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ASIAN CROPPING SYSTEMS RESEARCH

MICROECONOMIC EVALUATION PROCEDURES

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Asian Cropping Systems Research: Microeconomic Evaluation Procedures

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Abstract/Résumé/Resumen

This publication analyzes the microeconomics component of cropping systems research in Southeast Asia. More specifically, it examines the program of the Asian cropping systems network and the role of the International Rice Research Institute. The objectives of the study were to describe the multidisciplinary cropping systems research approach, with emphasis on the economic component and the role of the agricultural economist, and to develop informal economic analysis procedures that could be used by team economists on the respective research sites.

The cropping systems program involves a multidisciplinary team conducting interdisciplinary research on a specific problem set. The research sites are the farmers' fields with the farmer as a partner in the research. The major task of the agricultural economist on the team is to assist in the evaluation of the new technology arising out of the cropping systems research. A set of informal procedures was developed to utilize the case study approach in evaluating profitability of the new technology. These informal procedures involved partial budgeting, graphing for resource constraints, and program planning. They were tested against the more formal procedures for accuracy of conclusions as well as time and other resource requirements. The informal procedures were found to be less precise but equally accurate in predicting the acceptability of new technology arising out of cropping systems research in the farm environment. Furthermore, the informal procedures and results were found to be more easily understood by other team members.

Cette communication analyse la composante micro-économique de la recherche sur les systèmes culturaux en Asie du Sud-Est. Elle examine en particulier le programme du réseau asiatique de systèmes culturaux et le rôle de l'Institut international de recherche sur le riz. Les objectifs de l'étude étaient de décrire l'approche multidisciplinaire de cette recherche en s'attachant principalement à la composante économique et au rôle de l'économiste agricole, et de mettre au point des méthodes simples d'analyse économique pouvant être utilisées sur les différents sites de recherche par des équipes d'économistes.

Le programme des systèmes culturaux met en oeuvre une équipe multidisciplinaire effectuant des travaux de recherche interdisciplinaire sur des problèmes déterminés. Les sites de recherche sont les champs des cultivateurs, et le cultivateur est associé aux travaux de l'équipe. La tâche principale de l'économiste agricole attaché à l'équipe est de contribuer à l'appréciation des nouvelles techniques culturales résultant de la recherche entreprise. Un ensemble de méthodes simples fut mis au point en vue d'utiliser l'approche de l'étude de cas pour l'appréciation de la rentabilité des nouvelles techniques. Elles comprenaient le calcul de budgets partiels, l'établissement de graphiques pour déterminer les possibilités en matière de ressources, et l'élaboration de plans de production. Les conclusions et les données relatives aux ressources et temps requis ont été comparées aux résultats obtenus par des méthodes plus classiques. Les méthodes simples se sont avérées moins précises, mais d'une exactitude équivalente en ce qui concerne la prévision de l'adoption des nouvelles techniques résultant de la recherche sur les systèmes culturaux réalisée dans des exploitations agricoles. De plus, elles se sont révélés plus faciles à comprendre par les autres membres de l'équipe.

Esta publicación analiza el componente microeconómico de la investigación sobre sistemas de cultivo en el sudeste asiático. Más especificamente examina el programa de la red de sistemas de cultivo en Asia y el papel del Instituto Internacional de Investigación del Arroz. Los objetivos del estudio eran describir el enfoque hacia la investigación de los sistemas multidisciplinarios de cultivo, haciendo énfasis en el componente económico; el papel de los economistas agrícolas; y el desarrollo de procedimientos informales de análisis económico que pudieran ser utilizados por equipos de economistas en sus respectivos lugares de investigación.

El programa de sistemas de cultivo implica un equipo multidisciplinario que realiza investigación interdisciplinaria sobre un problema especificado. El lugar de investigación es el campo agrícola, en que el mismo agricultor participa activamente en la investigación. La tarea principal del economista agrícola del equipo es ayudar a evaluar la neuva tecnología que surge de la investigación de sistemas de cultivo. Se concibió un juego de procedimientos informales que utilizara el enfoque de estudio casuístico en la evaluación de los beneficios de la nueva tecnología. Estos procedimientos informales implicaban la presupuestación parcial, las gráficas de limitaciones de recursos y la planificación de programas. Todos ellos fueron probados, comparándolos con procedimientos más formales, para determinar la precisión de las conclusiones, así como el factor tiempo y otros requisitos de recursos. Se encontró que los procedimientos informales eran menos detallados, si bien igualmente precisos, al predecir la aceptabilidad de la nueva tecnología que surge de la investigación de sistemas de cultivo en el ambiente agrícola. Además, se encontró que los procedimientos informales y sus resultados eran más fácilmente comprendidos por otros miembros del equipo.

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Preface

Cropping systems research in Asia is a very dynamic program. New ideas are tried continually to improve the understanding of the systems being researched and the efficiency of the research. However, many of the economists at the sites have not had access to a simple set of procedures that explain the basic steps of analysis and help identify their role in the overall program. This publication should help them to be more productive members of the cropping systems teams by giving them a basic set of procedures that can be added to as their understanding increases. Even now, new ideas are being developed and used that are an improvement on those presented in this publication.

The ideas presented were not developed by me; they were borrowed from a variety of sources and were tested while I was interacting with agronomists, statisticians, pathologists, entomologists, breeders, and other economists. It is the farmer who does the final evaluation but, by using the procedure discussed, we can save ourselves and the farmer a lot of time that is wasted in trying new technology that has little chance of success.

Economists have a long history of evaluating after the fact but, if they are to function in an interdisciplinary team developing technology, they must be prepared to speed up their work and present their analysis and conclusion in an easily understandable form to the other disciplines in the team. By including information on how the research methodology and the parameters of the research system were developed, I hope to help economists to be more efficient and effective. To define goals and establish criteria, economists must have a thorough understanding of the system in which they are working.

IDRC was very supportive in the early years of cropping systems research when objectives and methodologies were being clarified. This support has allowed a network of researchers to develop and test a research methodology that is now being accepted throughout Asia and in many countries in Africa and Latin America.

I would like to thank IRRI for allowing me to return and use their facilities while doing the study, Dr T.A. Petersen for his guidance and patience, Drs F. MacHardy and L. Bauer for their many ideas, and Michael Graham for the massive editing job.

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Introduction

Cereals account for 80% of the food consumed in Asia. Although the per capita supply of food has remained relatively unchanged over the past several decades in Asia, the gross cereal deficit from country production has gone from an estimated 11.5×10^6 t in 1969–71 to 18.3×10^6 t in 1974–75, and it is expected to reach 46.3×10^6 t in 1985–86 (IFPRI 1976). This deficit has been met partly by imports and partly by hunger. For Asia to meet its food needs by 1985, total food production within Asia must increase by 4.2%/year; or even more if per capita income or population increase faster than projected (IFPRI 1976). So far, a growth rate of more than 4% in food production has been achieved by only a few countries, and for only a short period of time.

Because rice accounts for 59% of all food consumed, it is an important factor in the amelioration of Asia's food problem. The International Rice Research Institute (IRRI) has estimated that with an average 10% increase in fertilizer use, there could be an annual raise in rice production of 2.3% by 1985, if the irrigated area also grew at 3%/year. If the irrigated area grew at 2%/year, rice production would increase at 1.8% annually by 1985. A 3%/year increase in irrigated area would involve an annual investment of about U.S.$2 billion (IRRI 1978). However, even a 2.3% increase in rice production would not meet the needs. In a review of the implications of the study the IRRI economists state the alternatives very clearly (IRRI 1978, p. 383):

> The model's projections imply that in the absence of technology change, it will be impossible for production to grow fast enough to meet demand even with the level of annual investment twice as high as that of the past decade. . . . The results suggest that continued reliance on fertilizer and irrigation as major sources of output growth is likely to be extremely costly unless steps can be taken to increase the productivity of these inputs. This can be accomplished only through further emphasis on research and extension that will (1) close the gap between potential and actual yields with present technology, and (2) raise the potential by developing and disseminating better technology.

Population growth, available arable land, and crop production increases clearly indicate that there is a food problem in Asia that will get worse. A variety of recommendations and suggestions have been made on ways to solve or at least stave off the problem until population growth can be stabilized. Hopper (1977) suggests a massive irrigation program in the Gangetic Plain that could add 70 or 80% to present world grain output on a stable basis, but would require U.S.$60 billion. India's gross national product is U.S.$80 billion; therefore, there seems little chance of such a program. The limited probability of any such scheme being started with foreign aid is made clear when it is considered that the Indicative World Plan for Agriculture prepared in the late 1960s required U.S.$112.5 billion over a 23-year period. The plan called for U.S.$8.5 billion in 1962 and was to end with U.S.$26 billion in 1985. In 1975, the commitments to the plan were U.S.$3.5 billion, in constant 1972 prices, with 40% of this nonconcessional assistance (Bhattacharjee 1978).

The resources needed for such large programs are not going to be available in the near future unless there is a radical change in the actions of the materially rich countries. The countries of Asia need to make the best use of their resources by combining them with available technology to increase food production as quickly as possible. A relatively new research program being developed in Asia may be able to assist in meeting the food shortage. This program is called cropping systems research.

Food production in Asia will ultimately be decided by the 276 million people economically active in agriculture. They are called farmers for discussion purposes, although it is realized many are wives, children, and hired workers. Because these farmers are the ultimate users of agricultural research in Asia, it is important to understand some of their socioeconomic characteristics.

Asian farmers are not a homogeneous group. First, there is variation in their farm size: 25% are less than 0.5 ha in size; 20% are 0.5 – 1 ha; 22% are 1–2 ha, and 33% are over 2 ha (Harwood and Price 1976). Second, there is variation in production potential of the land ranging from 800 to 1750 kg of grain per ha (Buringh and Van Heemst 1977). Third, some have irrigation or partial irrigation, which totally changes their farming operation. Fourth, they face very different cost–price ratios. The fertilizer–rice price ratio is about 7 : 1 in Thailand and 3 : 1 in other parts of Asia (Castillo 1975). Fifth, they live in diverse cultures and so have different needs.

