with vegetables. The highest price consumers will pay for quality produce or high grade products must be determined because grading has overheads and good quality items cost more); and
f) the likes and dislikes consumers may have for a new crop introduced by researchers (for example, if groundnuts are agronomically feasible but consumers do not like them, there is little reason for introducing the product unless there is outside demand. If there is outside demand more information must be obtained about this market from other sources).

At the adaptive research stage, it may be necessary to guarantee a market for the produce that cooperating farmers produce on trials conducted in their fields.

Trader surveys

Information from trader surveys must be carefully examined, because traders often provide incomplete information. Traders accept new crops only if there is substantial local demand or if the crop can be transported at reasonable cost to a market where there is demand and where it can be sold for a profit.

For example, growing red rice varieties where consumers prefer white rice may be agronomically and economically justified if the trader can market the red rice somewhere else at a profit. When obtaining information about a local market from traders, it is possible to determine how much of the new crop they will purchase. For example, if soybeans are introduced to an area where they are not traditionally consumed they will be purchased by a trader if he knows there is a demand in urban areas. Therefore, although a particular crop may not have a local market or be preferred by farmers, if traders will buy it at a competitive price the crop can be introduced.

Transportation and storage facilities available to traders should be evaluated and it should be determined if marketing the new crop is likely to conflict with present marketing practices. If the new crop is harvested when the trader has idle storage and transport capacity, it is more likely that the crop will be accepted (assuming there is a demand).

The level of government intervention must also be assessed. Price support schemes such as floor price schemes and government purchasing centers, if they exist or are planned, must be considered and the extent to which such institutions operate in the locality must be assessed. This is particularly important if pilot production programs are planned.

CHAPTER 12

DATA COLLECTION METHODS FOR DEVELOPING AN INITIAL AGROECONOMIC PROFILE OF A RESEARCH SITE: SITE DESCRIPTION

M. VAN DER VEEN AND S. B. MATHEMA

One of the first steps taken by cropping systems researchers is to develop an agronomic and socioeconomic profile of cropping systems sites. Efforts are directed toward developing an understanding of: 1) what farmers are doing, 2) how they are doing it, and 3) why they are doing it the way they are (Hildebrand 1978). To understand these actions researchers must identify factors that influence farmers' choice of farming systems and factors that must be considered in attempts to improve farming systems.

An agronomic and socioeconomic profile of a cropping systems site is used a number of ways. Initially, the information provides knowledge needed to design cropping trials. The data also enable comparisons of net benefits which could potentially be derived by farmers using new or improved technology (as seen through cropping systems trials) to net benefits derived from farmers' present practices.

Information on technology in use and on the know-how of more successful farmers might aid in developing improved technology for other farmers. A good understanding of existing farming methods and the agronomic, economic and/or social constraints facing farmers also helps in determining how new technology has to be modified to be practical and acceptable to farmers. Finally, the information can be used as a bench mark or a measurement of the agronomic and socioeconomic condition of the site before cropping systems work is initiated. The bench mark enables measurement of progress made in increasing agricultural production and in improving farmer welfare as the cropping systems program develops.

Site description can be a difficult, time-consuming, expensive task and probably cannot be fully completed before beginning cropping systems trials. The list of information ultimately desired is long and involves detailed data on climate, soils, topography, farming practices, cropping patterns, crop yields, and a wide range of socioeconomic subjects (Zandstra et al 1981).

Data collection techniques used to gather information about farmers such as farmer surveys, case studies, and nonparticipant or participant observations require many man-hours, money, and calendar months. Often personnel and resources are limited, especially in early stages of a cropping systems program. Further, in

cropping systems programs agronomists are frequently interested in initiating trials quickly and are not inclined to wait the months required to complete an in-depth socioeconomic and agronomic site profile.

In general, site information is collected over time, up to a year or more, using a combination of techniques. Indeed, site description can be considered an activity which continues throughout the research period. Interactions with the people and the physical environment during research activities deepen the researchers' understanding. A number of short cuts in acquiring site information are used to provide a wide range of information quickly and economically.

Data collected quickly are used in early planning stages for cropping systems trials. Other more intensive, comprehensive, and time-consuming data collection techniques such as large farmer surveys and case studies are used when time and money permit and as the cropping systems program evolves. Later studies provide a deeper understanding of the site, information on topics which cannot be handled adequately by initial research, more accurate data, and information about specific problem areas.

This paper describes how data for developing a tentative agronomic and socioeconomic profile for a site can be collected quickly and economically so a profile can be available for use early in a cropping systems program.

DATA COLLECTION

Four complementary methods are commonly used to collect initial information about cropping systems sites. They are: 1) review of previous studies carried out in or near the site, 2) secondary data collection, 3) a nonstructured site reconnaissance, and 4) key informant surveys.

Literature review

A substantial amount of agricultural research has already been carried out in rural areas of countries in the cropping systems network — a complete review of this research, although useful, is beyond the capabilities of any program.

However, valuable information can be gained quickly by reviewing literature on studies carried out on or near a site and on topics of value to cropping systems research. For example, the Nepalese cropping systems staff found, in a report, that a detailed land survey had been carried out on a site (Mathema et al 1979).

Although the site covered only 110 ha, 6 land types were mapped. Each land type was described according to soil type, texture, topography, drainage, present land use, limiting factors, and potential suitability. Further, a farm survey had been taken in the area and the report included information on present farming practices including cropping patterns and crop yields, labor requirements for crop production, and recommendations for improved cropping patterns. Also included in the report were data collected by other agricultural surveys in the area and information from government officials. These studies provided much information needed to develop an agronomic-socioeconomic profile for the site.

Knowledge gained by reviewing previous research can also be useful in focusing the reconnaissance survey and in formulating questions to be asked of key informants.

Research findings can be located in development program reports, published books, papers from various governmental organizations, unpublished reports from governmental and other organizations, student theses, etc.

Secondary data

In most countries a great deal of useful secondary data exists at the local level and is readily available. This includes: weekly rainfall, temperature and other climatological data spanning several years, market prices of agricultural inputs and outputs, population by age and sex, area planted and harvested to each main crop by year, livestock population, maps, and aerial photos. These data will provide additional information for the reconnaissance team and can be included in the report of the key informant survey.

Site reconnaissance

A nonstructured reconnaissance survey is a visit to the cropping systems site by a group of cropping systems socioeconomic and agricultural scientists (Hildebrand 1978). The length of the visit can vary from one day to more than a week depending on the size and complexity of the site and the availability of scientists. Being already informed to some extent about the site from the reviews of previous studies and from the secondary data, group members can form general impressions about the farming systems followed and attempt to gain more knowledge concerning special areas. The soil scientist, for example, can classify land types by noting soil texture, structure and color, soil profile characteristics, and water table depth; and by measuring soil pH. Plant protection scientists can note insect problems, pests, and plant diseases in standing crops and can interview farmers about insect, disease, and rat problems in previous crops or years.

Useful information can be learned by the reconnaissance team by carefully interviewing farmers to determine their conceptualizations of major problems they face in increasing crop yields, in increasing the number of crops grown in a parcel in a year, and/or in changing crops. Farmers' responses can be discussed and analyzed by the scientific team.

The combined technical knowledge of the scientific group allows clearer definition of major crop production problems faced by farmers. This knowledge can help to determine cropping systems research priorities and also help identify problem areas where additional information must be collected either through a key informant survey or through some subsequent survey.

Dialect spoken, local agricultural vocabulary, and local units of measurement can also be recorded during the reconnaissance. This is useful information for any future survey work in the area.

First hand information gained by the reconnaissance group can also aid in interpreting data collected from subsequent socioeconomic and/or agronomic research.

KEY INFORMANT SURVEYS

In a key informant survey, individuals knowledgeable about certain subjects or topics are asked to supply information. For example, shopkeepers or merchants are

asked about prices of local commodities or the local elected leader is asked about topics related to the community. The key informant survey differs from a regular survey in that the respondent does not respond about himself but about the subject in which he is an expert. A knowledgeable farmer, for example, describes the farming systems followed by the farmers from his village and does not describe his own farm.

Advantages of key informant surveys

- Key informant surveys are quick and inexpensive and can be useful tools for collecting information about a cropping systems site. Carefully designed key informant surveys can quickly provide a large amount of high-quality quantified information at low cost. Only a few individuals at a cropping systems site need to be interviewed. Therefore, manpower requirements for carrying out the surveys are small (2-10 man-days in Nepal depending on the size of the site). Data processing requirements for data presentation in a report are also limited. The last key informant survey at a cropping systems site in Nepal resulted in a 50-page report. This report was finalized and reproduced within 2 weeks after survey work was initiated. Three men spent about 7 days (21 man-days) conducting the survey and preparing tables. The rest of the time was devoted to writing up the results, typing, and cyclostyling.
- A carefully administered key informant survey gives accurate results. Estimates of average crop yields derived from key informant surveys in Nepal were close to yield estimates from large farmer surveys and from standing crop samples.
- Key informant surveys can be carried out and the data processed by people who are not highly trained scientists. Skilled agronomists and other scientists in a cropping systems program have more important things to do than take surveys. Fortunately, individuals who have as little as high school education but who are intelligent, motivated, and have the right aptitude can easily carry out a key informant survey. All that is required is training and a good interview schedule.

Disadvantages of key informant surveys

There is one important disadvantage to using key informant surveys to collect information. Accurate and reliable (two or more informants give the same or similar answers to the same questions) data can be collected for only certain subjects. Answers of key informants on other subjects can be unreliable. For example, if farmers were asked about organic matter content of soil, answers might differ considerably between farmers (assuming they did not answer that they "do not know") and could also differ from the true organic matter percentage. However, if they were asked how many large threshing machines are found in their village, answers could be reliable and accurate.

Previous studies show key informants give precise and reliable answers to the following kinds of questions: questions about things that are publicly and directly observable, questions about well-known community traits, questions that require little evaluation or inference, and noncontroversial questions (Poggie 1972).

Key informants give the most unreliable answers to questions that ask for information directly observable, that require inferences, evaluations, or judgments,

and about typical individual behavior, activity, social relations, etc (Young and Young 1961).

Farmers would probably give unreliable information about the amount of rice being stored in the area (rice is stored in the home and is not publicly observable) but might give reliable answers about predominant cropping patterns in the area. Similarly, farmers may give unreliable answers to a question asking which political party best represents farmers' interests (controversial) but give reliable answers when asked if there is an agricultural cooperative in their village (directly observable and well known in the community).

There may also be technical questions or questions requiring inferences or evaluations which result in unreliable answers. In most cases, farmers are illiterate or have little formal education and are unfamiliar with concepts and terms employed by agricultural scientists. Questions involving panicle initiation stage of rice, organic matter content of soils, diverse vector, virus, fungus, chemical composition of fertilizers, and others could be beyond the scope of farmers. In Nepal, where illiteracy among farmers is high, unreliable responses were given to questions about percentages and proportions, but reliable answers were given to the same questions if they were asked about absolute numbers (farmers could count but had difficulty dividing). Care must be taken to assure the language used in questions is simple and understandable. These considerations apply not only to key informant surveys but also to farmer interview surveys.

One of the most difficult problems in any survey is developing questions that can be reliably and accurately answered by respondents. Questions must be simple and unambiguous. They also should concern topics familiar to farmers. If questions relate to farming practices in a geographic area, the area should be where farmers live and farm. It should also be reasonably small. Farmers can then be expected to know what happens in the fields on a daily basis. Boundaries of the geographic area under discussion should be clearly delineated by physical features such as streams and roads, or by political boundaries familiar to the farmers. This assures the farmers understand which specific geographic area is being discussed.

Preparing to conduct a key informant survey

When developing an interview schedule it may be difficult to decide if key informants will give accurate, reliable answers to questions asked. Some questions may require farmers to have considerable knowledge or good memories.

Careful pretesting of schedules to be used in key informant surveys is a useful tool to help ensure that informants can give reliable answers to questions. To pretest, persons with similar background, education, and experience to those who will be key informants are interviewed. Individual answers to the same set of questions are compared. Questions receiving similar answers from a number of respondents are considered reliable and used in the survey. Questions receiving very different responses should be eliminated or improved. Improved questions should also be pretested.

Reliability and accuracy of information collected from key informant surveys can be increased by carefully choosing the informants. The more a person knows about a subject, the better is the information he provides. In Nepal, persons selected to be key

informants on area farming practices were older, better educated farmers who had lived and farmed the survey site most, if not all, their lives. They were identified by local political or community leaders, local governmental personnel (usually extension workers), and local farmers. If questions are politically sensitive local political leaders should not be asked to identify key informants. Similarly, if land tenure relations is a controversial topic, care should be taken in choosing key informants. If it becomes obvious that a selected farmer is not adequately knowledgeable to answer questions, the interview should be tactfully ended and a more experienced farmer selected to be a key informant.

Guaranteeing accuracy

Another way to help ensure reliability and accuracy of data collected is to interview two key informants about the same topic. Their answers can be compared and discrepancies noted. If the interview schedule used was carefully developed and pretested and if the interviewers were well trained, answers of the two informants should be the same for most, if not all, questions. However, requestioning and additional questioning can be carried out for topics where informants gave different answers, in order to judge what the proper answer should be.

Getting key informant cooperation

Getting full cooperation of key informants is important in collecting reliable, accurate information. Suspicious, uncooperative informants, either because they do not understand the purposes of the interview, or for other reasons, may be guarded in their replies, may not answer truthfully, or may refuse to spend the time required to answer all questions in the schedule.

Steps can be taken to avoid uncooperative or suspicious informants. It may be worthwhile for members of the cropping systems program to explain the program to local farmers and officials. If farmers understand the program, locating cooperative key informants and farmers willing to devote land to cropping systems trials will be easier. It may be helpful to have an official letter signed by a high government official. The letter should state what organization is carrying out the key informant survey, explain the purposes of the survey, and request full cooperation for the study. A copy of the letter can be given and explained to each potential informant and local officials.