Generally, the farmers' resource bases differ, but they are usually very limited. They experience prices that vary widely not only from one location to another, but from one year to the next. All have different derived needs, but most of these needs can be met with a common unit, money.

One thing, however, is basic. The farmer is a rational decision-maker trying to meet his needs. Taiwan is often considered a leader in Asia in the development of its agriculture, and yet a survey of Taiwanese farmers came to the following conclusion (Hsieh 1963):

> In sum, the objective of farm operations in the survey area is still self-sufficiency. As crop production is mainly for home consumption, and livestock for compost producing, farmers' production planning is less influenced by the economic factors.

The concepts and attitude expressed by Allaby (1977) are in such complete opposition to this study they are worth noting:

> Farming though, is such an old business, and farmers have acquired such a range of skills, that always there are dangers of rediscovering the wheel, of devising a cunning new technique that in some odd corner peasants have been practising for centuries . . . I claim no originality for the discovery that if there is a world food problem it is not really susceptible to agricultural solutions.

Farmers, through centuries of trial and error, have learned a lot, and it should be one of the functions of agricultural scientists to learn, understand, and extend these ideas to others who have not discovered them. Other functions of agricultural scientists are to develop new technology that makes more efficient use of resources and to indicate to policymakers when a reallocation of resources will lead to greater productivity.

Given the agricultural situation in Asia, it is not difficult to understand why the direct transfer of Western technology has met with such limited success. The problem is not only that the direct transfer of technology has not worked, but also that the Western approach that produced this technology has not worked well in Asia. The discipline or commodity-specific research approach that was transferred to Asia to solve the farmers' problems has only worked in environments that are suited to specialization. In most of Asia, the trend is in the opposite direction. Due to population pressure on a limited land base, farms are getting smaller and there is more diversification as farmers try to utilize fully their limited resources. The overall need is to develop and implement research procedures that will produce new technology that is suited to small, diversified farms.

To develop technology that will be used it is essential to determine the current parameters of the farming system and to identify potential areas for improvement. This means that the current system must be understood. This understanding must include not only the cropping system but also its major interactions with other activities on the farm, and it should not simply be a list of input and output coefficients. Up to the present, a major portion of agricultural research in Asia has not considered the farm system into which the new technology must fit. In fact, little work has been done on developing an understanding of the farm as a production and consumption unit.

No one discipline can supply this. Interdisciplinary study is needed to effectively understand and describe the current Asian farms. It was to meet this need and to supply a basis for developing new technology that a cropping systems program was started at IRRI and tied into a network of similar programs in most Asian countries (the Asian cropping systems network). The cropping systems program is based on a multidisciplinary team conducting interdisciplinary research on a specified problem set. The overall objective of the team is to enable the farmer in a given environment to produce more food.

Systems Approach to Research

The concept of research based on a systems approach is not new in agriculture. Pliny noted that Roman farmers who used rotation cropping seemed to grow richer. Rothamstead station has shown that rotation is superior to monocropping for the last 200 years. Researchers who studied the systems before them without a strong training in one discipline could see the interactions in a system. By the early 1900s research had started to move into disciplines and by the early 1950s it was firmly entrenched. The sarcastic comment of Heady (1973) has the ring of truth in it:

> Over time the tendency has been for disciplines to dig deeper moats around themselves and to retreat further into the departmental bastions; while physically adjacent, their deeper discipline barriers permit simultaneous attacks on the major facets of relevant problems in isolation. In fact, furtherance of the discipline typically is taken as more important than the solution of people's problems.

Many people were dissatisfied with the tight disciplinary approach, particularly those who were at the interface between research and the farmer. The farmer viewed his farm as a system and had a working knowledge of the interactions of the present system. He could usually predict what the results of a change in one component of the system would be on the whole system. Most of the technology that came to him from research was considered, and later proven, not to contribute to the system's overall production. But, as Ebersohn (1976) observed, the research did not change — it became more specific:

> Increasingly detailed research is continually adding information on the components of agricultural systems. The effort is not being matched by synthesis of results into recipes that could be understood by farmers nor by predictions of the effect of adopted measures. These omissions have drawn criticism not only from farmers and their financing institutions who are left to their own devices to assemble the bits and pieces, but also from research administrators and scientists who are disappointed at the lack of impact their work makes on agricultural practice.

By the mid-1970s, serious doubts were being voiced about strict discipline-oriented research being able to solve the small farmers' problems. Based on its own experience and drawing from the experience of others, IRRI made a major commitment to systems research.

Systems research differs from traditional research in three major ways (Dillon 1976). The first difference lies in the way a problem is approached and analyzed. When initially looking at the problem, the whole situation in which it is found is considered; this is known as a holistic approach. The immediate goal is not to reduce the problem to the smallest part that will give a mechanical-type reaction. The interaction of the various components is noted in a systematic manner. Flow diagrams and matrices are two common ways of showing the interactions. The goal of the organization is taken as the end point. Then the various alternatives are considered based on the initial conditions and the desired end point. The components of the system are combined in such a way that the goal is met efficiently. There can be no measure of efficiency if a goal is not defined.

Because most problems on a farm deal with a set of different types of parameters, no one discipline is usually capable of adequately defining the problem. Systems research is normally associated with most agricultural situations. The researcher makes a set of subjective assumptions on the goals, resources, and synthesis of the components. These assumptions may be based on the best information available, but they are subjective, and another researcher with the same information may make a different decision.

The second major difference is that the selection of a research program is based on a systems basis. Through the use of a matrix or a flow diagram, some specific information is needed to show an interaction. If it is not known, and is considered important, finding that information becomes part of the research program. A systems approach identifies gaps in the data base. Evaluation of the need for missing data is subjective, but the criterion is its importance in relation to the final goal.

The third difference is that systems research is more likely to be efficient. Dillon (1976, p. 20) gives three reasons for using a systems approach in research: (1) the research is more purposeful, there is less danger of working on the wrong problem, and there is a greater chance of recognizing and responding to research needs and opportunities; (2) better research management is facilitated; and (3) agriculture is recognized for what it is — a hierarchy of systems with a purposeful nature.

Heady (1973) also refers to the administration of research using a systems approach: "Administrative control could be viewed in the context of a matrix where the rows are problem sets and the columns are disciplines." However, it would appear that the major reason for the efficiency of the systems approach is that an overall goal is defined, and each piece of research can be evaluated on what it can contribute toward reaching that goal.

There have been a variety of definitions put forward for the terminology used in agricultural systems research, particularly research directly relating to a farm. In 1978, a review of the work being done on farming systems in the International Agricultural Research Centres was made by the Technical Advisory Committee for the Consultative Group on International Agricultural Research (TAC, CGIAR 1978). Their definitions will be used:

> A *farming system* is not simply a collection of crops and animals to which one can apply this input or that and expect immediate results. Rather, it is a complicated interwoven mesh of soils, plants, animals, implements, workers, other inputs and environmental influences with the strands held and manipulated by a person called a farmer who, given his preferences and aspirations, attempts to produce output from the inputs and technology available to him. It is the farmer's unique understanding of his immediate environment, both natural and socio-economic, that results in his farming system.
>
> A *system* is defined as any set of elements or components that are interrelated and interact among themselves. Specifications of a system implies a boundary delimiting the system from its environment.
>
> *Systems analysis* refers to the holistic approach of studying the system as an entity made up of all its components and their interrelationships, together with relationships between the system and its environment.
>
> *Cropping system* refers to the set of crop systems making up the cropping activities of a farm system.
>
> *Crop system* comprises all components required for the production of a particular crop and the interrelationships between them and the environment.

The Current Cropping Systems Program at IRRI

The current cropping systems program at IRRI is aimed at increasing food production through more productive rice-based cropping systems in South and Southeast Asia. To meet this goal, four specific objectives have been defined: (1) to develop and extend research methodology in rice-based cropping systems, (2) to feed back specific problems found in the program to the concerned group, (3) to develop and test technology for agroclimatic zones similar to that of IRRI, and (4) to encourage and assist national cropping systems research programs in specific agroclimatic zones.

IRRI has divided cropping systems research into five phases: (1) description, (2) design, (3) testing, (4) preproduction evaluation, and (5) production programs (Fig. 1) (Zandstra 1977, p. 16). The descriptive phase is actually started before a research site is selected. Data are collected on soil characteristics, topography, rainfall patterns, current cropping systems, and temperature where applicable, and used in the final selection of a site. Once the site is selected, a baseline survey is done. This catalogs the resources available to the farmer and describes the present cropping system in some detail. A detailed listing is given by Banta (1977). This phase has two main functions. The first is to set out the situation found on arrival so that a comparison can be made later to determine if there have been any changes. The second and more immediately useful function is to serve as a guide to where opportunities may lie for new technology. These opportunities may arise both from constraints and from underutilization of resources in the present cropping system.

The design phase is the most critical in the research program. Here the knowledge of the different disciplines should be combined to produce a new cropping pattern that is more efficient than the present one. It is in this phase that the lack of clear objectives or the lack of knowledge shows most clearly

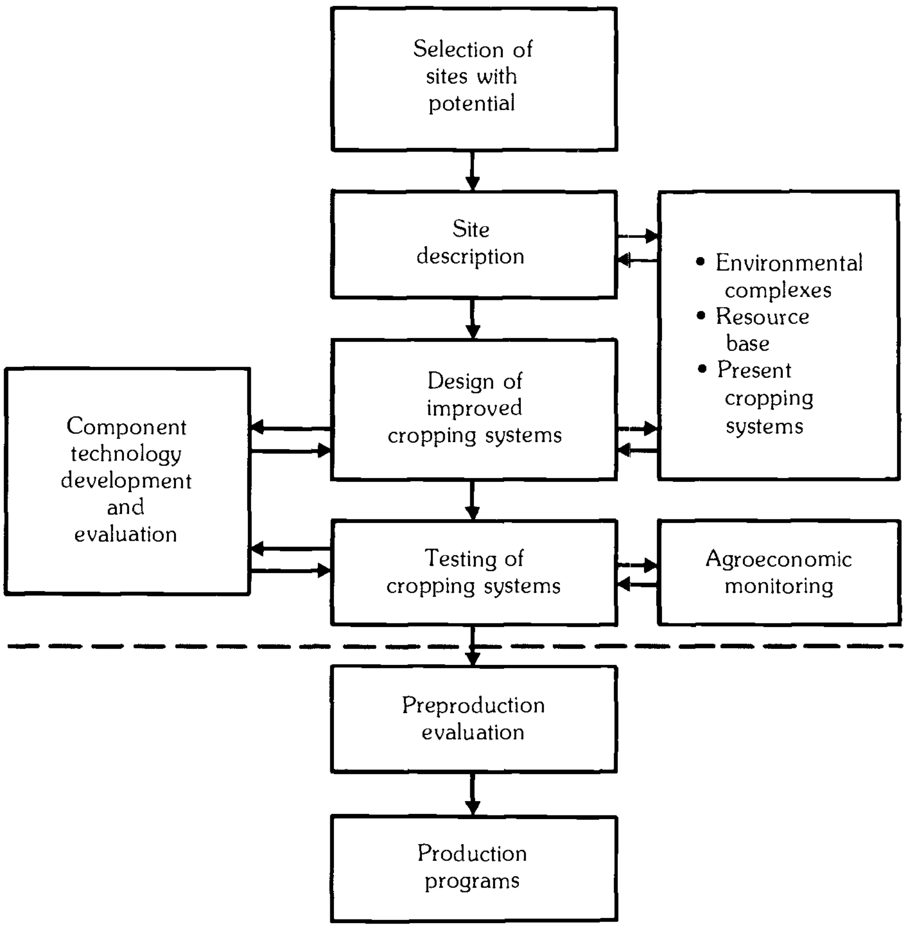

Fig. 1. Components of the cropping systems research methodology.

and can lead to major problems. When any one discipline cannot clearly communicate with the others, the pattern has less chance of meeting the objective set for it. The product of the design phase is a cropping pattern with all the production techniques specified, a list of data to be collected, and a set of alternatives if the weather or other environmental factors change. The design phase may also include a set of component technology experiments to give specific answers to problems found, or expected, in a pattern. These component technology experiments may be designed to be carried out on a research station, in a farmer's field under research management, or managed by the farmer in his field.

The design phase can be divided into two. The first design occurs following the description of the site. It usually has a wide range of patterns and tries to find out what is possible. The second type of design occurs after an experiment is finished, and the knowledge that has been gained is used to design the next experiment.

The testing phase is the actual production of crops in farmers' fields, the recording of all major factors influencing production, and the analysis of the results (Zandstra 1977, p. 24). While the crop is growing, all disciplines are monitoring the factors affecting the crop's growth and production. Although only one or two people may be in a field recording soil moisture, root depth, solar radiation, rainfall, seedling vigour, weed index, insect numbers, disease index, man-hours for an activity, inputs used, and the farmer's comments on what he thinks of the crop this information is used by all the disciplines to evaluate the pattern. The individual evaluations are then brought together and a decision is made on the pattern. There are three possible decisions: the pattern is rejected and no further work is done on it, the pattern is ready to pass to preproduction evaluation, or the pattern has potential but needs more research. If the latter decision is made it goes back to the design phase. A pattern may go through the design and testing phases several times. All testing of patterns is done on farmers' fields under farmer management, although some time may be spent with the farmer if a new technique is being used in the pattern. One simple test of a pattern is adoption by farmers around the site. However, this is not always an acceptable test, because they may try and fail if they do not understand and follow the required methodology.

The preproduction evaluation is the final research phase. In this phase, the pattern is put out on 30–50 farmers' fields with a complete set of instructions. It is one last evaluation of the pattern, but the main objective is to find if the technology can be understood and used by the farmers. At the same time any changes the farmers make are examined, and, if there are any major changes, the reasons for these changes are sought. Following this phase, which lasts for only 1 year, the technology is ready for extension in production projects.

The cropping systems teams have not been as effective as had been hoped. When any group decides to work together it is assumed that the product of its efforts will be greater than if each group member had worked alone. However, inherent in this assumption is another assumption, that each member of the group or team can and will contribute effectively to the team.

Throughout the cropping systems research programs in Asia there have been repeated discussions about the role of economics and its contribution.

Generally speaking, it is agreed that the economic component requires improvement. Several specific problems usually have been identified.

First, the economic results are of little assistance in the decision-making process. Usually this has been due to the late arrival of the results. Often the economic analysis of the research arrives after the next experiment has begun.

The second problem often mentioned is the economists' growing frustration about their work. The data are generated faster than they can handle them. At many sites, detailed record keeping takes so much time there is little time left to work on analysis. The frustration is aggravated by the fact that most of the other team members can finish their analyses in several weeks. The agronomist can discuss the results with the farmer while the factors regarding the research are still fresh in the farmer's mind, but the economist can contribute little due to a lack of timely analysis.

This book is concerned with finding more efficient procedures for the microeconomic evaluation of cropping systems research. Within this framework, there are two specific objectives.

The first objective is to review the validity and complexity of the econometric procedures that economists in the cropping systems program are now using. Most economists are using traditional econometric procedures and assuming that the basic assumptions of the procedures have been met and that they are the most efficient way to analyze cropping systems research.

The second objective is to develop a set of informal procedures that an economist can use to analyze the testing phase of cropping systems research. The procedures must have data requirements that allow the economist time for analysis and to conduct research on other problems. The results of the informal procedure must also lead to the same conclusions as a formal procedure such as linear programing. Each step in the informal procedure should lead to a decision answering the basic question: Is the alternative technology worthwhile? The informal procedure should be sensitive and complete enough so that relationships that are inconsistent with theory can be found and analyzed within the framework of the procedure.

Methodology and Analytical Procedures

To see how the economic component of cropping systems research can be of more assistance to Asian farmers, a framework is needed to better understand and analyze the farmers' current and potential decision-making situations. Farm management theory can supply such a framework.

Farm management is a special field of economics that considers the allocation of limited resources within the individual farm. It is a science of choice and decision-making, and thus, it is a field requiring studied judgment (Heady and Jensen 1964). Farm management is based on a study of the farm from the farmer's point of view. It considers the farm as a unit composed of production and consumption aspects in continual interaction. Thus, farm management is based on a systems approach. It has two goals: (1) to push profits to the level consistent with the capital resources and abilities of the farm operator and (2) to relate choices in farm operation to choices in the farm household in a manner consistent with the needs and wishes of the family (Heady and Jensen 1964). To meet these goals, farm management cannot function in isolation. It interacts with other social sciences to understand the social aspects of the farmer and his family in their environment. It interacts with biological and physical sciences to understand and evaluate biological and physical processes. It uses evaluation criteria from the disciplines of management and production economics. Farm management's role is to synthesize knowledge from a variety of disciplines to help the farmer achieve the greatest possible benefit from his farm operation with the resources available to him.

The Role of Management Science in Farm Management

Management is concerned with achieving goals or objectives. There are several approaches to understanding and describing management, and the approach that is used depends upon the environment and the objectives.

The classical approach assumes there is one best way to achieve an objective and that a set of rules should be laid down and followed to achieve this objective (Dessler 1979). This approach may be considered when the operation is highly structured and there are very few uncertainties, e.g., building a fence.

The behavioural approach is people-oriented and assumes that if a man is encouraged to take additional responsibility and is given flexibility he will increase his productivity (Dessler 1979). This approach has application in situations with limited structure and many uncertainties and could be used, for instance, when deciding if a new crop has a place on a farm.

Most managers use various proportions of these two extremes. On most farms there are many alternatives and a high level of uncertainty. Farm management tends, therefore, to put more emphasis on the second approach and tries to help the farmer understand his alternatives and make rational decisions to achieve his objectives.

Management guides the activities of individuals and organizations. Decisions are made and actions are taken in an attempt to reach goals in a world of uncertainty and scarce resources (Vincent 1962). The primary function of management is to recognize that a problem exists. This is the manager's acceptance that there is a gap between his present situation's likely outcome and his goal. The next step is to collect information regarding the present situation and the possible alternatives. When the information is collected it is analyzed in a manner that will allow comparison with the objective. Based on the results of this analysis, the manager makes a decision. He then takes action based on his decision and accepts responsibility for his action.

While decision-making is the heart of the management process, good decisions will not be made unless relevant facts are carefully analyzed and all the feasible alternatives are considered. Furthermore, a good decision will not bear fruit unless it is implemented through action. The evaluation of the outcome of his actions provides the manager with an opportunity to learn and to improve his managerial skills.

Objectives and goals are the reference points that allow an individual to decide if he has a problem. The closer his situation is to a goal, the smaller the problem. Objectives can be defined as the long-run aspirations of the farmer, and they are usually not thought of in specific quantitative terms. An objective might be to give his children a good education. Goals are more short-term and are usually thought of in more specific, quantitative terms. A goal might be to grow sufficient extra rice to pay school tuition of U.S.$50. Goals are usually intermediate steps in achieving an objective (Petersen 1976). Because all goals cannot be achieved at the same time, a manager must establish a hierarchy of goals.

Decision-making is thus an integral part of the management process. It is rarely a linear process; rather, it is iterative. The key factors in the decision-making process are: (1) a clear understanding of the goals and objectives so priorities can be established, (2) a clear definition of the problem, (3) information that supplies the analysis with relevant facts, (4) a logical and systematic analysis procedure, and (5) an efficient set of decision criteria. If any of these steps in the decision-making process are not followed the decision-maker lowers the probability of making a good decision.

The Role of Production Economics

While management science provides insights into the management and decision-making process, the field of economics, particularly production economics, provides the criteria the decision-maker uses in the economic evaluation of farm management problems.