To ensure good public relations, program understanding, and consent to the survey, all important local people should be contacted before data collection begins. People visited may be potentially cooperative key informants or may identify farmers who might be helpful informants. It may also be helpful to make appointments with key informants to ensure the interview is held when the informant has not planned other work.

Carrying out key informant surveys

Four key informant surveys were used at cropping systems sites in Nepal to help develop agronomic and socioeconomic profiles. Local merchants, the local manager of the Agricultural Development Bank and/or the manager of the local cooperative,

farmers, and an elected area official were interviewed. Copies of the English translation of the interview schedules used are in the Appendix.

Schedules were designed for the Hill region of Nepal and subsequent studies in cropping systems sites have shown that they elicited accurate information. However, the schedules might not be effective in other areas or countries and should be seen only as examples of the kinds of information that can be learned from key informant surveys. Types of data needed by cropping systems programs probably differ from country to country depending on farming conditions, problems, and/or the existing knowledge levels. For example, schedules used in Nepal do not provide information about tenancy relations at the sites, i.e. typical rental arrangements, rental rates, inputs provided by the landlord. This is primarily because previous studies showed almost all farmers in this area own their farmland. However, in other countries many farmers may not own the land they cultivate. If inadequate information exists about farm rental arrangements at a site, questions concerning this topic might be included in a survey.

THE PRADHAN PANCH AND MERCHANT INTERVIEW

Cropping systems research in Nepal is being done in governmental units called panchayats. Each panchayat contains about 1,000 families and 800 cultivable hectares of land, and is divided into 9 wards. The elected head of the panchayat, the pradhan panch, has a small office that generally maintains a large file of local data.

The first person surveyed in a key informant survey in Nepalese cropping systems sites is the pradhan panch. This survey (Appendix, interview schedule No. 1) elicits well-known information about the panchayat like climate, markets, and prices. Facts about each ward where cropping systems research will be done are also gathered. Local merchants are asked about prices of agricultural commodities to ensure price information accuracy.

Data concerning individual wards take two forms. One set of questions relates to general knowledge about the area. Answers can be provided by most people from the panchayat. Commonly known facts include locations of schools and hospitals, and common languages spoken. The second set of questions relates to topics that may not be generally known. The pradhan panch could be expected to have records answering these questions in his office. Subjects will likely include the amount of upland and lowland area, number of households, population, and number of students.

As will be explained below, data concerning cultivable land in wards and number of households in each ward were used in the farmer interviews.

The farmer interview

In the farmer key informant surveys (Appendix, interview schedule No. 2), two knowledgeable farmers from each ward where cropping systems research was to be carried out were interviewed. The farmers were asked about conditions in the ward where they lived and farmed. Answers given by the two farmers were compared to assess reliability. Requestioning or checking by other sources was carried out in the few cases where discrepancies occurred in answers given.

Information from the pradhan panch concerning cultivable land area and household numbers within wards was entered in interview schedule No. 2 before the farmer was interviewed. For example, amounts of cultivable upland and lowland were entered in questions one and eight, respectively. Household number was entered in question 50. Providing data in this way allowed the two farmers interviewed in each ward to start with the same reference point and helped gain more reliable data. Entering these facts also helped to assure reporting was complete. If there are 75 ha of lowland in a ward and a farmer reports cropping patterns for only 30 ha, something is wrong. Either the farmer has forgotten to mention some existing cropping patterns in the ward or perhaps there has been a misunderstanding about the area covered by a cropping pattern already mentioned.

Soil fertility was found to be a familiar concept to Nepalese farmers. Farmers used a five-point classification to rank the soil — very fertilie, fertile, intermediate, in-fertile, or very infertile (different soil characteristics may be more important in other countries). In the key informant interview, farmers were asked about the amount of land in the ward which is infertile or very infertile (questions 5, 6, and 10). These soils usually are low in nutrient content, in some cases are coarse textured and may be less intensively cultivated.

In questions 7 and 10 cropping patterns showing the crop, planting date, and harvesting date were drawn in. Land area devoted to each pattern was written at the bottom of the page and interviewers were asked to be careful to make sure all mixed-cropping was indicated. (Farmers have a tendency to mention the major crop, such as maize, but forget to mention soybeans, gourds or broad beans mix-cropped with the maize).

We found that when using the long, structured interview schedule in key informant surveys, it was better to interview the farmer when he was alone. Interviewing one farmer within a group can lead to discussions and waste time.

The credit and input supply interview

In Nepal, agricultural inputs such as seed, fertilizer, or chemicals are supplied to farmers by the Agricultural Inputs Corporation (AIC), usually through a local cooperative.

The local cooperative also gives credit to small farmers. Money for credit is provided by a local branch of the Agricultural Development Bank. The bank also grants credit directly to the larger farmers.

An informal key informant interview with managers of the local cooperative and bank was conducted to learn about credit and agricultural input supply situations at study sites. Interviews were informal in that an interview schedule was not used (see attachment). Topics were determined before the interview but much of the information desired was contained in bank or cooperatives records. These data were copied as they existed. No attempt was made to transform them in any way at the time of the interview.

Enumerators were instructed to report information provided by the managers as soon as possible. The person interviewed was asked to read the report, point out any errors, and make comments and/or suggestions. This helped assure the accuracy of the report and also helped assure bad relations did not develop between the cropping systems program and other organizations assisting local farmers.

PROCESSING THE KEY INFORMANT DATA

Reports of key informant surveys combine secondary data, information collected from key informant surveys, and information from previous studies, if available.

Data processing can be used to develop tables rapidly if careful planning is carried out detailing what data are to be collected and how these data will be presented in the report. For example, many tables can be taken directly from the interview schedules. Data collected about climate, and information collected from the farmers about fallow land, can be described in the text of the report. Simple hand calculators can be used to calculate multiple cropping indexes, percentages, etc.

The amount of data available can be very large and too detailed to be included in the report. Consequently, data can be aggregated and the report written at the village level. However, ward-level data should be kept in case information is needed about specific wards in the future. A report produced from the questions asked in the Appendix can be obtained from Mathema et al (1979).

A number of data collection techniques can be used to collect information quickly and economically to permit the development of agronomic and socioeconomic profiles. These include: a review of literature, collection of secondary data, an informal reconnaissance of the cropping systems site, and key informant surveys.

The most difficult part of conducting key informant surveys is developing interview schedules which elicit accurate, reliable data.

However, key informant interviews and data processing can be carried out by lower-level staff and can provide useful information during early planning stages of a cropping systems program.

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Appendix. English translation of interview schedules

Interview Schedule No. 1

Key Informant Survey of the Area

(Information collected from Pradhan Panch (Head of the village)

Zone _____

District _____

Panchayat (village) _____

Name of the Pradhan Panch _____ Date _____

(A) CLIMATE OF THE PANCHAYAT

1. What months of the year is rainfall generally enough for crop production in this panchayat?

2. Is flooding or too much rain a problem in this area?

   Yes /___/ No /___/

3. If yes, when? _____

4. What months in the winter did it freeze at night last year?

   _____

5. Is hail a big problem for the farmers in this area?

   Yes /___/ No /___/

6. If yes, how much are crop yields generally reduced by hail? _____

   _____

7. In what months did hail occur during the last five years?

	Months
1979	_____
1978	_____
1977	_____
1976	_____
1975	_____

(B) MARKETS

8. Where are the permanent market centers used by the farmers of this panchayat?

Name of market	Name of the village	Distance from the panchayat building (km)	Types of transport	Time in walking
(a)				
(b)				
(c)				
(d)				

9. Where are the temporary markets in this panchayat?

Name of market	Name of the village	Distance from the panchayat building (km)	Types of transport	Time in walking
(a)				
(b)				
(c)				
(d)				

10. Main items of transaction in the above markets.

IN PERMANENT MARKETS			IN TEMPORARY MARKETS		
Commodities	Unit	Price	Commodities	Unit	Price
(1)					
(2)					
(3)					
(4)					
(5)					
(6)					
(7)					
(8)					

11. What is the nearest source of inorganic fertilizer? _____

_____

_____

12. What types of inorganic fertilizer are available and what are the average prices farmers have to pay for them?

Types of inorganic fertilizer	Price
(a)	
(b)	
(c)	
(d)	
(e)	

13. Is inorganic fertilizer always available to the farmers when they need it?

Yes /___/ No /___/

Explain _____

_____

14. Do the farmers buy fertilizer from the black market?

Yes /___/ No /___/

15. If yes, when? _____

What prices do the farmers have to pay? _____

16. Where do the farmers generally purchase the following agricultural inputs? _____

INPUT	SOURCE
Improved seed	
Insecticides	
Herbicides	
Improved elements	
Improved breeds of livestock	
Fruit trees	

C. CREDIT

17. What are the most important credit sources for the farmers in this panchayat? _____

18. Are loans provided from land reform savings?

    Yes /___/ No /___/

19. If yes, how many farmers in this panchayat received loans from land reform savings during 1979? _____

20. Where is the nearest agricultural cooperative that provides loans to farmers? _____

21. How many farmers in this panchayat received loans from the cooperative in 1982? _____

22. Where is the nearest agricultural development bank? _____

    _____

23. How many farmers in this village received loans from the agricultural development bank in 1982? _____

24. Are credit facilities sufficient for improved farming?

    Yes /___/ No /___/

    Explain _____

    _____

(D) PRICES

25. Farm gate prices of agricultural commodities (1981-82) (Also to be asked of merchants and shopkeepers when time permits).

Cereals Crops	Varieties	Maximum	Months	Minimum	Months	Average
RICE						
WHEAT						
MAIZE						
BARLEY						
MILLET						
BUCKWHEAT						
POTATO						
PULSES						
OTHERS						

Cash Crops	Varieties	Maximum	Months	Minimum	Months	Average
SUGARCANE						
JUTE						
OILSEEDS						

(These questions to be asked for each ward where cropping systems research is to be carried out)

PANCHAYAT _____ WARD NO. _____

(A) GENERAL INFORMATION OF THE WARD

1. Amount of upland in ward _____
2. Amount of lowland in ward _____
3. Amount of pasture and/or forest land in ward _____
4. Number of households in ward _____
5. Number of households in ward who do not farm _____
6. Number of females over 14 _____
7. Number of males over 14 _____
8. Number of children less than 14 _____
9. What are the most common ethnic groups in this ward?

ETHNIC GROUPS	NUMBER OF HOUSEHOLDS
(A)	
(B)	
(C)	
(D)	
(E)	
(F)	

10. What are the common religions in this ward?

RELIGION	NUMBER OF HOUSEHOLDS
(A)	
(B)	
(C)	
(D)	
(E)	
(F)	

11. What languages do the farmers speak in their general daily conversations?

LANGUAGE	NUMBER OF HOUSEHOLDS
(A)	
(B)	
(C)	
(D)	

12. How many men of this ward are soldiers?

ARMY	NUMBER
Nepal Army	
Indian Army	
British Army	
Nepal Army (Retired)	
Indian Army (Retired)	
British Army (Retired)	

(B) EDUCATION AND HEALTH

13. Types of school

	Primary (5 to 10 years)	Middle (11 to 14 years)	High (15 to 16 years)	Adult
Nearest school				
Name of the village with school				
Average time walking from ward to school				
Number of people from this ward attending				
Proportion of school age children from this ward attending				

14. How many household heads in this ward can read and write?

_____

15. Health

	Health Center	Hospital	Ayurvedic
Nearest medical care			
Name of the village with medical care			
Hours walking from ward			
Number of people from the ward treated last year			

(C) SOURCES OF WATER

	Source	Average time walking from home to source
Source of water for livestock		
Source of water for washing		
Source of water for drinking		

Interview Schedule No. 2.

Key Informant Survey of the Area

(Information collected from two knowledgeable farmers in each ward)

Zone :

District :

Panchayat : Ward No. :

Farmer's name: Date :

1. In this ward, according to Pradhan Pancha there are ..... hectares of lowland. Do you thin this estimate is true? Yes /___/ No /___/
2. If no, what is the correct measure? .....
3. How many hectares of lowland are irrigated? .....
4. What are the sources of irrigation? .....
5. How many hectares of lowland are relatively infertile among the lowland and are irrigated during the whole year?
6. How many hectares of lowland are relatively infertile among the lowland and are irrigated only in rainy season or are only rainfed?

Irrigation supply	Total area (hectares)	Sources of irrigation	Area infertile (hectares)	Area others (hectares)
Lowland which is irrigated whole year (9 months or more)				
Total area of lowland which is unirrigated or irrigated only in rainy season				

7. What crops were grown on the lowland during 1978/79 and when? What were the planting and harvesting dates?

Lowland which is rainfed or irrigated only in rainy season		Irrigated throughout the year		Months
Infertile	Other	Infertile	Other	
				Mar - Apr 1978
				Apr - May 1978
				May - Jun 1978
				Jun - Jul 1978
				Jul - Aug 1978
				Aug - Sep 1978
				Sep - Oct 1978
				Oct - Nov 1978
				Nov - Dec 1978
				Dec 1978 - Jan 1979
				Jan - Feb 1979
				Feb - Mar 1979
				Mar - Apr 1979
				Apr - May 1979
				May - Jun 1979
				Jun - Jul 1979
				Area

8. According to Pradhan Pancha there are ..... hectares of upland in this ward. Do you think this guess is true?

Yes /___/ No /___/

9. If no what is the correct measure?

10. How many hectares of upland are infertile in this ward? .....

Cropping patterns

Upland		Months
Infertile	Other	
		Mar - Apr 1978
		Apr - May 1978
		May - Jun 1978
		Jun - Jul 1978
		Jul - Aug 1978
		Aug - Sep 1978
		Sep - Oct 1978
		Oct - Nov 1978
		Nov - Dec 1978
		Dec 1978 - Jan 1979
		Jan - Feb 1979
		Feb - Mar 1979
		Mar - Apr 1979
		Apr - May 1979
		May - Jun 1979
		Jun - Jul 1979
		Area

11. Do the farmers who own more than one hectare of land practice cultivation differently from those farmers who own less than one hectare?