The basic problem in most farm-management decisions is not only whether an alternative is profitable but, more important, whether it is more profitable than the other feasible alternatives. The economic principles of production economics can supply the criteria on which to base this decision. Production economics puts technical and biological production information into an analytical framework and applies costs and returns to provide answers to: Is it profitable? Is it the most profitable alternative? The analytic framework used in production economics initially provides the technical substitution ratios between resources, between resources and their products, and between products, and then uses price ratios as decision criteria. An example is the technical relationship between nitrogen fertilizer and a rice crop. When this relationship is known, the relative price of nitrogen fertilizer and rice are used to decide what rate will give the most profit.

The Basic Economic Decision in Production

A farmer achieves many of his goals by converting his resources — land, labour, and capital — into products. The more valuable the set of products he can produce from his resources, the more profit he can make and the more goals he can achieve.

To realize the greatest possible profit from his resources, a farmer uses the management process and economic criteria to make three basic decisions regarding the production process. They are: (1) How much to produce? (2) How to produce? and (3) What to produce? In making these decisions, the farmer decides on the kinds, amounts, and combinations of resources to use in the production process, and the kinds, amounts, and combinations of products to produce. The "how to produce" decision deals with the combination of inputs. "How much to produce" relates to the production process. The combination of outputs is a result of the "what to produce" decision.

"How Much to Produce"

In deciding "how much to produce" the decision-maker is first concerned with the technical relationship between input and output. The farmer needs to know the effect of nitrogen fertilizer on rice yields before he can start to decide on its use. The technical relationship between input and output is known as a production function. A production function can be written in the form of an equation: $Y = f(X_1 | X_2 \ldots X_n)$; this equation shows that the output Y is a function of a variable input X_1, with other inputs $X_2 \ldots X_n$ held at a constant level.

The relationship between the variable input and product can be presented in an equation or in a diagram. Most production functions related to biological processes have a sigmoid shape. A typical production function is shown in Fig. 2. As increasing units of input X are applied, the total production (TP) curve increases first at an increasing rate, then at a decreasing rate, and finally decreases in absolute terms. This phenomenon is known as the "principle of diminishing returns" and is a common characteristic of biological production functions.

The TP function can be further analyzed by deriving the average production (AP) and marginal production (MP) functions. The average production function is defined as Y/X and expresses the average production per unit of input of the variable X. The marginal production function, on the other hand, is defined as $\Delta Y/\Delta X$, and expresses the rate of productivity change at a given point on the total production curve.

The production function can be divided into three stages (Fig. 2). Stage II is the only rational decision-making area. Stage III is irrational because more output can be obtained by using less input. Stage I is irrational because average returns per unit of input are increasing; consequently, if the input pays at all, it will continue to pay better as long as the average production curve is rising. This leaves stage II as the economic decision-making area of the simple production function. Stage II can also be described as that portion of the production function where marginal production is negatively sloped but greater than zero and less than the average production function.

It should be noted that a producer will only produce to the end of stage II (where total production is at a maximum) when the input is free. If the input is severely rationed, he will apply it at a level consistent with the beginning of stage II, when the average product per unit of the input is highest.

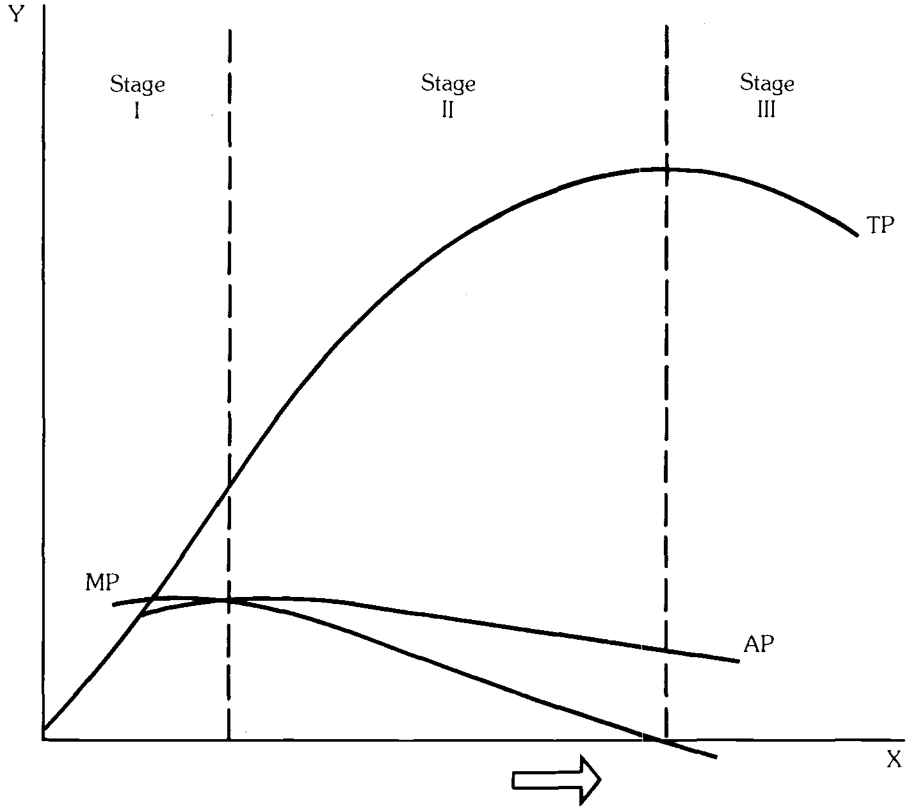

Fig. 2. Production function with average and marginal products.

However, the technical ratio $\Delta Y/\Delta X$ alone will not allow a decision to be made within stage II. The values of the input and output are also needed. The ratio of these values is known as the economic choice indicator. PX/PY is the price of a unit of input over the price of a unit of output. This ratio is used in stage II to determine the optimum level of output. The optimum output occurs when $\Delta Y/\Delta X = PX/PY$. By rearranging the equation the optimum level of output occurs when $\Delta Y \cdot PY = \Delta X \cdot PX$ or, added returns equal added costs. Often resources cannot be added in a continuous flow. If this is the situation, the optimum is reached when added returns are greater than or equal to added costs: $\Delta Y \cdot PY \geqslant \Delta X \cdot PX$.

To maximize profit from an input-output relationship a decision-maker equates the input-output ratio with the inverse price ratio. As long as added returns are greater than or equal to the added costs, the farmer is sure of making an economically desirable decision.

"How to Produce"

When deciding "how to produce" an output, the decision-maker is concerned with the combination of inputs that will produce a given output. There are three ways in which resources combine to produce a product: fixed proportions, constant rate of substitution, and decreasing rates of substitution. Inputs that combine in fixed proportions, such as a wooden plow and a man, require no decision about combination. A plow without a man will not affect production. Inputs that combine at a constant rate, such as yellow or white maize in the diet of a chicken, will not be used in combination. The most efficient decision will be to use all of one or the other. The reason will be explained later.

Most inputs in agriculture have decreasing rates of substitution. As an example, if land preparation hours are represented by X_1 and weeding hours by X_2, as land preparation hours increase, fewer hours of weeding are needed to produce a given amount of rice. The ratio of $\Delta X_2/\Delta X_1$ is a technical relationship known as the marginal rate of substitution. It is the rate at which X_1 substitutes for X_2 for a given level of output. The marginal rate of substitution alone cannot be used to make a decision; prices are needed also. The economic choice indicator for input-input decisions is: $\Delta X_2/\Delta X_1 = PX_1/PX_2$, the marginal rate of substitution equals the inverse price ratio. Rearranging the equation gives: $\Delta X_2 \cdot PX_2 = \Delta X_1 \cdot PX_1$, the reduced cost equals the added cost. This equation is used to decide which input to use if the inputs have constant rates of substitution. Because the marginal rate of substitution is constant, comparing the reduced costs and added costs at any point will show which to use. To minimize costs, a decision-maker equates the marginal rate of substitution with the inverse price ratio. By equating reduced costs and added returns, a farmer can make an efficient decision on how to produce.

"What to Produce"

When a farmer decides "what to produce" he determines what portion of his farm to plant to rice and what portion to maize. This is an output-output decision. Outputs can have different types of interactions with each other. There are both positive and negative biological interactions. A legume-grain interaction is usually considered positive, while cattle in a rice paddy is usually negative.

There are also economic interactions that can be beneficial or detrimental. A crop of maize after a crop of rice might be beneficial if most of the resources are not being used. However, a crop of maize at the same time as rice might be detrimental if few resources are available to grow either. The decision-maker must find the net effect of all relevant relationships.

There are three output relationships: complementary, supplementary, and competitive (Fig. 3). A complementary relationship exists between AB on the isoresource line. As Y_1 increases, Y_2 also increases. This is an irrational area of production because more of both products can be produced with the same resources. A supplementary relationship is shown at BC, i.e., as Y_1 increases, Y_2 continues at the same level. This also is an irrational area of production. A competitive relationship exists between C and D. It is in this area that an economic indicator is needed, because an increase in Y_1 causes a decrease in Y_2. This relationship is referred to as the marginal rate of transformation, $\Delta Y_2/\Delta Y_1$. For a competitive relationship, the economic optimum is achieved when: $\Delta Y_2/\Delta Y_1 = PY_1/PY_2$, the marginal rate of transformation equals the inverse price ratio. The equation can also be written: $\Delta Y_2 \cdot PY_2 = \Delta Y_1 \cdot PY_1$, or reduced returns are equal to added returns.

The maximum profit from an output-output relationship is obtained when the marginal rate of transformation equals the inverse price ratio. The farmer who equates reduced returns with added returns will make the most efficient decision on what to produce.

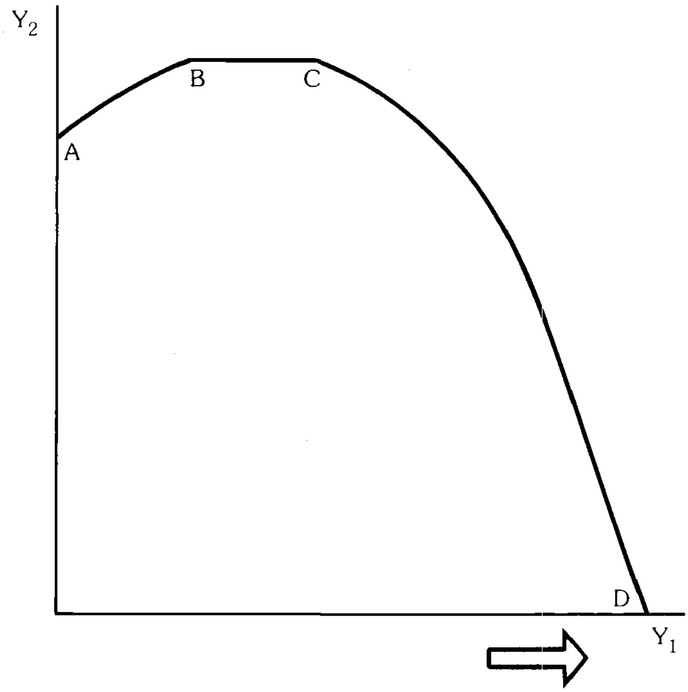

Fig. 3. The complementary, supplementary, and competitive output relationships as shown on the isoresource line.

Opportunity Cost

When a resource is limited, a decision criteria is needed to decide where it should be allocated and what value it should have. The question of value is particularly important for inputs, such as family labour, that are not usually bought or sold in the market. The principle of alternative opportunity cost can be used to make these decisions. The alternative opportunity cost of a resource is the return the resource can earn when put to its best alternative use. If the farmer can earn U.S.$10 a day working for his neighbour, the alternative opportunity cost of working in his own field is U.S.$10. The farmer then decides if working in his own field will pay U.S.$10 or more. By using this principle the decision-maker can decide if the resource is being used most efficiently and, if not, where it should be used.

The principle of alternative opportunity cost is important because it is a method that can be used to attach values to many inputs that do not enter the market place from a particular farm.

Dynamic Versus Static Analysis

All of the foregoing analyses are static. It is assumed that the production process is timeless and that the decision-maker knows with certainty all relationships and prices that affect the production process. Neither of these assumptions is valid. Most production processes on a farm are biological and take time. Neither the farmer nor the researcher knows what the output will be nor what the value of the output will be at harvest. Agricultural production is a dynamic process; therefore, modifications and adjustments must be made to the choice indicators that were used in the static analysis.

Time is an important factor, and there are two concepts that deal with time in decision-making. The first is discount or interest charges. A return of U.S.$100 in 10 years does not have the same value to a decision-maker as U.S.$100 now. Future income is discounted to obtain a present value. The amount of the discount depends upon the alternative opportunity cost of money, which is usually the prevailing interest rate. A farmer could not make a rational decision on whether to plant maize or fruit trees without discounting the future income from the trees. In the analysis of annual crops the time periods considered are nearly the same so discounting is not normally used.

The second concept of time deals with the flow of services from the resources used in the production process. This concept has major implications in cropping systems research. The inputs for a process may appear to be available when considered in total, but the input use pattern may show that at a given time there is a constraint. Most farms show a surplus of labour over the year, but at planting and harvesting many farms do not have sufficient labour. A graph showing the inputs that are available and that are required at each point in time is an effective decision-making tool.

Most of the parameters in the static analysis are really unknowns. In deciding between alternatives, the decision-maker does not know what output he will get from a given input, what the value of the output will be, what combination of inputs will give a certain output, and he may not know what the cost of the inputs will be when he takes action. An individual farmer faces many unknowns. The traditional approach to making decisions about unknowns is to divide them into risk and uncertainty. When a decision-maker knows the possible outcomes of a production process and the probabilities associated with each outcome, this is called risk, and an expected profit can be calculated.

Uncertainty occurs when the decision-maker does not know the possible outcomes. There is no generally accepted method of analysis. One method is to discount the expected profit by some arbitrary percentage. Recently, the concept of subjective probabilities has been used to deal with unknowns. Subjective probability is based on the degree of belief or strength of conviction a decision-maker has about a given outcome (Anderson et al. 1977). Thus, all outcomes are given a probability. The product of the expected outcome times its probability is then compared to the price ratio of the alternatives.

Present Status of Farm Management Economic Research

Until the early 1960s, farm management made a significant contribution to solving farmers' problems. The objective of most of the work was to understand and help solve the problems farmers were facing. By the mid-1960s, most production economists had access to computers and, therefore, could use sophisticated mathematical programing and econometric procedures. The emphasis in much of the production economics work shifted from solving farmers' problems to exploring the potential of the new procedures. Farm management, which used production economics procedures, could make little use of this new work. The result was growing frustration within the farm management discipline.

In his major review of farm management and production economics literature from 1946 to 1970, Jensen (1978) devotes 22 of the 75 pages to the question: "What is farm management, what is it doing, and where is it going?" From his review, it is clear that there is a dichotomy between those who are trying to solve problems and those who are developing methodological and theoretical issues, mainly for their peer group. The latter dominate: basically everyone is developing ways to do the work, but no one is doing it. Although considerable advancement has been made in advanced mathematical and econometric procedures, there appears to be little help for the economist trying to solve basic farm management problems. The cropping system economists are going to have to solve many of these problems themselves. By working at the sites with biological scientists and farmers, the economists are going to have to select the economic procedures that are really useful in understanding the farmer's current system, comparing it with the new technology that is developed and deciding where it may fit into the system.

The Economist's Role in Cropping Systems Research

To illustrate the role of economics and how it fits into a cropping systems program, the current research approach adopted at IRRI will be briefly reviewed.

Cropping systems research is based on a systems approach that requires an understanding of the resources, interactions, and goals of the organization under study, in this case the Asian rice farmer. The farmer's resources and the interactions that take place on his farm fall under a variety of different disciplines. Rather than have one discipline try to study the whole system, the various disciplines are brought together to study the system. A group of scientists working together to try to solve a single problem set is referred to as a multidisciplinary team conducting interdisciplinary research. A multidisciplinary team is the most effective method for studying cropping systems.

Of the five phases in cropping systems research, only the first three will be considered in this book: describing the present cropping system in a given environment; designing new technology; and testing the new technology using the criterion: "Will it help meet the farmers' needs?" The first phase will be considered only as it affects the second and third phases; thus the objective is to design and test new cropping patterns and their related technology to see if they meet the farmers' needs in a given environment.

Each member of the cropping systems team has a responsibility to contribute the knowledge of his discipline to the design and testing phases of the research. Economics is concerned with the allocation of scarce resources to meet man's needs as fully as possible; therefore, the economist's role is to help design experiments that will test the efficient use of the farmers' scarce resources in different cropping patterns and evaluate the results using economic procedures.

To make the greatest possible contribution, the economist must be able to interact with the other team members. This means he must understand economics well enough to explain it in language all can understand, have a good grasp of basic agricultural technology, and be able to conceptualize and organize the economic research component of the research program. The demands on an economist working in a cropping systems program are greater than if he were working in a single discipline program. Economists with a background such as this are rare, and a lack of reference materials has meant that most programs have young economists who have a hand calculator, limited experience, and are learning on the job.

The methodology used in most programs is based on the methodology used at IRRI — a baseline survey of about 100 farmers, with 300–500 questions per farmer followed by detailed record-keeping of farm or cropping activities on 30–50 farms during each year the site is in operation. On each farm there are about eight crops per year and about 30 observations per crop. Assuming only 300 questions on the baseline and 40 farmers per site the first year, there are at least 40 000 data points. This does not include any household or noncrop activities, any results from agronomic work, or any price or rainfall data. Thus, in the first year there are likely to be 50 000 data points for a young economist with a hand calculator.

Economic Analytical Procedures

Given that the economists in the cropping systems teams will be using the basic choice indicators previously discussed and that the current methodology is not proving satisfactory, the next step is to review the economic analytical procedures that are being used and those that could be employed.

Few economic problems are so simple and clear-cut that one approach can be used to solve them. There is usually a sequence of decisions that must be made to arrive at the most efficient alternative. A farm management researcher using production economics tools has a range of procedures to choose from, and his choice depends upon the resources available, the skill of the researcher, the type of problem, and the clients.

There are two general types of procedures available: (1) formal, and (2) informal. There is no clear-cut line dividing them and the same choice indicators may be used in both. The main difference is that the formal procedures have a set of rules that must be followed in the analysis, while the informal procedures are more flexible and leave many of the decisions to the researcher's judgment. Informal procedures are more subjective but allow for more learning on the part of the researcher.

Formal Procedures

The two most commonly used formal procedures are econometric-based production function analysis and linear programing. Each of these procedures has been developed with a complete set of mathematical rules governing its use and solution. Because of the strict set of rules governing their solution both procedures can be solved by standard computer routines. This feature has meant a great saving in resources for researchers. The computer can handle masses of data with great precision. Unfortunately, precision and accuracy can be confused. The ease of computation has allowed a person who has little understanding of a production process to produce very precise solutions that may be inaccurate. The basic concepts of each procedure will be discussed in turn.

Production functions, when used in economic analysis and recommendations, can provide one of the two sets of information needed for choice and decision-making (Heady and Dillon 1961). A production function defines the technological relationship between inputs and output of a given production process. The other set of information needed is the prices of inputs and outputs. A production function usually shows only the inputs under consideration and assumes a given set of other resources. In cropping systems, production functions are used: (1) as a means of evaluating current and future use of resources, and (2) to study the efficiency of new technology. Before a production function is used a set of basic assumptions must be considered: (1) the production process is independent and additive, (2) the number of inputs is finite and can be cardinally measured, (3) the inputs are independent, (4) a given input is homogeneous, (5) the output is homogeneous, (6) the output is cardinally measurable, (7) the production period is long enough to include all input and output flows, and (8) the production period is short enough to exclude any technological or environmental changes.

Jensen (1978, p. 46) concludes that production functions are of limited value:

> Given the problem of specification bias, intercorrelations among input catagories, and problems growing out of aggregating inputs and outputs, it is questionable whether aggregate production function analysis should play any role beyond that of a diagnostic technique in the preliminary stages of analysis (i.e. for suggesting possible resource malallocation).