Yes /___/ No /___/

12. If yes, in what way does cultivation differ? .....
.....
.....

13. Has there been any change(s) in the method of cultivation in the upland within the last five years?

Yes /___/ No /___/

14. If there was, explain .....
.....

15. Has there been any change(s) in cultivation methods in the lowland within last five years?

Yes /___/ No /___/

16. Explain, if yes .....
.....

Fallow land

17. Does any cultivable land remain fallow at any time of the year in this ward?

Yes /___/ No /___/

18. If yes

Land type	Locality	Where? (direction)	stimated area	What months of the year
Upland	Locality - 1			
	Locality - 2			
Lowland	Locality - 1			
	Locality - 2			

(Compare this information with the cropping pattern information)

Fallow Upland

19. What are the main reasons for keeping this upland fallow? .....
.....

20. Do the farmers feel there is a possibility of cultivating any crop in this land within the fallow period?

Yes /___/ No /___/

22. If yes which crops _____

Why don't farmers cultivate these crops within the fallow fields?.....
.....

23 How much yield, on an average, can be obtained from those crops when grown in the fallow fields? .....

24. During the fallow period do the farmers who have fallow upland spend most of their time cultivating other land? .....
.....

25. If they do, which crops are grown? .....
.....

26. Do the farmers face difficulties in farming their upland fields because they have to work in other fields? .....

27. Explain .....

28. What work would the farmer who owns the fallow upland and his family members be doing during the fallow period of this upland?

29. Do the farmers mostly live far from the uplands that are left fallow?

30. Are upland fields used for grazing cattle?

31. If fallow upland fields are brought under cultivation, will it be difficult to get fodder materials for cattle from other sources?

32. Do the farmers of this ward feel they will cultivate the fallow uplands in future?

33. Yes /___/ No /___/

34. Why? Explain .....
.....
.....

Fallow Lowland

35. What are the main reasons for keeping this lowland fallow? .....
.....

36. Do the farmers feel that there is a possibility of cultivating any crop in this land within the fallow period?

Yes /___/ No /___/

37. If yes which crops .....
Why don't farmers cultivate these crops within the fallow fields?.....
.....

38. How much yield, on an average, can be obtained from those crops when grown in the fallow fields? .....
.....

39. During the fallow period do the farmers who have fallow lowland spend most of their time cultivating other land? .....
.....

40. If they do, which crops are grown? .....
.....

41. Do the farmers face difficulties in farming their lowland fields because they have to work in other fields? .....

42. Explain.....

43. What work would the farmer who owns the fallow lowland and his family members be doing during the fallow period of this lowland?

44. Do the farmers mostly live far from the lowlands that are left fallow?

45. Are the lowland fields used for grazing cattle?

46. If fallow lowland fields are brought under cultivation, will it be difficult to get fodder materials for cattle from other sources?

47. Do the farmers of this ward feel they will cultivate the fallow lowlands in future?

48. Yes /___/ No /___/

49. Why? Explain .....
.....
.....

Land Tenure

50. According to Pradhan Panch, in this ward there are ..... farming households. Do you think it is true?

Yes /___/ No /___/

51. If no, how many farming households

52. Amount of land the farming households in this ward cultivate including leased in land and land outside of the ward:

Land (farm) size	Total no. of households	No. of households* owning lowland mainly	No. of households* owning upland mainly	No. of households* owning mixed lowland and upland	No. of households* who have leased in land only
0.15 hectare or less					
0.16 to 0.30 hectare					
0.31 to 0.60 hectare					
0.61 to 1 hectare					
2 to 5 hectares					
6 hectares and more					

* less than 20% of the other land type.

Production of main crop and use

What are the main varieties of crops grown in this ward and how much was the average yield from these main crops last year (1978-79)?

Crop	Variety	Land type	Average yield per hectare	No. of farmers growing this crop	No. of farmers who have used chemical fertilizer	Average amount of chemical fertilizer used (per hectare)	No. of farmers who consume all the yields for household use	Average selling price	Main uses of the plant residues
Wheat									Wheat straw
Paddy									Straw Chaff
Maize									Plant Husk
									Leaf Cob
Linseed									Plant

Crop	Variety	Land type	Average yield per hectare	No. of farmers growing this crop	No. of farmers who have used chemical fertilizer	Average amount of chemical fertilizer used (per hectare)	No. of farmers who consume all the yields for household use	Average selling price	Main uses of the plant residues
Soyabean									Plant Chaff
Barley									Plant Chaff
Millet									Plant Chaff
Pulses									Plant Chaff

Crop	Variety	Land type	Average yield per hectare	No. of farmers growing this crop	No. of farmers who have used chemical fertilizer	Average amount of chemical fertilizer used (per hectare)	No. of farmers who consume all the yields for household use	Average selling price	Main uses of the plant residues
									Plant
Potato									
Others									

54. Can you explain the cultural practices followed in growing the major food crops (especially about the land preparation, seeding, compost application etc)?

Paddy

(a) _____

_____

_____

Maize

(b) _____

_____

_____

Wheat

(c) _____

Mill

(d) _____

_____

_____

Livestock

55. What kinds of animals do the farmers of this ward keep?

Livestock	No. of households who do not have any:	No. of household who have one:	No. of household who have two:	No. of household who have three:	No. of household who have four:	No. of household who have five or above:
Cow						
Calf						
Ox						
She-buffalo						
Calf						
Goat						
Sheep						
Pig						
Improved pig						
Chickens						

56. What are the main food materials fed to the animals by the farmers of this ward and where are the animals fed?

	Winter (what is fed? Describe)	Location (check)			Summer (What is fed? Describe)	Location (check)		
		House	Field	Pasture		House	Field	Pasture
Cow not milking								
Cow milking								
Bullock not working								
Bullock working								
Buffalo not working								
Buffalo milking								
Calf								
Goat								
Sheep								
Pig								
Improved pig								
Chicken								

57. Is it difficult to get enough grass or fodder for cattle in this ward?

Yes /___/ No /___/

If yes, why .....

.....

58. In which months do the farmers have the most difficulty in getting grass or fodder for cattle in this ward? .....

59. Why? .....

.....

60. How many hours distance is the pasture areas from this ward? .....

.....

Compost

61. How many farmers of this ward dig pits for keeping compost? .....

.....

62. Do some farmers of this ward practice scientific methods for keeping compost?

Yes /___/ No /___/

63. How many? .....

64. What method do most farmers of this ward use for making compost?

.....

Labor and power

65. What is the busiest time of year for the farmers?.....

.....

66. What do the farmers do in this time? .....

.....

67. Besides this, are there any busy times for the farmers?

Yes /___/ No /___/

If yes, when .....

68. What do farmers do? .....
.....

69. What are the leisure times for the farmers? .....
.....

70. Do the farmers exchange labor? .....
.....

71. If yes, for what tasks? ....
.....

72. Do the farmers of this ward hire laborers on contract basis for working in their fields?

Yes /___/ No /___/

If yes

Male

Types of work	No. of households hiring labor	How many days in a year on average	What months	Wage (include meals)

Female

Types of work	No. of households hiring labor	How many days in a year on average	What months	Wage (include meals)

73. Do the farmers of this ward hire villagers as laborers on daily wage for working in their fields?

Yes /___/ No /___/

If yes

Male

Types of work	No. of households hiring	How many days in a year on average	What months	Wage (include meals)

Female

Types of	No. of households hiring	How many days in a year on average	What months	Wage (include meals)

74. Do the farmers of this ward have problems in hiring labor during any times of a year?

Yes /___/ No /___/

75. If yes

When? .....

Why? .....

76. How many farmers use bullocks to prepare their land in this ward?

.....

77. Do the farmers hire bullocks to get their work done? .....

.....

78. Do the farmers use bullock for growing every type of crop? .....
Explain .....
.....

79. Are bullocks used both in upland and lowland? .....

80. Explain .....
.....

81. Are there any times of a year when there are shortages of bullocks for work? .....
Explain .....
.....

Other occupations besides farming

82. How many farmers of this ward go to the Tarai or India for one month or more every year for employment or marketing?

Purpose	Number of farmers	What month
(a)		
(b)		
(c)		
(d)		
(e)		
(f)		

83. What other types of occupations do the farmers have besides farming?

Types of work	Which member of the family is engaged	No. of households doing this sort of work	What months of the year	Average work days in a year	Average work hours in a year
(a)					
(b)					
(c)					
(d)					
(e)					
(f)					

Sources of fuel (for burning)

84. What are the main sources of fuel? .....
.....

85. Do the people of this ward collect their own firewood or do they purchase? .....

86. If they collect

How much time does a family, on an average, spend for cutting firewood or other materials for burning?			
Person	What months	How many days in a year	How many hours in a day
Head of the family			
Wife			
Children			

General information

87. What are the major problems of the farmers of this ward in increasing agricultural production? .....
.....

88. What are the reasons for decreasing yields in the last years? .....
.....
.....

89. What are the reasons for yield increases in the last years? .....
.....
.....

90. What type of changes in varieties of crops would the farmers like to have? .....
.....

91. What are the major obstacles to the development of agriculture in this ward? .....
.....

92. What do you suggest for the agricultural development in this ward?
.....
.....

93. Do the farmers of this ward produce enough food materials for household use from their own fields or do they have to get food from other sources? .....

94. How many small farms are there that cannot grow the required food grains for household consumption? .....

95. How many farms generally grow just enough for household consumption?

.....

96. How many farms generally produce more grain than is required for the household? .....

Fruits

97. What fruits are grown in this ward?

Types of fruit	Improved (number)	Local (number)
Mango		
Orange		
Pear		
Apple		
Papaya		
Banana		
Lemon		
Jack fruit		
Guava		
Pineapple		
Others (specify		

CREDIT AND INPUT SUPPLY STUDY

CROPPING SYSTEMS PROGRAM

We want to see how adequate the supply of agricultural credit and agricultural inputs (inorganic fertilizer, seeds, insecticide etc) are for the farmers at the sites. This will be achieved by collecting information from the cooperatives, agricultural development banks, local people, etc. We would like to know the volume of credit and inputs supplied to farmers in each site over the years, the number of farmers helped, main problems, costs, etc. The following questions could be asked:

From the cooperative

1. Name of cooperative
2. Location
3. How organized
4. Area of coverage
5. Number of members
6. Number of members from site
7. Is membership increasing?
8. Procedures for becoming a member
9. What is the membership fee?
10. Can any one join? Explain.

If credit is provided:

11. What are the procedures for getting a loan?
12. How much credit have the farmers at the site received over the last few years, how many farmers received credit and what were the main purposes of the loans?
13. Who can qualify for a loan?
14. What are the procedures for applying?
15. When are applications for loans rejected?

16. Are there any problems with default? Explain.

17. What are the repayment procedures?

18. How can the credit system be improved?

19. Are you able to provide credit to more farmers in the site? Explain.

If inputs are sold

20. What products are sold by the cooperative? (State amount sold by type by year for the farmers in the site.

21. Who can buy and how many farmers from the site did buy inputs last year?

22. Have there been problems in supply, i.e. have the inputs always been available when the farmers need them? Explain.

23. What are the sources of the inputs?

24. What are their prices (last 5 years)?

25. What other services does the cooperative provide?

26. What are the main problems of the cooperative?

27. Will the cooperative expand in size and in volume of credit and business in the near future? Explain.

28. How can the cooperative be improved?

From the Bank

Name _____ Location _____

1. What volume and types of loans for agricultural purposes has the bank provided over the last few years?

2. How many cooperatives are you providing loans to?

3. How much have you loaned to the cooperative in our research site over the last years?

4. What procedures should be followed to get a loan from the bank?
   (a) Cooperative (b) Individual farmer
5. How much have you loaned to farmers at our site over the past years?
6. How many farmers received credit and what were the main purposes of the loans?
7. What types of farmers generally receive loans from the bank?
8. What determines the size of loan you can give?
9. For what purposes can you give loans?
10. What are the repayment procedures?
11. Are there problems with default? Explain.
12. How can the credit system be improved?
13. Will you be able to provide more credit to farmers and to cooperatives in the future? Explain.

There may also be local businessmen who supply agricultural inputs who can be interviewed.

The Pradhan Panch and others can also be asked about how well these institutions presently meet the credit and input needs of the farmers, what the problems are, etc.

Also answers, tables, data provided should be written down on another piece of paper and a report written as soon as the interview is over. If possible, the person interviewed should be asked to read the report and make sure that it is accurate.

CHAPTER 13

COLLECTING AND ANALYZING FARM-LEVEL SURVEY DATA

P. E. CHURCH

A sound understanding of the structure and performance of small farm agriculture is essential for agricultural research aimed at designing and testing new technologies suitable for farmer adoption. Farm-level surveys contribute to that understanding. However, results of farm surveys are useful only when prepared in a readily usable form for researchers and analysts. Good farm surveys, therefore, must meet three requirements:

1. *they must be representative* — this requires statistically reliable samples of respondents,
2. *they must be accurate* — this requires careful measurement and computation of a broad range of factors involved in farm operations, and
3. *they must be timely* — to be useful to analysts and policy makers they must be available within weeks — not months or years — after the survey is conducted.

To collect and analyze farm-level agroeconomic data, certain steps must be taken. This study guide describes and illustrates steps field staffs should follow when collecting, tabulating, and/or analyzing data needed to produce farm-level agroeconomic studies. For researchers involved in all these activities or with prior experience, these steps can be used as a checklist or work plan. For those involved only in part of the study process, these steps will show how their specific activities relate to the whole process of collecting and analyzing farm-level survey data.

WHY CONDUCT FARM-LEVEL SURVEYS?

Why must we use elaborate and complex procedures to collect agroeconomic data from farmers? Why survey farmers at all? Why don't experiment station trials or a few interviews with easy to reach, knowledgeable farmers or community leaders provide enough information?

The answer is that the real world is much more complex and much less controllable than conditions at agriculture experiment stations. At experiment stations, scientists can conduct trials on uniform soil types, using controlled water and pest management practices. Conditions are a great deal more variable in the farmers' environment. Land, water supplies, and growing period often vary within small

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geographical areas and between farms. Farmers also differ, by education level, family size, land and asset ownership, and world outlook. These differences determine how they cultivate their crops.