Linear programing is the analysis of problems in which a linear objective function of a number of variables is to be maximized (or minimized) when the variables are restrained by linear inequalities (Dorfman et al. 1958). The objective of linear programing is to find the maximum (or minimum) in a given situation. The linear objective function is composed of the factors considered to be relevant to achieving the goal. One or more of the factors must be limited, and each limitation or set of limitations is shown in a separate equation. One further restriction is that no factor can have a negative quantity. There is no limit to the number of factors that can be included. Data availability and computational time usually act as the limitations. Numerous articles and books on linear programing are available; one based on farm management problems is by Heady and Candler (1958).

Informal Procedures

A wide variety of informal procedures is used in economic analysis. These range from quick guesses to simulation models developed from gambling games played with farmers. Unlike linear programing, however, they all have one thing in common: the researcher's opinions and decisions are a definite part of the solution process. Thus, the researcher's intuitive knowledge is used throughout the decision-making process. No two economists are likely to get the same precise solution starting from the same data base if they use informal procedures. However, if both have a clear understanding of the goals and the alternatives of the study they are likely to arrive at the same conclusions and so make the same decision. The economist at the site has learned a lot about the current cropping system from his discussions with the farmers and can contribute to the design phase. There is no easy way to quantify this information, but the more time the economist spends with the farmers, the more complete his understanding of the system. Interaction between the disciplines at the site can lead to advances that do not show in the data from that year's work. This is one of the main strengths of the site approach to research. Because agricultural economics still has many problems to resolve before a clear formal analytical procedure can be provided, the importance of the economist's informal understanding and input can hardly be overestimated.

The procedures to be discussed are based on the premise that an approximate answer on time is of more use than a precise answer that arrives too late. Thus, these procedures for evaluating the design phase of cropping systems research are simple and informal. The simplified procedure has a set of sequential steps, in which each step results in an answer on which decisions can be made. After each step, those cropping patterns, or the components of a pattern, found to be less efficient than others are dropped from further analysis. This sequence of steps leads to a final decision on whether the research under investigation is likely to lead to an increase in the farmer's well-being. Is it worthwhile? This is the question that should be answered at each step of the analysis. The procedures can be divided into three stages: budgeting, graphing, and program planning.

In the budgeting stage the new technology is compared with the current technology it is to replace. If it is found more profitable, it is carried on to the graphing stage. Graphs of resources used over time show if there is a constraint and, if so, where it occurs. If there is no major constraint, the economic analysis is finished. If there is a constraint, the new technology is analyzed by program planning to determine if it is likely to fit into the current farm operation and, if so, to what extent.

Budgeting

A partial budget provides a framework in which to make decisions on the three basic production economic problems: how much to produce, how to produce, and what to produce. It has a strong grounding in marginal analysis. A budget is an estimation of possible changes in costs and returns in a given time period when there is a contemplated change in the use of production resources (Fellows 1960). The general format used in partial budgeting is:

Added costs Reduced returns	Added returns Reduced costs
Economic disadvantages	Economic advantages

In marginal analysis, the decision on how much to produce is made by the relationship $\Delta X \cdot PX \leqslant \Delta Y \cdot PY$. In partial budgets this decision is made by the relationship: Added costs $\leqslant$ Added returns. The decision on how to produce in marginal analysis is made by equating $\Delta X_1 \cdot PX_1 \leqslant \Delta X_2 \cdot PX_2$. Using partial budgets this is given by: Added costs $\leqslant$ Reduced costs. The decision on what to produce is made by equating $\Delta Y_2 \cdot PY_2 \leqslant \Delta Y_1 \cdot PY_1$ in marginal analysis. Partial budgets supply the decision by equating: Reduced returns $\leqslant$ Added returns.

In addition to these specific analyses, the partial budget can be used to compare the complete effect of an alternative. If the economic disadvantage is larger than the economic advantage, no change should be made.

When partial budgeting is being used to compare alternatives, all changes in costs and returns must be included. One of the weaknesses of partial budgeting is that the format is so simple that it can lead to hastily thought-through analysis and, therefore, inaccurate conclusions. Although based on the marginal concept, partial budgeting differs slightly from marginal analysis. Partial budgets use the total added and total reduced values, whereas marginal analysis considers only the last unit of change. Thus, there is a difference in precision, particularly if the changes are large.

Hypothetical Example — A farmer has sufficient lowland to grow the rice his family needs, and has an additional 20 ha of land that is in sugarcane. The price of sugarcane is falling, and he is looking for alternatives. Cropping systems experiments have been conducted on similar upland areas. The crops tested were rice, mung bean, maize, sorghum, and tomatoes. Should he stop growing sugarcane and switch? If so, to what?

The first step is to find if the new crops are more profitable than sugarcane. Table 1 shows the gross returns and variable costs associated with each crop. With this information a set of partial budgets can be used to find which crops are more profitable than sugarcane (Table 2). In the comparison of sugarcane and rice, rice will be added and sugarcane removed. The added costs are the costs that will be incurred in growing rice. The reduced return is

Table 1. Gross returns and variable costs: an example ($/ha).

	Variable cost	Gross returns
Sugarcane	260	300
Rice	70	150
Mung bean	10	60
Maize	200	250
Sorghum	70	100
Tomato	400	600

Table 2. Example of partial budgets ($/ha).

Comparison			
Sugarcane and rice			
Added costs	70	Added returns	150
Reduced returns	300	Reduced costs	260
Economic disadvantage	370	Economic advantage	410
Sugarcane and mung bean			
Added costs	10	Added returns	60
Reduced returns	300	Reduced costs	260
Economic disadvantage	310	Economic advantage	320
Sugarcane and maize			
Added costs	200	Added returns	250
Reduced returns	300	Reduced costs	260
Economic disadvantage	500	Economic advantage	510
Sugarcane and sorghum			
Added costs	70	Added returns	100
Reduced returns	300	Reduced costs	260
Economic disadvantage	370	Economic advantage	360
Sugarcane and tomato			
Added costs	400	Added returns	600
Reduced returns	300	Reduced costs	260
Economic disadvantage	700	Economic advantage	860

the loss in income due to sugarcane not being grown. The economic disadvantage is the sum of the two. The added returns come from the rice and the reduced costs are the costs saved by not growing sugarcane. The sum of these two is the economic advantage of switching from sugarcane to rice. A comparison of the economic advantage and disadvantage values allows a decision to be made. In this case, the alternative is more profitable. The same procedure is used for each of the alternative crops. All the crops except sorghum are more profitable than sugarcane. Sorghum is dropped, and the analysis continues to the next step in the procedure.

Graphing

The next set of analytical procedures utilizes graphs to study resource use over time. These analytical procedures have three functions: (1) to remove any technologies that have a resource use pattern that cannot be met by the farmers' resources even if used on a relatively small scale, (2) to show resource use levels over time so that new technology can be designed either to even out the flow for those resources that give a flow of service or to make greater use of resources that would be or are underutilized, and (3) to detect the specific periods when resource constraints appear. These resource constraints at a specific time are used for the next set of analytical procedures.

The use of each resource in a production process is put on a graph with time on the X axis and resource uses per unit time, per set of other resources, on the Y axis. The resource base assumed for the farmer from the data collected is used to determine the constraints for that resource at a specific time. If the resource is considered a stock, that is, it can all be used at one point in time, a calculation is made on what portion of the resource can be utilized by the new technology. If the new technology will use more of a resource than the technology it is expected to replace, a major constraint has been found. This constraint will be carried over to the next step in the analysis. A second major use of these diagrams is to show where resources are underutilized in both the current and proposed systems. Two additional graphs can be used but are optional. These graphs would show the flow of cash and rice over the year. The current system's flow is shown along with the expected flow from the new technology so that major deficiencies or lags can be seen.

Hypothetical Example — In the partial budget example, rice, mung bean, maize, and tomatoes were more profitable than sugarcane. The next step is to find if the farmer can grow them with the resources available to him.

The farmer has U.S.$1500 available to purchase seed, fertilizer, and chemicals at the start of the season. There is no cash income between planting and harvesting, so cash can be considered a stock of resources. When a resource is a stock there is no need for a graph when studying a single enterprise. Simply dividing the resources required per unit into the total stock of resources will show if there is a limitation and, if so, how many units can be produced. The cash costs of production are: rice U.S.$50, mung bean U.S.$10, maize U.S.$100, and tomatoes U.S.$300. By dividing each of these into U.S.$1500, only maize and tomatoes cannot be grown on 20 ha. Maize can be grown on 15 ha and tomatoes on 5 ha. The farmer does not see the 5 ha of tomatoes as a constraint, because he has no intention of planting more than 1 ha of tomatoes. Thus, there is a 15 ha cash limitation on maize and a 1 ha management limitation on tomatoes.

The next resource to consider is labour. Labour gives a flow of services that are either used or lost. It cannot be stored. In Fig. 4, the labour requirements for each crop are shown over their production period. There are two periods when labour is a limiting factor — weeks 30 and 44. Tomatoes can only be grown on a small area due to the labour limitation in week 30; mung bean and maize cannot be grown on all 20 ha due to labour limitations in week 44. At this point, a subjective decision must be made: Should tomatoes be rejected completely? The decision is not to, because it showed the highest profit and the farmer is willing to grow only 1 ha. From this graph it can be seen that rice is the only crop that can be grown on all 20 ha. However, because rice has a low profit, the decision is made not to discard any of the alternative crops due to labour limitations. The decision implicitly assumes a combination of crops will be grown.

Animal power is another resource that produces a flow of services. It is handled the same as labour. Animal power is only needed for land preparation; therefore, the time period when it must be analyzed is much shorter (Fig. 5).

There is a major limitation in week 28 for animal power for rice. Only one-half of the 20 ha can be planted to rice due to this limitation. Maize uses all of the animal power if planted on the 20 ha. Animal power in week 28 is another limitation.

No crops have been discarded, but limitations have been identified for the next stage. They are cash for tomatoes and maize, labour in week 30 for tomatoes, labour in week 44 for mung bean and maize, and animal power in week 28 for rice. In addition, the farmer has put a management limit of 1 ha on tomatoes.

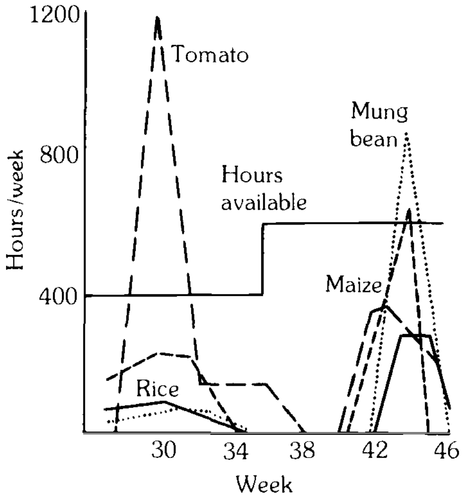

Fig. 4. Labour requirements for maize, mung bean, tomato, and rice (20-ha example).

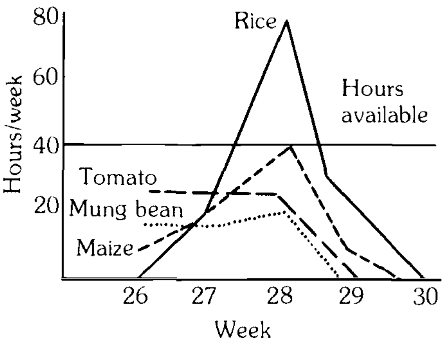

Fig. 5. Animal requirements for maize, mung bean, tomato, and rice (20-ha example).

Program Planning

The third stage of the procedure is to use approximation methods to obtain an optimum or near optimum combination of resources. Program planning, which is the approximation method used here, can be divided into two stages: (1) a first feasible solution (FFS), and (2) iteratively improving solutions (IIS) (Muller-Merbach 1974). The first feasible solution stage simply finds a solution in which the constraining conditions are met. This is a necessary step before improved solutions can be found. The iteratively improving solution stage requires a sequence of iterations in the feasible range until no further improvement to the gross margin (GM) can be made. This is exactly the procedure followed in linear programing. The difference is that in linear programing there is a predetermined procedure to follow in deciding which activity to adjust in the next iteration; in program planning there is no such rule.

Two general approaches have been used in IIS. The first, defined as "eager but tedious," simply solves the problem at all solution points without attempting to always search for an improved solution. If some thought is applied, many of the possible solutions can be bypassed on the road to an optional or near-optional solution. This has been referred to as "reflective and skillful seeking."

The emphasis is on site-specific research in cropping systems work; therefore, the economist at the site will be responsible for most of the economic decisions made in the planning phase. By using the "reflective and skillful seeking" approach, advantage can be taken of the economist's subjective knowledge by utilizing it in a formal procedure. This approach will also allow him to explore possible new technologies before they are tried on the farm. However, as with any new tool it will take practice to become skillful in its use. It must also be remembered that it is not likely to give the most efficient solution; rather, it is likely to give a set of possible solutions.

By the time the program planning stage of the analysis is reached, there should be a very small number of alternative enterprises to consider and a limited number of constraints. The smaller the number, the more easily and quickly a solution can be found. The required data are tabulated to show the production process, the resource constraints under consideration, the resources required for each unit of output from the production process, and the limits on the production process (either minimum or maximum).

Hypothetical Example — Table 3 (part A) shows the initial layout of a hypothetical case. Twenty hectares are available for additional rice, maize, mung bean, or tomatoes (column 1). Column 2 shows the gross margin, which is gross returns minus variable costs. Column 3 is the land required for each crop plus the total area available. The cash cost of growing 1 ha of each

Table 3. Program planning example.

Production process	Gross profit ($/ha)	Land (ha)	Cash cost ($/ha)	Labour week 30 (hours/ha)	Labour week 44 (hours/ha)	Power week 28 (buffalo days/ha)	Maximum area/crop (constraint)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Part A							
Additional:							
Rice	100	1	50	5	10	4	10 ha (power)
Mung bean	50	1	10	10	50	1	12 ha (labour, week 44)
Maize	150	1	100	10	40	2	15 ha (labour and cash, week 44)
Tomato	300	1	300	60	10	1	1 ha (farmer's decision)
Resources		20	1500	400	600	40	
Part B							
Tomato	300	1	300	60	10	1	
Maize	1800	12	1200	120	480	24	
Resources	2100	13	1500	180	490	25	
Part C							
Tomato	300	1	300	60	10	1	
Maize	1500	10	1000	100	400	20	
Rice	400	4	200	20	40	16	
Resources	2200	15	1500	180	450	37	
Part D							
Tomato	300	1	300	60	10	1	
Maize	1500	10	1000	100	400	20	
Rice	300	3	150	15	30	12	
Mung bean	150	3	30	30	150	3	
Resources	2250	17	1480	205	590	39	

crop plus the total cash available are shown in column 4. Column 5 shows the labour required per hectare to grow each crop in week 30; a total of 400 hours is available. Column 6 is the same labour data for week 44. Buffalo days per hectare per crop, in week 28 are given in column 7. Column 8 indicates the maximum area that each crop can occupy. These are established either: (1) by setting a limit, such as 1 ha of tomatoes; or (2) by dividing each number in the row into the total available resource in its column and taking the smallest number. For additional rice: 1500/50 = 30; 400/5 = 120; 600/10 = 60; and 40/4 = 10; therefore, power in the 28th week limits additional rice area to 10 ha.

The next step is to put the crop with the highest gross profit in part B, in this case tomatoes. Because it is limited to 1 ha, the gross profit is 300 and each of the other rates is written in for 1 ha. There are still resources left; therefore, find the crop with the next highest net profit (maize) and write it in column 1. To decide how many hectares to plant, check column 8 to find which resource was limiting, in this case, labour in the 44th week and cash. Tomatoes used little of that labour, so it is likely that cash will be limiting. Tomatoes used U.S.$300 cash. There is U.S.$1200 left and maize takes U.S.$100/ha, therefore, 12 ha can be planted. Now the maize row can be filled in by multiplying each number in part A for maize by 12. Gross margin equals 150 × 12 = U.S.$1800; land 1 × 12 = 12; cash cost 100 × 12 = U.S.$1200; labour in week 30, 10 × 12 = U.S.$120; and so on. Because all the cash is used up and no activity requires zero cash, stop. Add each column. The gross margin is U.S.$2100, but only 13 ha of land, 180 hours of labour in week 30 and 490 hours of labour in week 44 have been used, and the buffalo only worked an equivalent of 25 days. Cash is the limiting resource in this solution. Now the solution is deteriorated and another try made. A hectare of rice takes only half the cash that maize does, U.S.$50 versus U.S.$100 in column 4. The limiting factor is power in the rice row in part A. If 3 ha of maize are dropped, leaving 9, an additional 6 ha of rice can be grown because of the two to one ratio in cash. Checking the power requirement: tomato 1 × 1 = 1; maize 9 × 2 = 18; and rice 6 × 4 = 24; or a total of 43, but only 40 are available, therefore, try 10 ha of maize and 4 ha of rice. The gross margin is increased by 100. No more rice can be added due to the power constraint. Now deteriorate part C and try again. Mung bean used little cash or power. Its constraint is labour in the 44th week. There are 150 hours (600 − 450) unused (column 6). Adding 3 ha of mung bean would increase the gross margin U.S.$150, which just equals 1 ha of maize. One hectare of rice will be removed to get cash to grow the mung bean, part D. Gross margin has increased by U.S.$50. The constraint is labour in the 44th week. If more labour were available, there would be sufficient resources to grow one more hectare of mung bean. The farmer would have to hire an additional 40 hours of labour to harvest mung bean for an additional gross margin of U.S.$50. If labour were worth less than 50/40 = U.S.$1.25/hour it would pay him to do so. The U.S.$1.25/hour is known as shadow price.

From this example, it is clear that program planning does not have a strict set of rules to follow. Guesses or estimates must be made. However, with a small amount of practice the economist soon develops the ability to run his eye over the rows and pick out opportunities to increase profit. With a little experience, program planning can be a very useful tool. It uses judgment plus systematic procedures.

Analysis and Results

In this chapter, data from the IRRI cropping systems research site at Cale, Batangas, are used to develop and pretest the informal procedure for economic analysis. This procedure is then compared with the linear programing method of analysis using data from cropping systems sites in Iloilo and Pangasinan, Philippines. Because large amounts of data are a problem at most cropping systems sites, this comparison is based on data from 36 farms and five case study farms. The objective is not to supply a detailed study of the sites but to compare the results and conclusions derived from the different procedures.

The three major crops grown in Cale are rice, maize, and vegetables. Although the farms are small, they are quite complex. The cropping patterns combine into cropping systems that form part of the farming system (Fig. 6). Initially, the farmer starts the season with a set of resources (cash, cereals, labour, and power). He can allocate these resources to three enterprises. In addition, he can use share labour and land. The cash market will give credit that can be used by the family or in an enterprise. In the first crop period, the farmer put P2800 (P0.1240 = U.S.$1.00) into the market and took an additional P400 in credit, which he paid back after the harvest of the second crop. In the first crop period, share labour, i.e., labour that works for a specific share of the crop, put 80 hours into the crop enterprise and received 400 kg of rice. No data were collected on the crop residue used by the draft animals. The farmer had a good year because he ended up with P1640 and 1 t of rice more than he had at the beginning of the year.

This type of chart is useful in describing a system but is of little use in detailed analysis. A more specific diagram can be developed for a cropping system or a cropping pattern to show the returns to each factor of production, but it is tedious work and is again of little use in analysis. Such a diagram, however, does give the research team a clearer understanding of the flow of resources to enterprises and the return to these resources. It also helps in understanding the high level of interaction between household and farm activities, particularly for cash requirements. These diagrams require a lot of time to complete and, although they might be completed for five farms, they could not be done for 30 farms.