Variability in cultivators and cultivation conditions makes it necessary to use statistical sampling and survey techniques developed to assure an accurate understanding of the differences and their effect on cultivator behavior. These techniques identify and measure differences among cultivators and cultivation conditions, and assess how these differences affect the adoption and effective use of cultivation practices.

DETERMINING SURVEY OBJECTIVES

Farm-level surveys are a tool used to accomplish a task. Requests to field researchers for farm survey data should be made with a specific purpose in mind. Although computers with the capacity to handle huge volumes of data can process information from large surveys using complex questionnaires, results from extravagant survey efforts are not often useful. Clear objectives limit surveys and reduce time and resources needed.

Farm-level surveys are time-consuming, expensive, and prone to error. The decision to conduct a farm-level survey should be carefully considered. Will the survey data contribute to a valid objective? Are there sufficient resources to do a survey that will achieve the objectives?

Site description

Farm-level surveys often help scientists understand the agroeconomic environment where they propose to work. These surveys, often called baseline or benchmark surveys, identify the greatest potential for and constraints to improved agricultural production. They can also show where the greatest pay-off to scarce agricultural research money and manpower will be. Descriptive surveys are often the most expensive and time-consuming to undertake because a wide range of information is usually collected from a large sample of respondents.

Experiment monitoring

Once key problems have been identified and new technologies developed to improve cultivation practices in a particular site, regular and periodic monitoring of their performance among a limited number of farmers is needed so the best practices can be selected for distribution to potential users. Often data are collected from users and non-users of new technology (seed variety, crop management practice, or production input) to compare their relative performance. This type of data collection, farm record keeping surveys, is also expensive and time-consuming because frequent, even daily, visits with farmer cooperators are essential to monitor their crop cultivation decisions and activities.

Production evaluation

When new technologies have been introduced to the farm population, sample surveys can be valuable in assessing the pace and direction of adoption by farmers.

Farm-level surveys also can provide data to show how efficiently new technologies are being used by farmers and if there are unexpected constraints to optimum performance under farmer cultivation. Cost of production or farm-budget surveys assess production performance because both level of physical output and level of monetary reward are used in evaluation.

Consequences assessment

New technologies that have a favorable impact on farm resource use also change the socioeconomic environment in which the cultivator and his family live. Socioeconomic changes may be favorable or unfavorable for the farmer, his family, and his community. Socioeconomic surveys collect data to show how farmers are affected by the changing environment. This information helps researchers who are modifying technologies to fit changing socioeconomic conditions and policy makers seeking to promote socioeconomic conditions that will ensure maximum benefits from new technology adoption.

FORMULATION OF HYPOTHESES

Most field researchers understand how to formulate hypotheses for agronomic field research experiments. When hypotheses are stated (for example, different yields can be expected from different levels of input application) experimental design is straightforward.

In many farm-level surveys, however, field researchers forget the value of formulating hypotheses.

Formulation of hypotheses is essential to successful research that involves agroeconomic data collection. Most agroeconomic studies require complex combinations of data that not only include amounts of inputs used, but input types and costs, sources, and time of use. These added dimensions require a hypothetical foundation, to help focus data collection and analysis.

Let us formulate a hypothesis to be used to assess the relative profitability of local and modern seed cultivation and develop it through data collection and analysis steps. The hypothesis is: modern seed varieties (MV) outperform local seed varieties. In economic terms that means MV yield higher and provide farmers higher incomes.

To test the hypothesis, be careful to control for variables that might bias results. For example, we should compare MV and local variety cultivation costs and returns using the same fields to avoid differences in soil types that would affect plowing time and costs, or water and fertilizer requirements.

Selecting crops cultivated on similar fields limits the chance that land and its costs will influence results. The land *variable* becomes a *constant*, and it can be eliminated from the analysis in the comparison of the economic performance of modern and local rice varieties.

By making land a constant we have made it unnecessary to collect data on land values and rents, and avoided the need to ask farmers about land ownership that might make them reluctant to provide other more necessary data.

Are there other confounding factors such as credit (see Appendix 1) or farm size that can be eliminated from consideration in the analysis of the hypotheses?

Table 1. MV and local variety rice cultivation costs per hectare.

Item	Modern variety	Local variety
Labor		
Hired		
Family		
Draft Animals		
Hired		
Family		
Seed		
Manure		
Fertilizer		
Urea		
TSP		
MP		
Pesticides		
Irrigation		
Total cost (₱/hectare)		
Yield (t/hectare)		
Cost per unit (₱/t)		
Price per unit (₱/t)		
Total income (₱/hectare)		
Net income (₱/hectare)		
Benefit-cost ratios		

A hypothesis helps a field researcher know what data he needs for analysis in advance. If he does not know, more data may be collected than he can use, which wastes his and the farmer's time, and limits the number of farmers who can be contacted.

CONSTRUCTING MASTER TABLES

To test hypotheses we have formulated requires collecting substantial data. Data must be organized to be understood. A *master table* helps the field researcher organize data. A master table is an organized table that will be completed when survey data are analyzed. It should reflect the hypothesis that is being tested. Table 1 is an example of a master table that might be used to organize data collected to test the sample hypotheses. It is a preliminary data list and outline for a survey questionnaire. Inputs for which amount and cost data must be collected are shown in the table. It also shows that input and output price information collected from respondents or local markets will be needed. A master table will help identify information needed in the analysis and organize it for use.

For example, labor costs will be derived from the number of labor days used in cultivation activities, wages paid, and meals given if labor is hired. Table 2 records all labor cost components. Similar tables can be generated for other inputs.

Table 2. Labor use and costs per hectare in cultivation of modern and local rice varieties.

Cultivation activity	Man-days			Wage rate			Cost		
	Family	Hired	Total	Cash	Kind	Adjusted	Family	Hired	Total
Plowing									
Land preparation									
Sowing									
Transplanting									
Fertilizer application									
Pesticide application									
Manual weeding									
Irrigation									
Harvesting									
Postharvest									
Total									

SURVEY QUESTIONNAIRE DESIGN

A form or questionnaire to record field data is used for most sample surveys that collect agroeconomic information for analysis. The survey questionnaire is an important field survey tool because it stores data for future tabulation and analysis. It must be carefully designed. If a field survey is not carefully designed, the value of the survey is reduced because:

1. important questions are omitted;
2. poorly formulated questions produce erroneous responses;
3. unnecessary questions are included; and
4. poorly organized questions cause delay and errors in coding and tabulating of responses.

These problems can be avoided by following the steps in sample survey preparation. For example, carefully stating the hypotheses to be tested and designing master tables to record data can help identify the information needed and the type of questions to ask.

Understanding available time and resources will help determine length and complexity of the questionnaire. The survey technique and sample size needed to produce statistically reliable results also determine the length of questionnaire and the type of questions to ask. Finally, how questions are formulated and organized will depend on how the data are tabulated (manually or electronically) when the field survey is concluded.

Although there is no ideal questionnaire or set of rules for designing a farm-level survey questionnaire some general guidelines apply in most survey settings (Appendix 2).

Single objective

Multipurpose surveys usually result in a cumbersome census-type document that is difficult to analyze and will hinder gathering and processing data needed for the primary objective of the study.

Completeness

Preliminary formulation of hypotheses and preparation of master tables will assure that all data needed are included in the questionnaire.

Organization

Organizing data to be collected will help both the surveyor and respondent. When data are needed on crop production, farm-level survey questionnaires are often organized to follow the sequence of cultivation practices and input use followed by farmers, beginning with plowing and planting and ending with harvest and post-harvest activities. Sections may be added to record special information about farmer assets, labor availability, and other data that need only be collected once. Ask sensitive questions after your respondent understands your goals. For example, questions about income or land ownership might follow after general questions about cultivation practices or input use.

Clarity

When possible, units of measurement should be specified. Special instructions (record labor in hours) should be with the question or columns where the data will be recorded. Separate instruction sheets are seldom consulted in the field. It is always wise to pretest your questionnaire to determine the best wording to use in the actual survey. Instruct surveyors to record answers in local measures for conversion later. There is seldom time to do calculations in the field. Provide space for surveyors to record local measures and their equivalents in metric or other standard terms.

Length and content

Each question takes time, and costs money, to ask, process, and analyze. Be selective. Screen proposed questions carefully and decide if the respondent is the appropriate source for the answer, or if the answer can be more readily obtained elsewhere.

Avoid leading questions. Many people try to please the questioner with their answers. Others will distort their answers depending on how they perceive the answers may be used. You cannot eliminate all response problems, but you can improve surveys by phrasing questions objectively to avoid hinting at the desirable answer. If there is a strong element of doubt or distortion in the answer, ask some objectively verifiable cross check questions.

Recall questions must be formulated with special care.

Consistency

Record data carefully. Separate plot-level and farm-level questions to avoid confusion over measurement.

Indicate missing information. To say no fertilizer was used is different from saying information on fertilizer was not collected because the respondent gave no answer. A non-answer incorrectly tabulated as none used will bias results. Non-answers must be considered missing and coded to ensure such cases are excluded from calculations of sample averages. All questions must be answered.

Single vs multiple forms

For some survey conditions it may be necessary to decide if one questionnaire form is appropriate or two or more forms are more suitable. In cropping systems research where data on the economic performance of different crops may be required, this choice may need to be made.

One long form with provisions to handle several different crops may waste space because questions for all crops must be included although each form will be used for only one crop. However, forms designed for specific crops may be more wasteful if they share many common questions. Two forms also cost more time in printing and collating.

Multiple forms add to training burdens and lead to confusion in the field when one form runs out or the wrong one is grabbed in haste to get to an interview on time. Multiple forms also add to tabulating burdens. Field experience suggests that the simpler the questionnaire form the better the chances of meeting the requirements of representativeness, accuracy, and timeliness for farm surveys.

FORMULATING SURVEY QUESTIONS

There are several ways to ask a question and each is appropriate under certain conditions. The three most popular types of questions are the open-ended question, the multiple choice question, and the quantitative question.

The open-ended question format records the respondent's own words. Samples are: "What did you do last season to control pests?" or "How did you market your harvest?"

Open-ended questions are suitable if questionnaires are short (it takes time to write responses), and sample sizes are small (it takes time to tabulate results). Open-ended style questionnaires are suitable for *key informant* surveys and are useful when surveyors are unfamiliar with an area and wish to test responses before undertaking larger sample surveys.

Open-ended questions are easy to formulate, allow maximum freedom of reply, and are useful when surveyors do not know local conditions. However, responses are difficult to classify and tabulate, and surveyors recording responses are difficult to control.

Multiple choice questions are often used when the objectives of the survey are to classify farmers by crop cultivated, land tenancy arrangement, or particular cultivation practices. Less than ten response choices are usually provided. The surveyor determines the category of the reply.

Multiple choice questions are used when quick overviews of large survey areas are needed to guide future sample survey work. For example, a multiple choice questionnaire to determine how many farmers grew selected crops may help in designing a stratified sample of respondents that includes enough cultivators of each crop to be studied (Table 3).

Multiple choice questions also categorize respondents when comparing yield costs, returns, or other measures of economic performance.

Multiple choice questions remind respondents and surveyors what the management options were, are easy to code and tabulate, and are quick to ask and fill in.

Table 3. Multiple choice question format used in a weeding survey.

Indicate how you controlled weeds in your crops on this plot last season:

(Circle one) ▭

0 No response
1 No weeding done
2 Hand - own labor
3 Hand - hired labor
4 Hand - owned and hired labor
5 Mechanical weeder - owned
6 Mechanical weeder - rented
7 Herbicide
8 Hand and herbicide
9 Hand and mechanical
10 Mechanical and herbicide
11 Hand, mechanical, herbicide
12 Others

However, they give "how" information only, may put words into the respondents' mouth, and may not include all possible responses.

Quantitative questions provide data on specific amounts of inputs used by farmers to be used in detailed and rigorous agroeconomic analysis. Collecting accurate quantitative data requires careful formulation of questions. Reference to land area must be precise and measures (often local) must be specified (Table 4).

Quantitative questions are essential to most cost-of-production studies and studies of agronomic or economic efficiency of labor or input use. They should be designed for computer processing because sample sizes must be fairly large, given the variability of responses and degree of reliability desired.

Quantitative questions allow surveyors to record quantitative information, require respondents to give careful answers, and responses can be computerized for rapid analysis. However, they require more time to complete and careful attention to response coding, and may not include all possible responses. Appendix 3 gives an example of a cost of production survey questionnaire.

There are many pitfalls to formulating survey questions that will provide accurate responses. Table 5 gives an example of what can happen if a question is not asked clearly.

SELECTING THE SURVEY SAMPLE

When survey information needs are established and a questionnaire has been designed to collect and record data, we must determine from whom data will be collected. *Purposive* and *probabilistic* methods of selecting survey respondents can be used.

Purposive selection is the conscious choice of respondents by established criteria, such as surveyor access, crops cultivated, or membership in organizations. Although purposive selection helps surveyors get results quickly, they do not allow our findings to be generalized to the population of farmers being studied because the respondents may not be representative farmers. For example, surveying farmers selected because they were by the side of the road may produce respondents who are market oriented and perhaps more technologically advanced than farmers in remote areas.

If precise data that are representative of all farmers in the survey population are

Table 4. Quantitative question format used in a weeding survey.

1. When did you do first weeding? mo ____ wk ____
2. How many weedings did you do? _____
3. What kind of herbicide did you apply? (name) _____
4. What amount of herbicide did you apply? (grams) _____
5. What cost of herbicide? M ____ per ____
6. Indicate days of labor used in weeding control:
   a) Family labor ____ days ____ hours
   b) Hired labor ____ days ____ hours
   c) Exchange labor ____days ____ hours
7. What wage did you pay for weeding?
   a) Cash ____/day
   b) Kind ____ /day

Table 5. An example of the Dangers of Poor Survey Questions.

Ten farmers with exactly the same yield were asked: "What rice output did you get on your land last year?" When converted to tons per hectare all answers were different. Below are the answers and reasons why.

Farmer	*Response*	*Explanation of Response*
1	5.0	This is the correct answer.
2	2.5	The farmer was a tenant and deducted the landlord's share.
3	3.0	The farmer answered for the crop grown last *season* not last year.
4	3.5	The farmer converted paddy (rough rice) to clean rice.
5	4.0	The farmer deducted the rice he sold.
6	4.5	The farmer deducted a 1/10 share he paid to the harvester.
7	6.0	The farmer harvested his crop wet (24% moisture); no adjustment to dry equivalent was made.
8	7.0	The farmer incorrectly reported the size of his plot and the surveyor did not check it.
9	10.0	This farmer replied for his whole farm not for the plot being surveyed.
10	100.0	The farmer responded in local measure (cavans) and the surveyor did not convert it to tons.

needed, a *probability* sampling method can be used to assure that each respondent in the survey population has an equal probability of being selected. Probabilistic selection is used in most farm-level surveys. There are several methods for drawing probability samples from a population, each with certain advantages.

If each respondent in the population is equally important, we can use a *simple* or *systematic random sample*. If the characteristics of individuals within the population

differ and they can be categorized, random samples from each category might be selected to improve the validity of the survey. This is called a *stratified random sampling*. Cluster sampling may be used when travel between fields is difficult, or when travel time and funds are limited.

Simple random sampling

If the only information we have about a farm survey population is a list of its members, then simple random sampling is the best method of selecting respondents. Obtaining lists of farm-households is possible only if the survey area is small or a recent census list is available. Respondents can be randomly selected from farm-household lists using random numbers tables that use the digits 0-9 in an unstructured, unsystematic, random manner, where each digit occurs with about the same frequency. To select respondents:

1. Obtain a count of the population under study.
2. Use the size of the population to determine the grouping of random digits in the table that will be used. For example, if the population is between 10 and 99, use digit groupings; between 100 and 999, use 3-digit groupings; between 1,000 and 9,999 use 4-digit groupings, etc.
3. Assign sequence numbers to the population members.
4. Select any point in the table to start.
5. Proceed in any systematic manner (down, across, etc) selecting and recording those numbers that fall within the population range, and disregarding numbers outside the range, until the total designated sample size has been selected.

Systematic random sampling selects items from all parts of the population in an unbiased systematic manner rather than picking items at random. To use systematic random sampling:

1. Assign a sequence number to each member of the population.
2. Determine the skip interval by dividing the number of units in the population by the sample size:

$$i = \frac{P}{S}$$

Where: i = skip interval,
P = population size, and
S = sample size.

3. Select a starting point in a random digit table.
4. Include that item in the sample, and every "i" th item thereafter, until the total sample has been selected.

Sometimes, items in a population are arranged in a repetitive or cyclical pattern. If the skip interval is on the same cycle, your sample items may not be representative of the total population but may all have the same characteristics.

The greatest shortcoming of simple and systematic random sampling procedures is the need to have a complete list of all population units from which to randomly select sample respondents. If surveys for site description, production evaluation, or consequences assessment are to be undertaken, populations may be too large for total enumeration.

If researchers know that some characteristics of individuals within a population differ and that these differences are significant to the survey problem, and it is possible to classify these individuals by their characteristics, a more accurate description of the population can be made by selecting a random sample from groups of individuals with similar characteristics. This is known as *stratified random sampling.*

For example, if the yields of rice farms in a province are to be studied it might be useful to stratify the farms by irrigated, rainfed, and upland because these characteristics are known, can be classified, and are significant factors in determining rice yields. Results using stratification are more meaningful than selecting farms randomly.

The sample size drawn from stratifications should be proportionate to the size of the group, which reduces the analytical problems in evaluating the results. For instance, if we wanted to survey 200 ha from South Cotabato and the province had been stratified as indicated below, the sample size for each category would also be based on the same percentage, thus:

Stratification	*Hectares*	*Percentages*	*Sample size*
Irrigated	35,000	46.5	93.0
Rainfed	31,728	42.2	84.4
Upland	8,500	11.3	22.6
Total	75,228	100.0	200.0

Sampling within each stratum can then be done by any of the other methods discussed.

Cluster sampling is the only practical means of gathering data where there are time limitations and/or difficult field travel conditions. Cluster sampling is also practical when a multistage surveying process is feasible — where provinces are randomly selected, then villages, areas within villages are partitioned, and smaller areas are randomly chosen for a total survey of all farms.

In cluster sampling many or all respondents are querried at a few sites. Whenever possible, the total appropriate population (all rice farmers in a selected barrio) are interviewed.

It may take 2 or more days and extensive traveling for an interviewer to obtain responses from 10 farmers by simple random sampling if they are scattered all over the province. By randomly selecting two barrios, and interviewing as many farmers as possible within those barrios, more farmers can be contacted in less time.

Because this sampling method draws responses from a limited cross section of the total population samples should be larger than minimum sample size specifications. As many clusters as can be accommodated by the time/budget limitations should also be selected. Clusters should be of equal size.

It is important to remember that the clusters must be selected on a scientific basis and that sampling done within the cluster should also be random.

DETERMINING SAMPLE SIZE

One of the most difficult decisions field researchers must make is the choice of the number of farmers and survey plots from which to collect data for analysis.

Suggestions range from using a few case-study respondents on plots to samples of 5, 10, or 20% of the farm population of a survey region that may include several hundred thousand respondents.

Collecting and evaluating data from large samples are difficult and information from a 5 or 10% sample is not more statistically reliable than a 1 or a 0.01% sample. Statistical reliability depends not only on the number of respondents but also on the variability of data.

If wide variability is found, a relatively large number of sample respondents or plots must be selected to ensure that mean values calculated from the sample accurately estimate the mean values for the entire population. If variables differ only slightly then a smaller sample of plots can be selected to estimate mean values reliably.

We want to have 90 to 99% statistical reliability in our sampling, but must realize that having limited control over manpower, time, and money limits the number of respondents that can be reached.

To achieve a suitable level of sampling reliability and enhance the credibility of our survey results the degree of variability in the data collected must be reduced. Variability can be limited by carefully defining the survey population.

Precise formulation of hypotheses reduces data requirements, population size, and reduces the data variability. By specifying objectives of the sample, survey variability in observations and sample size can be reduced. For example, modern and local varieties may each perform differently under rainfed and irrigated conditions. Limiting the survey to a study of the relative economic performance of MV and local variety cultivation under irrigated conditions will reduce data variability and requirements for large numbers of plot experiments and farmer interviews.

Special care must be taken not to eliminate variables that are closely associated with the characteristics of the technologies being tested. For example, MV yields may be more sensitive to planting dates than those of local varieties. To reduce variability and sample size requirements by limiting analysis of data to MV and local variety, rice cultivators who planted after/before a certain date might remove an important variable from the analysis.

SELECTING THE DATA PROCESSING PROCEDURE

Data tabulation and analysis test the study hypotheses and reveal new findings. However, data tabulation and analysis can be tedious and time-consuming if data processing methods were not planned early in the survey design process.

If samples are small (less than 100 respondents) and the analysis is site specific, tabulation and analysis can — and often should — be done in the field by field researchers. Field researchers know the data and the farmers best, and are often the best judges of survey results. Field tabulation and analysis help researchers focus future surveys and studies. However, field-level analysis requires greater supervision and additional field staff training.

Larger samples or cross-site analyses require centralized tabulation preferably supported by computer processing. If indeed computer processing is used computer specialists should help design questionnaires and supervise data coding. These tasks

should not be the responsibility of field researchers, and they must not be allowed to interfere with their primary duties.

If hand tabulation with pocket or desk calculators is used data must be transferred from survey forms to tabulation sheets or, if the questionnaire is short, transferred directly to the calculator. Data taken from short questionnaires tabulated using a small programmable calculator with basic statistical operations can be successful and efficient. When forms are grouped for analysis the field researcher can enter all the values for one variable and quickly calculate means, variances, and numbers of observations on a separate sheet.

Statistical measures calculated for a single variable from modern and local varieties can then be compared using, for example, a t-test to determine if there are statistically significant differences between the two groups. If more than two groups are involved other statistical tests of significance can be used.

When descriptive statistics (means, frequencies, variances) and related statistical tests (standard deviation, t-test, F-test, chi-square) are recorded, questionnaires can be regrouped to test whether other characteristics of the respondents or their crops explain their economic performance. Tabulation sheets can be used in the same way, although with more difficulty because the researcher must use the error-prone process of pick and choose according to the classification needed. Physically sorting the questionnaires into piles reduces errors.

CONDUCTING THE SAMPLE SURVEY

The sample size chosen for a farm-level survey will depend on the number of farmers the field researcher and his staff or colleagues can interview with the time and money available. Although no strict rules on sample size apply, there is a simple formula for farm-level agroeconomic survey size.

Between three and four farm-level surveys can be conducted per man-day of surveyor time in the field. This includes multiple visits (three half-hour visits at preplanting, preharvest, and postharvest) or one 2-hour postharvest visit plus a crop-cut for comparison of measured yields with farmer estimates. Survey times include the time used going to and from the farmer's home or field, returning when he is not available, etc.

A 2-man field team, with 50 working days (10 5-day weeks) in the field can reach between 300 and 400 respondents during a crop season. This is a small percentage of the farm population or number of crop plots cultivated in most survey environments, and again underscores the need to carefully define survey objectives and formulate survey hypotheses.

Optimum sample size differs with the objectives of the survey. A common erroneous idea is that the larger the sample the better the sample. Larger samples require more supervision and more field staff training. Errors happen when large numbers of poorly trained surveyors are used instead of a small group of well-prepared, motivated field researchers.

Differences in interviewers' personalities and questioning techniques affect the responses they obtain. These differences can never be eliminated but they can be minimized. The following are techniques that will reduce interviewer bias.

Brief the interviewers

A survey is rarely conducted by one individual. Make sure all interviewers understand the purpose of the survey, the definition of terms, and the meaning of the questions to be asked, and have a uniform way to record answers. Provide a procedural guide to follow when they encounter difficulties. If possible, arrange for a dry run interview session to supplement the orientation process.

Have the interviewer brief respondents

When you meet the respondent you should:

- introduce yourself,
- verify who you are speaking to,
- explain the reason for the survey and how it will be used,
- tell the respondent how he was selected for the interview,
- assure him that results are confidential,
- tell him how long the interview will last,
- ask if now is convenient for the interview, and
- find a suitable place to conduct the interview. (Privacy is desirable, especially if personal questions will be asked.)

Conducting the interview

Decide whether to follow a structured questionnaire format reading or an unstructured interview style. The structured style may get a response to every answer, but you may scare or inhibit the response, especially if you record the answers during the interview. Unstructured interviewing generally leads to wider ranging discussion, is longer, and may gather useful supplementary data. However, you may also miss important questions.

Field computations

Use local or familiar measures and minimize respondent computations. Get raw data that you can convert later. For plot-level surveys of cultivation costs and returns, the parcel size is important and should be measured whenever possible. (A method for measuring irregular plots is described in Appendix 4).

Do not rush

Avoid leading questions designed to elicit a quick reply. Take time to verify responses for accuracy by cross-checking and/or backtrack repetition. Often individuals misunderstand what you are asking, or only tell you what they think you want to hear. They may be trying to impress you, or gain your sympathy. Repeat your questions several different ways to ensure that they are understood and the person being interviewed is responding accurately.

Remember who you are

Do not promise anything, except to pass on information, unless you have authority to take corrective action. You are usually there only to observe and gather facts. The respondent, on the other hand, often regards you as a government representative who can and should do something about the situation. Idle promises cause a lack of confidence and lessen later cooperation.

ANALYZING SURVEY DATA

After data have been gathered and recorded on the survey forms, they must be edited, weighted, calculated, and interpreted. Consistent guidelines must be used to screen raw data gathered by different enumerators. Screening helps review for clarity, internal consistency, correction, and conversions for further processing.

Clarity

Data recorded in the field are sometimes illegible and/or unintelligible to a staff editor. Numbers may be illegible and comments may have been added to the standardized responses that might qualify the answers from "Yes" to "Yes, but . . . " Wherever possible, questionable items should be reviewed with the surveyor.

Where multiple choice responses were not used it is difficult to develop a standardized classification of open-ended comments. It may also develop that some questions that were overlooked in designing the questionnaire are significant. Thus, some preliminary modification or elimination of questions and responses may be necessary.

Internal consistency

Multiple choice questions may have been marked with multiple answers although one of the above was specified. There may be clarifying comments or no explanation. Editing of numbered responses is frequently necessary to place the recorded value into the standardized units requested. Sometimes a conversion factor is provided, sometimes it has been overlooked.

Correction

A whole range of important decisions about data treatment must be made during editing. Should it be rejected as erroneous, counted at face value regardless of error, or accepted but reduced in value, with an attempt to figure the intent?

Conversions

Some responses may need to be converted to common measures by editors or coding assistants. Sometimes a computer being used in the analysis can do the conversions if local measures are used throughout the survey.

THE FINAL REPORT

The final report describes the researchers' farm-level data collection and analysis. It must be clear, concise, and well-organized. Here, too, earlier formulation of hypotheses will be of help. Style manuals can be used to guide the structure of the final report so that they can be easily understood by users.

There is no fixed format for farm-level agroeconomic study reports. Their length, content, and organization are determined by the field researcher. Certain components of the study effort should be present, however. Among these the field researcher may wish to consider the following:

1. *Preface or acknowledgments.* Agroeconomic studies are undertaken in the belief that better knowledge about how agriculture works will contribute to better agricultural programs and policies. This is the place to say it. Persons who participated in data collection, analysis, and in financing and supervising the study effort deserve mention here. Do not forget to acknowledge the cultivator respondents who contributed their time to the study.
2. *Summary of findings.* A one-page summary of findings that includes page references to additional information is useful to readers. The field researcher should give the hypotheses and indicate if they were proven true. Suggestions for further refinement of analysis of future research can also be mentioned here or, if somewhat lengthy, in a final chapter.
3. *Introduction.* A brief description of the background and objectives of the survey is sometimes useful to the reader. For example, an analysis of the economic performance of MV and local rice cultivation may have been motivated from findings that MV adoption rate by farmers has slowed in recent years and that there may be an economic explanation for this trend. In such a case, a table showing national level MV and local rice hectarage trends over several years might help set a focus for the study. The objectives of the survey should include the hypotheses and the expected findings.
4. *Sampling methodology and survey procedures.* The sample population, how it was selected, and the methods used in the survey should be discussed here. Reasons for limiting the sample to those respondents/plots with special characteristics should be explained. Describing when and how respondents were interviewed gives readers an idea of the quality of data collection. A brief description of the survey sites may be appropriate here or in the annexes.
5. *Analytical findings.* This section describes the survey results and analysis. Agroeconomic studies generally begin with summary tables that support main survey findings such as the one used for illustration in this chapter. Following the summary tables there may be separate sections with tables (such as Table 2) discussing each of the inputs recorded and their rates of uses in the calculations. If further breakdowns of the data on costs and returns are called for, they usually follow in separate sections or become part of special annexes to the report, depending on how central they are to the objectives of the study.
6. *Annexes.* These are additions at the end of the report that can be used by readers interested in probing further into the study findings. The annexes also present subject matter that requires detailed discussions that would detract from the main purposes of the study. The following topics are frequently annexed to agroeconomic studies:
   a. *Respondent profiles* describe family size, land ownership, attitudes, etc that help the reader determine how representative the survey respondents are of farmers.
   b. *Site profiles* describe temperature, rainfall, soil type, infrastructure, and land use patterns, that describe the site where the survey work was done.
   c. *Sampling procedures* give further detail on how respondents were selected, a list of the survey villages, special characteristics of survey plots, or other case-specific information.

d. *References* list research conducted at the same survey site or on the same study topic in other sites that were used to guide this study or that might be useful for readers interested in pursuing the problem further. References to books containing explanations of the analytical or statistical procedures followed in the study also may be included.

SOME FINAL POINTS ON REPORTING SURVEY RESULTS

1. Avoid technical jargon.
2. Round off numbers. Although you may have gathered data in hectares, or tenths of hectares, the final report will probably be in thousands, tens of thousands, or hundreds of thousands.
3. Use graphs instead of tables. Usually the trend of data is more important than the precise numbers.
4. Where you do use tables try to get all the data on one page.
5. Tables should be *organized* to highlight a single message. Comprehensive matrixes of basic data are useful only for researchers' analysis — they do not communicate anything until they are interpreted. If you need a comprehensive table the appendix is the place for it. Extract from it the point you wish to make, then prepare a condensed version for the text.
6. Summarize tables in the text so readers understand them more thoroughly. Some people have a mental block against numbers and read only the text.
7. If you need more detail on a point, and it will clutter the text, use a footnote or appendix. Footnotes are best seen at the bottom of the page they refer to.

Appendix 1. Credit and interest.

Of all inputs used in crop cultivation credit (or capital) is the most difficult to measure and analyze.

Credit may be obtained for several purposes, some not related directly to agricultural production. Although farmers may obtain production loans to buy seed, fertilizer, and other inputs used in cultivation, some of the money may be used to pay market expenses until harvest.

Credit may also be used to buy all or part of the inputs for several plots. If survey data are collected only for one plot, the researcher must assign part of the credit costs to the single survey plot.

Credit costs are often hidden. Interest charges may be only part of the costs to borrowers of institutional (bank) credits. Special assessments (even bribes), documentation (deeds to land or registry of residency), and multiple visits from farm to bank branch add substantial costs to institutional credit. Local moneylenders may charge higher rates than banks but borrowers may not have to pay the other expenses associated with bank loans.

Farmers also use their own resources or those of relatives and friends. No interest payments are made for these resources but there is an economic cost because that money, otherwise invested in a savings account, for example, would have earned the farmer interest which is lost because it was needed for cultivation. The cost of lost interest earnings must be included when calculating a farmer's real production costs.

There are three ways of handling credit farm-level agroeconomic analysis:

1. *Credit costs can be ignored.* Some agroeconomic studies consider credit an irrelevant variable. For example, in the illustration used in Chapter 14 where the economic performance of modern and local seed varieties is being compared, credit costs, like land costs, can be excluded from the analysis, if their cash costs were similar.

   Care must be taken, however, to assure that the *financial* conditions are similar for both MV and local variety users.

2. *Credit costs can be imputed.* If credit costs should be included in analysis, the most direct method to use is to impute or estimate credit costs. The field researcher must decide what total value of credit should be used and what interest charge should be applied to it. Several choices exist for setting credit values and interest charges.

   Some analysts prefer to use the total of all input costs at market prices as the credit value. Others use the total of all cash costs — excluding the value of family labor and draft animals. Total of all cash cost is used by many agricultural banks, which often lend to finance borrowers' cash costs of production.

   Interest rates vary among credit sources. Banks generally charge low, often subsidized, interest rates. Moneylenders often charge high interest rates which may or may not be justified given their risks, the true cost of money, etc. Somewhere between these probably lies the true cost of capital (see Chapter 3 for a further discussion of how to calculate capital costs). Each of these rates has its merits in analysis. Perhaps the best rule to follow is once a rate is chosen do not change it.

3. *Credit costs can be tabulated.* A third alternative is to tabulate credit costs from data supplied by respondents. This method may be useful if credit is used by a large percentage of respondents, because then it is possible to obtain a subsample of data credit users large enough to achieve statistically reliable results. Of course, the problem of attribution of credit to production, mentioned earlier, must be recognized. In areas where production credits are extended in kind as part of broadly based production promotion schemes, this method of calculating credit costs may be suitable.

Appendix 2. Agroeconomic questions most frequently asked about crop cultivation practices.

Although area circumstances may be unique several questions are frequently asked in agroeconomic surveys of farmers' cultivation practices. Here is a list that can serve as a guideline in considering what to include in your survey.

Cultivation activity: _____

A. Area cultivated _____ ha /___/___/___/

B. Method employed (circle one) /___/

1 -
2 -
3 -
4 -

C. Number of applications /___/

D. Date activity began ____ (wk) /___/___/

E. Family labor: No. of persons _____

Days ____ Hours ____ /___/___/___/

F. Hired labor: No. of persons ____ /___/___/

Days ____ Hours ____ /___/___/___/

G. Exchange labor used (Circle one)

1 - None 3 - Most
2 - Some 4 - All /___/

H. Type of input used (circle one) /___/

1 -
2 -
3 -

I. If none used, why? (Circle one) /___/

1 - Not available when needed
2 - Cost too much
3 - No money to buy
4 - Not required
5 - Conditions not suitable
6 - Other _____

J. Amount of (input) used _____ kg /___/___/___/

K. Cost of (input) used _____₱/kg /___/___/___/

Appendix 3. Cost of production survey questionnaire.

(Date) _____ (Location) _____ (Code) _____ (Surveyor) _____

Farmer: Name _____ Age _____ Education _____

Owned area: MV _____ Local _____ Other crop _____ Total _____

Rented area: MV _____ Local _____ Other crop _____ Total _____

Family size: Adults: _____ Children: _____ Workers: _____ Survey plot size _____ (ha)

Draft animals: Owned: _____ Leased: _____ Shared: _____

Cultivation activity	Date the activity began (mo/wk)	Family days	Hired days	Total days	Day wage (M/day)	No. of meals	Real wage	Total cost
Labor inputs								
Plowing (man only) no. ____	____	____	____	____	____	____	____	____
Land preparation	____	____	____	____	____	____	____	____
Sowing (Broadcast or seedbed)	____	____	____	____	____	____	____	____
Transplanting	____	____	____	____	____	____	____	____
Fertilizer (topdress)	____	____	____	____	____	____	____	____
Pesticide (no. ____)	____	____	____	____	____	____	____	____
Weeding (no. ____)	____	____	____	____	____	____	____	____
Irrigation (no. ____)	____	____	____	____	____	____	____	____
Harvesting (if contract share of crop indicate %)	____	____	____	____	____	____	____	____
Postharvest optimum	____	____	____	____	____	____	____	____
Total (Labor Use)		____	____	____			____	____
Draft animal use								
Land preparation		____	____	____	____			____
Threshing/carrying		____	____	____	____			____
Total (Draft animals)		____	____	____	____			____

Continued on opposite page

Appendix continued

Input	If non used, why?	Source	Amount	Price	Cost
Seed: _____ (Variety)	_____	_____	_____	_____	_____
Fertilizer:					
Organic	_____	_____	_____	_____	_____
Basal Urea	_____	_____	_____	_____	_____
Basal TSP	_____	_____	_____	_____	_____
Basal MP	_____	_____	_____	_____	_____
Basal _____ (Others)	_____	_____	_____	_____	_____
Topdressed urea	_____	_____	_____	_____	_____
Topdressed _____ (Others)	_____	_____	_____	_____	_____
Pesticide: _____ (Type)	_____	_____	_____	_____	_____
Irrigation: _____ (Type)	_____	_____	_____	_____	_____
Fixed Input: _____ (Type)	_____	_____	_____	_____	_____
Credit: Cash/kind (circle one)	_____	_____	_____	_____	_____

Soil Type: 1 - Sand 2 - Clay 3 - Loam
4 - Sand/Loam 5 - Clay Loam
6 - Sand/Clay 7 - Other

Output prices: Grain _____ Straw _____
Output amount: Grain _____ Straw _____
Output value: Grain _____ Straw _____

Total input cost _____
Total production cost _____
Gross income _____
Net income _____

If plot leased/rented, share/payment to owner: _____

Appendix 4. Measuring a survey field of irregular shape

Agricultural economists are frequently asked to gather plot-level information on farmers' crop production practices. Data must be converted from plot-specific measure to per hectare or other standard unit measures to permit comparisons of farmers or between farmer and experimental trial results.

Accurate measurement of the farmers' plots is critical to obtaining reliable per hectare measures. Because of limited time and resources many surveyors depend on farmers' estimates of their field sizes. Although generally reliable, farmers tend to overestimate their field sizes, causing input level per product yield to be underestimated when the conversion per hectare or standard units is made.

When possible, surveyors should measure the fields to verify farmers' estimates. Farmer fields, however, often are irregular in shape making the area difficult to calculate. Surveyors who try to avoid these difficulties by seeking out only regularly shaped (square or rectangular) fields to gather survey data introduce biases into their results.

It is important to understand how to measure irregularly shaped fields. The method is called *measurement by triangularization* and is done by pacing (walking along the edges and counting the number of steps or paces on each side) or by using a steel tape measure and right angle bar.

Pacing the field is an acceptable way of field measurement. If the length of the average step has been accurately measured an estimate of field area that is within less than 1% of an estimate made using a steel tape measure can be obtained.

Measurement by triangularization

Irregular-shaped fields can be measured by partitioning their areas into right triangles, squares, and rectangles whose heights and bases are easily measured. Then all external sides of the partitions are measured by pacing or with a steel tape measure. Measuring only the external sides is practical because often it is not possible to walk through the field because of flooding or because the standing crop could be damaged.

Use measurement by triangularization to calculate the area of the irregular field drawn to a scale of 1:10 m in Figure 1.

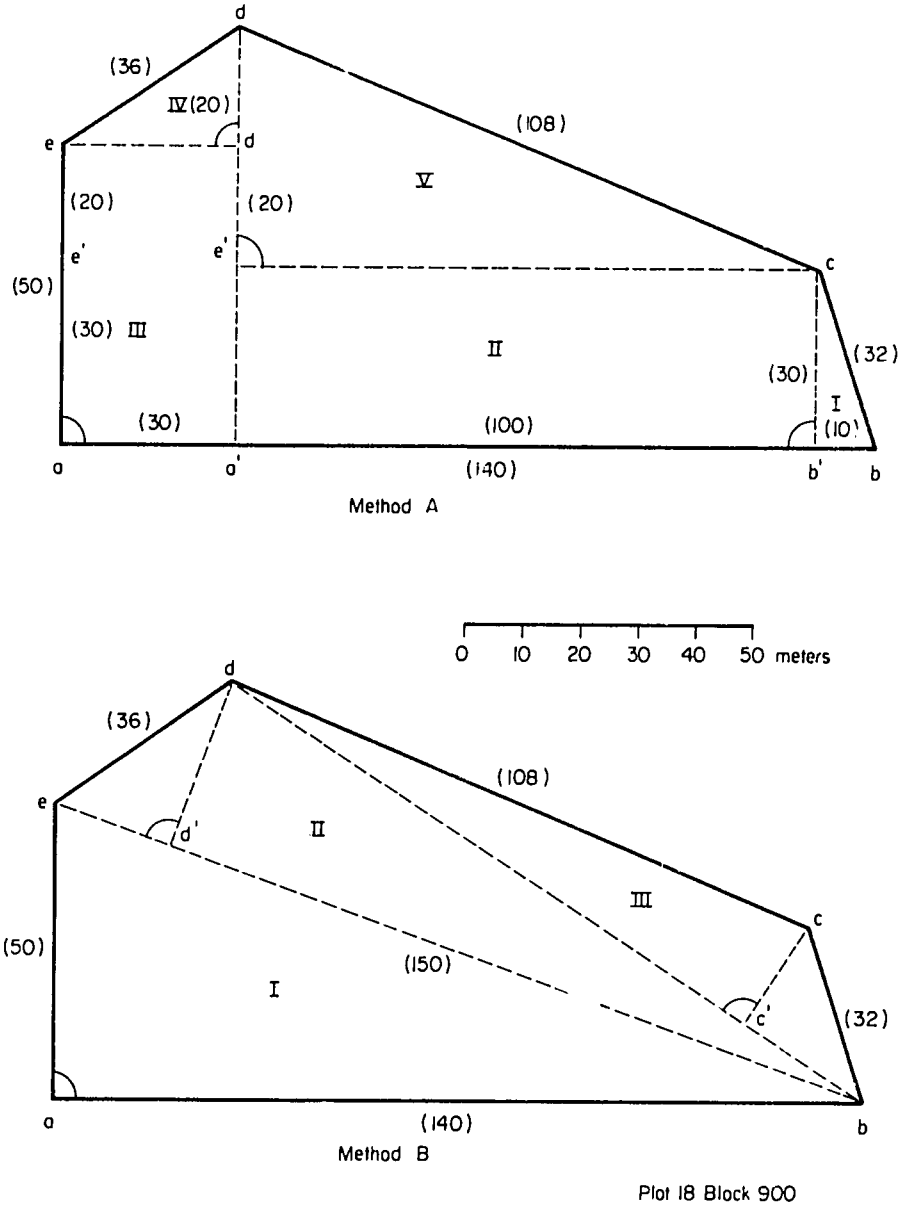
Step 1. Calculate the length of your average pace:

a. In a field of comparable soil conditions take 10 normal paces along a steel meter tape measure;
b. Do this three times and record the distance walked each time; sum the values and divide by 30 for the average length of your pace in meters.

M = _____ m
M = _____ m
M = _____ m
Total = _____ m

Average = (Total) ÷ 30 = _____ m

Step 2. On a piece of paper draw a sketch of the field as closely as you can determine visually (Fig. 1).



1. Measurement by triangularization.

Step 3. Divide the sketch of the field into triangles and rectangles.
(Note: Experiment to get as few partitions and internal sides and angles as possible. Two partition methods are shown here. Method A should be used when only the sides of the plot can be measured. Method B can be used when it is possible to walk in the field.)

Step 4. With a right angle bar and bamboo sticks locate the right angle vertices of each triangle. Then, by pacing or by steel tape, measure all sides of the survey plot and record their lengths on the sketch. (If measured by pacing, be sure to convert to meters.)

Step 5. Number the triangles, squares of rectangle partitions, and set up a working space to record the bases and heights of each as shown below.

(Method A - sides only)

Partition	*Base*	*Height*	*Area*
I	bb' = 10	b'c = 30	½ (30 X 10) = 150
II	a'b' = 100	b'c = 30	30 X 100 = 3,000
III	a'a' = 30	ae = 50	30 X 50 = 1,500
IV	a'a' = 30	d'd' = 20	½ (20 X 30) = 300
V	a'b' = 100	c'd = 40	½ (40 X 100) = 2,000
Total	—	—	— = 6,950 m^2

(Method B - sides and interior measures)

Partition	*Base*	*Height*	*Area*
I	ab = 140	ae = 50	½ (50 X 140) = 3,500
II	eb = 150	dd' = 30.4	½(150X30.4) = 2,280
III	db = 130	cc' = 18	½ (130X20) = 1,170
Total	—	—	— = 6,950 m^2

Step 6. Calculate the area of the field by totaling the corresponding areas of the triangles.

CHAPTER 14

DATA COLLECTION FOR EVALUATION OF NEW TECHNOLOGIES AT RESEARCH SITES

S. K. JAYASURIYA AND G. R. BANTA

Simple procedures which can be used for evaluating new technologies were discussed in Chapter 10. Data collection at a research site obtains information required for the evaluation process. To evaluate a new technology an understanding of the farming system is required. In cropping (or farming) systems research a preliminary understanding of the system at the research site is obtained from a site description survey. This survey provides the foundation for designing new technologies. In Chapter 12, methods and procedures for doing a site description survey are discussed.

During new technology testing additional data are necessary. Rainfall patterns, prices, and wages change over time. Agronomic and economic crop performance is affected by these changes. Performance of new and existing technologies must be compared under similar conditions. Accurate data on the performance of new and existing technologies on similar land types should also be obtained, and the preliminary profile from the site description survey should be confirmed and refined. This process will help researchers understand how farmers allocate resources to different activities and better assess the interactions between various subsystems in the farm.

In the following sections we will describe the kind of data that should be collected at a site during the testing phase of research and procedures for collecting appropriate data using limited resources. We assume that a preliminary site description survey has been conducted previously.

DATA TO BE COLLECTED

Site-level, farm-level, and plot-level data will be collected. Some data must be collected periodically while other data may be collected only once, unless major changes have occurred since the data were first collected.

Site-level data

Most site-level data are collected during the site description survey. However, some important site-level variables change significantly over time.

Data must be regularly collected for:

a) farm product and input prices,

b) wage rates and contractual arrangements,

c) custom hire rates for farm machinery and animal power, and

d) credit facilities and interest rates.

Input and output prices, custom hire rates, and wage rates can change substantially during the year (seasonally). They should be carefully monitored to determine seasonal patterns. All rates, including interest rates, change over time. Data gathered the first year of research may be outdated by the second year.

Wages and product prices can be obtained from farmers who are regularly interviewed by site staff. Remember, farm-gate prices can differ significantly from the price at the market even in the nearest town. The price farmers get for their rice, for example, may be much lower than the official price at a state-administered purchasing center. Farm-gate product prices can be different from retail prices in the same area, particularly for storable goods. Thus, the retail price of rice at a shop may remain relatively unchanged over the year whereas farm-gate prices fluctuate substantially.

Wages and prices should be monitored monthly and if resources permit, weekly. Appendix 1 gives examples of data collection methods that can be used to regularly monitor and record wages and prices.

Input prices can be obtained most easily from dealers. If farms are far from markets transportation costs may be significant and should be added to input purchase price.

When technological changes take place, tenancy and other contractual arrangements also tend to change. Prevailing contractual arrangements (landlord's share, harvesters' share etc) should be checked at least twice a year.

Chapters 4 and 11 discuss procedures for obtaining appropriate wage and price data.

Farm- and plot-level data

Most farm- and plot-level data about existing farmer technology can be obtained by regularly monitoring a group of carefully chosen typical farmers (see Zandstra et al 1981).

How many farmers to monitor?

At least 5 plots of each major farmer technology on a given land type where research will be conducted must be monitored. A technology that covers 30% or more of the area of the particular land type is a major technology. There can be as many as 3 major farmer technologies on a given land type. If this is the case at least 15 plots must be monitored.

If research is conducted on 2 land types and there are 3 major technologies on each, a minimum of 30 plots must be monitored. If there are several cropping patterns grown on a specific land type, one farmer will usually use several technologies. Using the guidelines given in the next section, every effort should be made to minimize the number of farmers monitored by selecting farms with the different land types and several technologies.

Table 1. Characteristics of modal farmers.

Farm size	2-3 ha
Irrigated area	10-20%
Number of draft animals	1
Tenure	Share-tenant
Fertilizer use in rice	20-40 kg/ha

How to select farmer-cooperators

Because random sample methods are widely recommended for use in farm surveys, it is often thought economic-cooperators at research sites should be selected in the same way. This is not always correct. Indeed, it is incorrect when trying to choose a small number of farmers with multiple characteristics. If you want to find five typical farmers, you are likely to do a better job choosing them purposely than if you pick five farms randomly from a list of farmers in the village.

Generally, farmers who are representative of the majority of the target population are needed. Because farmers have many characteristics, they must be representative of the most important of these characteristics.

List the three or four characteristics that will be most important at the site. These may be farm size, farm composition (irrigated land, semi-irrigated land) tenure, ownership of draft animals, and level of fertilizer use.

From our initial farm survey we know the characteristics of the *modal* (most common) farmers. Table 1 gives the characteristics of 75% of the farmers in the area.

If many farmers have these five characteristics several more criteria, such as off-farm income, household size, etc, might be added to ensure we get modal or representative farmers. Because many decisions will be based on data from these few farms extra time and effort at this stage are worthwhile.

Now farmers who have approximately these characteristics and are on the land type we want should be chosen. If a farm survey of a substantial number of farmers has already been conducted, information obtained from that survey can be used to select the cooperators.

If the site description was done using a different method, such as a key informant survey, we do not have data on individual farms. In such a situation, a rapid survey of several farmers must be conducted to obtain data on the farm-level factors identified as the most important during site description. Check carefully to see that the farmers are not too different from typical farmers in other ways. (We might find a farmer who has all required characteristics, but who has a son sending money from Saudi Arabia and has bought a 4-wheel tractor and a rice mill. This farmer is certainly not typical.)

Use your judgment to make sure the farmer is typical, even when he meets all the important requirements. Remember, there is a tendency to pick the better farmers rather than typical farmers. The objective is to know how the majority is performing; so the typical, not the better, farmer must be examined.

Basic farm-household data from economic-cooperators

Before beginning regular monitoring of relevant farm activities, a profile of each cooperator farm household must be developed. This profile, to be expanded over

time, provides the framework and the data base for studying the farming system and the interactions of different components.

Appendix 2 is an example of the type of questionnaire we can use to collect these data. These data should be collected once at the beginning of our regular data collection and used to develop a resource flow model of the farm household.

Regular data collection

Ideally, data on all farm-household activities should be collected regularly. However, if all activities are monitored at once the data load is large, the cooperators become bored and/or reluctant to give truthful information, the enumerators become bored and careless, and the analysis is delayed or never completed. Therefore, it is important that we collect only those data that are essential to the evaluation procedures discussed in Chapter 10. It is most important to collect useful, accurate data on farmer technology (or technologies) on the land type(s) of interest.

When the basic whole farm information has been obtained, select one parcel for intensive monitoring. A parcel is a contiguous area with a single land type. It should usually be the largest parcel of the land type we are interested in. If we are interested in more than one land type and the farmer has those land types, then we can select one parcel of each type for intensive monitoring.

Use a questionnaire like that in Appendix 3 to obtain data on farm cropping activities on a weekly basis. If the parcel is planted to two or more crops, collect data on all crops grown on a significant area. Although daily collection may give better data, remember that our resources are limited. Detailed data should be obtained for only the selected parcel(s). For other parcels, record when major operations (land preparation, crop establishment, harvesting, etc) are done. These data help check the nature of labor use distribution on the farm. Also record use of fertilizer and chemicals. During his weekly visit the enumerator can ask the farmer if he did any major operation on his other parcels and record the response. Major operations must be clearly specified so the enumerator is not confused. Data obtained during site description can be used to estimate labor use levels for these parcels.

If a crop fails, record the time and reason for the failure. Major insect and disease attacks should also be recorded.

Maintain a map of the farmer's land area. At the beginning of every crop year, record what crops are grown in each parcel and the areas devoted to them. As new crops are planted, record how the land area is reallocated to different crops. Farmers may often plant the parcel to one crop at the beginning of the year, then divide the parcel and grow several different crops simultaneously. For example, a 1-ha parcel may be planted to rice as the first crop. After rice is harvested, the farmer may grow mungbean on .25 ha and tobacco on .5 ha, and leave .25 ha fallow. Three different cropping patterns should be recorded for the same parcel: 1) rice - fallow, .25 ha; 2) rice - mung, .25 ha; and 3) rice - tobacco, .5 ha.

If watermelon follows in .1 ha of the land planted to mung, the number of patterns increases to 4:

1) Rice - fallow, .25 ha;
2) Rice - mung, .15 ha;

3) Rice - mung - water melon, .10 ha; and
4) Rice - tobacco, .5 ha.

When another crop is established we should clearly indicate where in the parcel it is being grown so the different plots in the parcel can be determined. A plot is a contiguous area of land planted in a homogeneous manner during a defined period, normally 1 year (Zandstra et al 1981). Unless there were major differences in the management and input use within areas where a particular cropping pattern was grown, the area under each cropping pattern can be treated as a single plot. If there are differences in technology, patterns must be differentiated into different plots, even if the crops are the same. For instance, if .5 ha was transplanted (TPR) and .5 was direct seeded (DSR) in the first rice crop and tobacco was subsequently grown in .25 ha of the transplanted rice area, and the rest of the transplanted area was left fallow, the cropping patterns in that parcel would be:

1) TPR - fallow, .25 ha;
2) TPR - tobacco, .25 ha;
3) DSR - mung, .15 ha;
4) DSR - mung - watermelon, .10 ha; and
5) DSR - tobacco, .25 ha.

We now distinguish between direct-seeded rice and transplanted rice as two technologies employed by the farmer in rice cultivation.

The data from the intensive parcel should be transferred to an appropriate sheet (see Appendix 4 for an example) immediately after collection to permit rapid analysis. At the end of each crop season and crop year, data should be analyzed for each crop and presented as in Figure 1.

When the data are to be analyzed and presented based on different technologies, input-output data for the individual plots must be presented. When the plots have been specified using the maps where successive crops were recorded, inputs and outputs must be allocated to different plots. The common procedure is to allocate them in proportion to the areas. For instance, if the mung bean yield from .25 ha was 100 kg, 40 kg is the mung yield in the DSR - mung - watermelon pattern and 60 kg, the mung yield in the DSR - mung pattern. The same applies to inputs.

Labor data

After the first year, labor data for common operations need not be collected because it is not likely to vary much from year to year. Work out standards based on data from first year and use these for the analysis. A common exception is weeding labor, particularly in rainfed conditions. This can vary substantially from year to year. If this is the case (check with farmers), record it regularly even after the first year.

Sometimes, information on labor requirements for many common operations may be available from other studies in the same site or in similar environments. Using these data can reduce the regular data collection load.

Output data

It is important that the outputs from the different plots are accurately recorded when comparing farmer technologies with new technologies. Farmers usually measure

COSTS AND RETURNS OF CROPPING PATTERN TRIALS
PATTERN SUMMARY

Country _____ Program _____ Site _____ Year _____ Pattern _____

	First crop:								Second crop:								All crops						
Plot no.	Yield /ha	Costs per ha			Returns				Yield /ha	Costs per ha			Returns				Costs per ha			Returns			
		Labor power	Mate-rials	Total var	Gross /ha	Net /ha	To L&P	To mat		Labor power	Mate-rials	Total var	Gross /ha	Net /ha	To L&P	To mat	Labor power	Mate-rials	Total var	Gross /ha	Net /ha	To L&P	To mat
Total																							
No.																							
Mean																							
S.D.																							
G.V.																							

1. Form for analyzing data for each crop in a cropping pattern trial. (Source: Price & Banta 1977)

crop output from major grain crops at harvest. Phrase questions about crop output carefully when interviewing farmers about total crop output. Otherwise, instead of total output the farmer may report the amount he obtained after deducting shares paid the landlord and/or laborers and others.

Crop cuts are an objective way of measuring yields but farmers may not like researchers to take crop cuts. Also, crop cuts tend to overestimate plot yields by 10-20%.

When a crop is harvested more than once and much of it is used for home consumption, accurate measurement is more difficult. The enumerators must take extra care to obtain reasonable estimates of such products if these crops are important.

When we have the basic input-output data required for calculating a budgeting analysis of farmer technology and the data to develop annual labor use schedules and graphs for specific land type(s) and the whole farm (using data on operations in the other parcels together with estimates of labor use), a questionnaire like the questionnaire given in Appendix 5 can be used to regularly record (weekly if possible) major incomes and expenses during the year. After 2-3 months, it will be possible to estimate the average monthly expenditure for basic consumption items. If resources are limited we can stop collecting this information and record only other major expenses.

However, income and expense data are difficult to obtain accurately and many farmers are unwilling to divulge details of these personal activities. When resources are limited and/or farmers are uncooperative, it may be best to assess the general level and pattern of cash flows by informal questioning and interactions, with farmers and other members of the community such as shop keepers, extension agents, and officials. Careful, sensitive observation of a community can give a researcher a good idea of cash flow. Village festivals and ceremonies when expenses are high should be noted.

The basic objective of these activities is to obtain an insight into the general level and pattern of cash flows during the year, and to identify when cash is likely to be scarce or plentiful. We also want to determine how expenses, particularly production expenses, are financed and the availability of credit facilities.

Sequential evaluation and changes in data collection

New technologies should be evaluated at the end of each crop season and particularly at the end of the crop year.

Plot-level analysis, supplemented by information on farm-level considerations, particularly labor and cash flow, should help researchers understand major interactions between activities on the land type being studied and other farm components (subsystems).

When these interactions appear important, data collection should be adjusted to obtain more precise, complete information. For example, we may find that operations on a dryland area tend to coincide with operations specified by the new technology for a lowland area. In this situation, it is important to have accurate data on labor use in the upland area. During the next cropping year labor use during the relevant period in the dryland area would be monitored to determine if the conflict in

labor needs is likely to hamper acceptance of the new technology. Also, it may be decided to reduce the volume of data being collected for a farm component that appears unlikely to have an important interaction with the new technology if it is introduced.

It is most important to remember that collecting data is not an end in itself. Data are collected so new technologies can be compared with present farmer technologies. We have to collect, process, and analyze data using limited resources and time. An approximate answer in time is infinitely more useful than the perfect answer too late. Data collection methods and volume should be constantly reviewed and adjusted based on experience. Data irrelevant to the basic problem of new technology evaluation or data that we lack the capacity to analyze should not be collected. Collecting data that cannot be analyzed in time serves only to reduce the amount of useful research.

Zandstra et al (1981) and Price and Banta (1977) discuss this in more detail.

REFERENCES CITED

Price, E. C., and G. R. Banta. 1977. Economics handbook. *In* The proceedings of the 6th working group meeting of the Asian Cropping Systems Network. IRRI.

Zandstra, H. G., E. C. Price, J. A. Litsinger, and R. A. Morris. 1981. A methodology for on-farm cropping systems research. International Rice Research Institute, Los Baños, Philippines.

Appendix 1. Prices and wages.

1. Labor wages[a/] (monthly)

	Month											
Operation	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Plowing												

[a/] Make sure the wage is the total wage. Add the cost of food, snacks, etc to the cash wage. You must estimate the value of the typical noncash payments.

2. Power tiller hire rate[b/] (monthly)

Operation	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
plowing												
harrowing												

[b/] Clearly specify unit such as per hectare, per day, etc.

3. Carabao hire rate[c/] (monthly)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
₱20/day											

[c/] Add to the cash payment the value of any food or snacks given to man handling carabao.

4. Thresher hire rate[d/] (monthly)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1/10th of paddy											

[d/] Clearly state unit of payment.

5. Products[e/] (weekly or monthly)

5.1 Rice (paddy) - Place: Farm Gate, Barrio, St. Antonio

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
₱90/ha											

[e/] Clearly state unit.

5.2 Maize (green) Place: _____

MONTHLY

INPUT PRICES

Obtain the following data from the local input supply store:

Input[a] \ Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

[a] List all major purchased inputs and describe them clearly (e.g. Furadan, granules), and make sure the unit is clearly indicated (kg, kg a.i., etc)

Appendix 2. Profile of economic cooperators.

Site:

Farmer's name: Date:

Village: Enumerator's name:

1. Household details

Relationship to operator	Age	Sex	Education	Main Occupation	Months available for farm work

2. Major sources of cash income

Source	Amount[a]	% of total cash income
Farming		
Crops		
Livestock		
Nonfarming		
Total		

[a] Only approximate figures can be obtained; ask for figures for the last year or if it was an atypical year, obtain figures for a normal year.

3. Membership in any farmer organization (where membership gives access to credit, inputs, etc.)

Organization
1.

4. Farm assets: Land

4.1 Map

Draw a map of the parcels with area and distance from farm and number them.

4.2

Parcel number	Area (ha)	Tenure	Arrangement	Irrigation status	Topography	Soil color/ texture	Other	Present[b/] cropping pattern(s)
1	.7	Share-tenant	50:50 cash costs 2/3:1/3 output	Pump-irrigated	Side slope	Black, heavy clay		Transplanted rice - tobacco (60%) Rice - garlic (40%)
2	.5	Amorti-zation	500 kg rice/ crop	Canal-irrigated (8 months)	Plain	Clay loam	Near main road	Wet-seeded rice-wet-seeded rice (40%)
3								

Note:

(a) Take particular care about parcels that are the same land type as those for which new technologies are designed. Measure the area carefully and indicate any factors which may affect crop performance.

[b/] The technology expected to be used this year if it is early in the crop year or the technology used during last year if the crop year is finished (or nearly finished).

4.3 Cropping practices input use

Input	Amount or quantity used		
	Rice	Maize	Tobacco
Fertilizer			
1. Urea	40 kg	20 kg	60 kg
2. TSP			
Insecticide			
1. Furadan			

5. Farm assets: Livestock

Type	Number
Work animals	
Water buffalo	2
Other	
Water buffalo	1
Cow	1
Chicken	6

6. Farm assets: Equipment and machinery

Type	Number
Plow	1
2-wheel tractor	1
4-wheel tractor	0
Sprayer	1

7. Farm products used within the farm

Product	Used for[c/]					
	Human consumption (%)	Animal consumption (%)	Sale (%)	Crop production (%)	Others	Not used
Rice	80		20			
Rice bran		100 - for pig				
Rice straw		60		20 mulch for tobacco		
Mung	70		30			
Milk	80		20			
Cow dung	40 as fuel			60 manure		

[c/] If used for more than one purpose indicate approximate percentage in each purpose.

8. Remarks

Appendix 3. Questionnaire to obtain data on farm cropping activities on a weekly basis.

Site :

Farmer's name :

Village :

1. Data from selected intensive monitoring parcel:[a]

Parcel number

Crop 1

Date planted:

Date (week) harvested: 1.

2.

3.

1.1 Labor

Week	Operation	Quantity			Total	Payment			
		Family[b]	Exchange	Hired		Cash		Kind	
						Wage	Meals	Product	Amount of produce	Meals

[a] All weeks can be conveniently numbered by numbering the first week. 1-7 Jan as week 1, 8-15 Jan as week 2, and so on up to week 52.

[b] A worker less than 14 years old is counted as .5.

1.2 Fertilizer

Input	Week	Type	Amount	Cost
Fertilizer (Inorganic)				
Manure				
Insecticide				
Herbicide				
Others				

1.3 Power

Machine	Operation	Cost

1.4 Yield

Week	Produce	Amount

2. Other plots

Plot 2 (lab)

Week	Operation

Fertilizer - Type/quantity

Chemical -

Yield of crop 1[c/] =

Yield of crop 2 =

Yield of crop 3 =

Plot 3

Week	Operation

Yield of crop 1 =

Yield of crop 2 =

Yield of crop 3 =

Plot 4

Week	Operation

[c/] Specify clearly how yield is measured $\frac{1}{M}$ paddy, green maize, dry maize, etc.

3.1 Crop and livestock sales

Week	Product	Amount	Value	Where sold

3.2 Off-farm incomes

Month	Source	Amount

3.3 Expenses

Week	Source	Amount

Appendix 4. Cost and returns of cropping pattern trials.

Plot Summary

Country _____ Program _____ Site _____

Farmer _____ Plot _____ Plot size _____

Cropping pattern A

ITEMS	1st crop					2d crop				
LABOR	wk /no	lh[a] /plot	lh[a] /ha	cost /h	cost /ha	wk /no	lh[a] /plot	lh[a] /ha	cost /h	cost /ha
Plowing 1	16	3	30	1.50	45	43	2.5	25	1.50	37.50
Plowing 2	18	2	20	1.50	30					
Harrowing 1	19	3	30	1.50	45					
Harrowing 2	25	2	20	1.50	30					
Seedbed preparation	22	2	20	1.50	30					
Plowing 3	25	4	40	1.50	60					
(Other) F'xing bunds	29	2	20	1.50	30					
TOTAL LAND PREPARATION		18	180		270		2.5	25		37.50
Planting/Transplanting	26	20	200	0.50	100		0.5	5	0.75	3.75
Replanting										
Thinning										
TOTAL PLANTING		20	200		100		0.5	5		3.75
Hand weeding 1	30	5	50	0.50	25					
Hand weeding 2										
Cultivation 1										
Cultivation 2										
(Other)										
TOTAL WEEDING		5	50		25					
Fertilization 1	26	1	10	0.50	5	43	0.5	5	0.50	2.50
Fertilization 2	30	1	10	0.50	5					
Insecticide Application 1	29	0.5	5	0.50	2.5	44	0.4	4	0.50	2.00
Insecticide Application 2						45	0.4	4	0.50	2.00
Herbicide Application 1	30	0.5	5	0.50	2.5					
Herbicide Application 2										
Nonchemical pest control										
Mulching										
Watering										
Draining										
Canopy manipulation										
(Other) Fertilization 3	37	1	10	0.50	5					
		4	40		20					
TOTAL OTHER CARE							1.3	13		6.50
Harvesting 1	41	60	600	1.50	900	56	26	260	2.00	520
Harvesting 2										
Harvesting 3										
TOTAL HARVESTING			600		900					520
TOTAL LABOR			1070		1315		30.3	303		567.75

[a]lh = labor hours.

Appendix 4. continued.

ITEM	1st crop						2d crop				
MATERIAL	Kind	Amt /plot	Amt /ha	a.i. /ha	Cost /ha		Kind	Amt /plot	Amt /ha	a.i. /ha	Cost /ha
Seed		12 kg									
Fertilizer 1	14-14-14	20 kg	200		220		14-14-14	30	300		330
Fertilizer 2	Urea	15 kg	150		180						
Total N		14.3	143					4.2	42		
Total P		2.8	28					4.2	42		
Total K		2.8	28					4.2	42		
Insecticide 1	Carbaryl	0.2	2 kg	1.5k/ha	20		Azodrin	0.15	1.5	0.25	110
Insecticide 2							Azodrin	0.15	1.5	0.25	110
Herbicide 1	2,4-D gran.	2.5 kg	25 kg	0.8 kg/ha	150						
Herbicide 1							Azodrin	0.15	1.5	0.25	110
Herbicide 2											
Fungicide 1											
(Other) Fertilization 3	Am. sulfate	20 kg	200		200						
TOTAL MATERIAL					670						550
POWER	Type	h /plot	h /ha	Cost /ha	Cost /ha		Type	h /plot	h /ha	Cost /ha	Cost /ha
Plowing 1	Animal	3	30	1.50	45		Animal	2.5	25	1.50	37.50
Plowing 2	"	2	20	1.50	30						
Harrowing 1	"	3	30	1.50	45						
Harrowing 2	"	2	20	1.50	30						
(Others)	"	4	40	1.50	60						
TOTAL POWER					210			2.5	25		37.50
PRODUCTION	Grade	Amt /plot	Amt /ha	Price /unit	Value /ha		Grade	Amt /plot	Amt /ha	Price /unit	Value /ha
Harvest 1- unmilled rice		500 kg	5000 kg	1.10	₦5,500		Mung	80	800	5.00	₦4,000
Harvest 2											
Harvest 3											
TOTAL PRODUCTION					₦5,500						₦4,000

SUMMARY OF COSTS AND RETURNS PER HECTARE

	1st crop	2d crop	Both crops
Yield	5000 kg	800 kg	
Gross returns	5500	4000	
Labor and power cost ₦	1525	605.25	
Material cost ₦	670	550	
Total variable costs ₦	2195	1155.25	
Returns above variable costs ₦	3305	2844.75	
Returns to labor and power costs ₦/₦			
Returns to material cost ₦/₦			

Appendix 5. Incomes and expenditures.

1. Incomes

1.1 Crop and livestock sales

Week/month	Product	Amount	Value

1.2 Off-and non-farm income

Week/month	Operation	Number[1/] of days (if relevant)	Amount

[1/] if worked as laborer, etc.

1.3 Others

Week/month	Source	Amount

2. Expenses

2.1 Regular household expenses

Week/month	Item	Quality	Amount
Jan	Meat	3 kg	₦ 60.00

2.2 Regular payments

Week/month	Item	Amount
Jan	School fees	₦ 200.00

2.3 Farm inputs

Week/month	Type	Amount	Value

2.4 Others

Week/month	Item	Value

Credit use

Borrowing

Week	Amount	Source	Interest rate/arrangements	Purpose

Repayment

Week	Amount	Source	When borrowed	Interest rate