Cost and Returns from Farm Data

All Farms

Once a basic understanding of the farm and its activities has been obtained, the next step is a cost and return analysis of the major crops. Table 4 presents the mean costs and returns over the 4-year study period for rice,

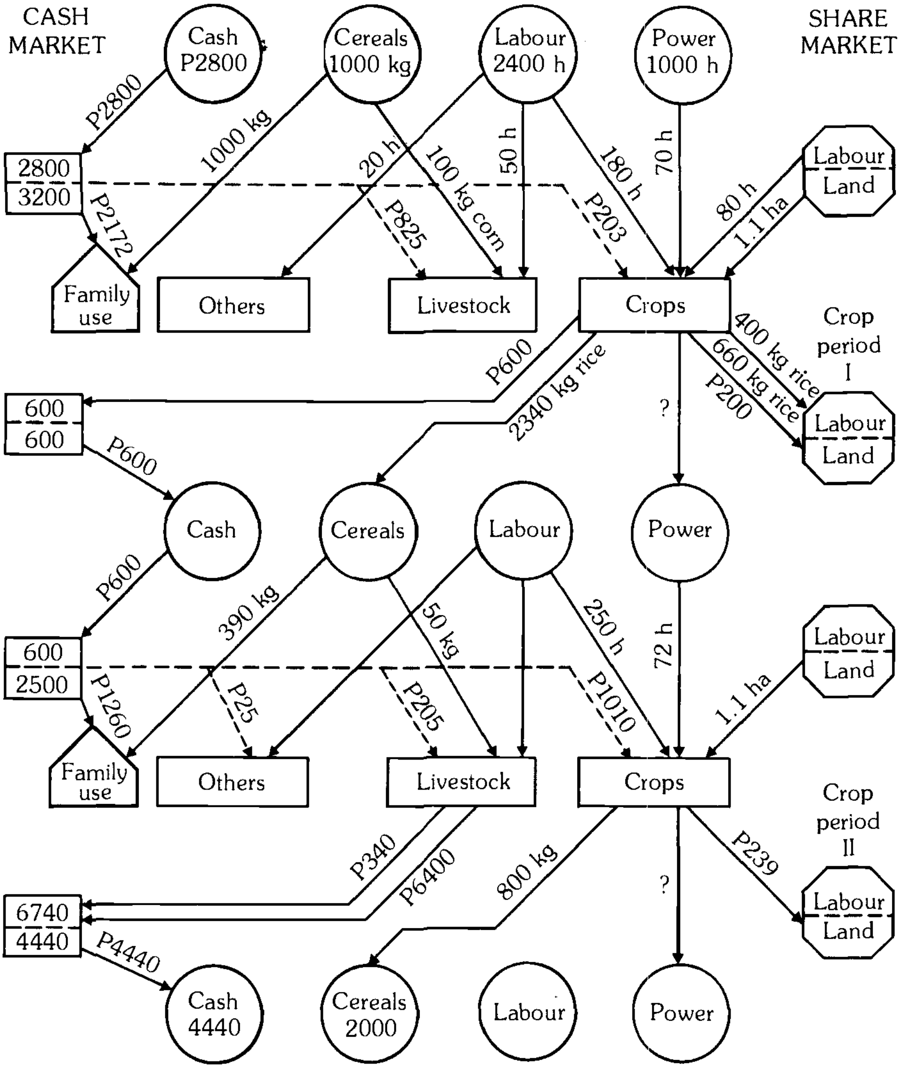

Fig. 6. Schematic diagram of a typical farming system (farm 20).

maize, and vegetables. Rice is the major crop in Cale. The farmers grow a traditional upland cultivar known locally as dagge, which gives a stable yield of about 1.8 t/ha. High coefficients of variation (CV) were found for most of the factors of production, and this is typical of small rice farms in Asia. The effects of these high coefficients of variation on analysis will be examined in more depth later. The costs and returns for maize over the 4-year period had even greater fluctuations than rice. Maize is the second crop and must compete with vegetables for the farmer's resources; consequently, its yields are partially a function of vegetable yields and prices. While maize competes with vegetables for land, the analysis showed that the farmers' input levels were near optimum for both crops. A cursory observation indicated low input levels for some maize. This was discovered to be related to input levels on the previous rice crop rather than to a shortage of funds for maize. Maize requires less labour and shows a higher return per hour of labour than rice or vegetables.

The vegetable grouping contains more than 30 different crops ranging from radishes, which take only a few weeks, to gourds, which continue to grow over both crop periods. The farmers mix the vegetables in a variety of ways, and more than 100 cropping patterns were found on 36 farms. The vegetables are high risk in terms of both yields and price. Farmers abandon fields if the price drops below harvest costs or insect damage becomes too

Table 4. Mean costs and returns over a 4-year period (P/ha) for rice, maize, and vegetables in Cale (1973–77).

	Rice (269)[a]			Maize (304)			Vegetables (710)	
Costs	Cash	Imputed	CV	Cash	Imputed	CV	Cash	Imputed
Materials								
Seed (kind)		120		38	24		124	
Pesticides				2			41	
Fertilizer	207		134	366		143	370	
Subtotal	207	120		406	24		535	
Labour								
Land preparation								
Family	78	78	136		66	98		
Cultivation								
Family		53	186		42	116		
Weeding								
Family		181	170		64	138		
Hired	16		384					
Harvesting								
Family		110	291		65	156		
Hired (kind)	396		219	74		96		
Subtotal	412	422		74	237		77[b]	925[c]
Land rental[d]								
Family		484			250			598
Landlord (kind)	484			250			199	
Total cost	1117	970		731	511		811	1523
Gross return	2858		171	1996		113	4787	
Return								
Over cash and kind costs	1784			1265			3976	
Overall cost	814			754			2453	
Per peso spent	1.6			1.7			5.1	
Per hour family labour		3.6			4.2			3.6

[a] Number of observations.
[b] Total for hired labour.
[c] Total for family labour.
[d] For rice calculated on basis of one-third to land after cash costs and share labour payment removed and one-half of land owned by operator; for maize on basis of one-fifth to land after cash costs removed and one-half of land owned by operator; for vegetables on basis of one-sixth to land after cash costs removed assuming three-quarters of vegetable land owned by operator.

great. The risk associated with vegetables is exemplified by garlic, which is grown by many farmers. It costs about P3000/ha to establish a crop of garlic. Due to tremendous fluctuations in price and yield, however, many farmers lose money while a few make more than P20 000/ha. Interestingly, yield has no relationship to area planted, or to number of years experience.

The costs and returns in Table 4 for vegetables cover all fields whether harvested or not. Because there is a mixture of crops, no coefficient of variation was calculated as some crops such as garlic, with very high costs, would dominate. Over the 4-year period, vegetables gave good returns to most farmers.

The summary of costs and returns for rice, maize, and vegetables in Table 4 gives a general idea of the input-output relationships. The high variability of inputs and lower variability of outputs for rice and maize is notable. The mean return per hour of family labour for 4 years is about the same for all three crops. The return to cash inputs is about the same for rice and maize but much higher for vegetables, indicating the risk premium for vegetables.

Five Farms

Collecting and analyzing the data for the more than 30 farmers requires a lot of resources. Because these resources are usually not available at cropping systems sites, a small number of farmers were analyzed to determine if the same conclusions could be obtained with a smaller sample. A test group of five farmers was selected as being typical of the majority of farmers in Cale. The data for inputs and production of these farmers was analyzed individually for each of the 4 years, 1973–77. Table 5 presents the data for one of these farms as an example. Maize and vegetables were combined in the analysis because the farmers grow these to sell, whereas they grow rice to eat.

Two main characteristics of the farms were shown by the analysis of the five farms. First, analysis of the 4-year time series indicated a high variability in inputs for the individual farms. Second, income variability was low. It would appear that the farmers have the ability to stabilize income regardless of price and yield fluctuations. Variability was greater between farms in the same year than for an individual farm over time. This suggests that cross-sectional studies are likely to overestimate the variance a farmer can expect for most of the key variables. This explains in part the high coefficient of variation for inputs in the costs and returns for over 30 farmers (Table 4).

More important is the variation in output. The coefficient of variation was 0.96 for the five farmers over the 4 years, whereas the five individual farmers had coefficients of variation of 0.10, 0.37, 0.21, 0.28, and 0.55 over the same period. The cross-sectional data appear to have overestimated the variation in returns to the farmer by two or three times. In agronomy trials managed by farmers there is probably also an overestimation of variance as these are analyzed cross-sectionally in most studies.

Transferring Income Variability

Although the crop returns to a farm family were fairly stable, the returns to share labour and share land had a high degree of variability. The return to share labour varied by 100% and to share land by 50%. The usual share system in Cale gives one-sixth of the rice yield to the harvesters. The landlord gets one-third of the rice yield after the harvesters' share and fertilizer costs have been subtracted. There is no share labour on the other crops. The landlord gets between one-quarter and one-sixth of other crops after fertilizer costs have been subtracted.

The analysis of the tenant and sharing system at Cale showed that share labour accounted for a disproportionate percentage of the variation in production. Because share labour is only used for rice harvesting, a family that has a poor crop may decide to harvest most of it themselves, although this is considered antisocial. What most families do, is to make sure that all family members participate in the harvest of their own fields so they get a substantial part of the one-sixth share.

The share harvest system is an old tradition that gives village families a chance to secure rice if their own crops have failed. Rarely are outsiders

Table 5. Input by source and production for farmer 20, Cale, 1973–77.

	1973–74		1974–75		1975–76		1976–77	
	Rice	Maize and vegetable	Rice	Maize and vegetable	Rice	Maize and vegetable	Rice	Maize and vegetable
Family inputs								
Cash (P)	90	284	190	520	338	291	93	275
Labour (hours)	295	349	307	397	313	463	213	426
Land (ha)[a]	0	0	0	0	0	0	0	0
Share inputs								
Labour (hours)	305	0	63	0	146	0	368	0
Land (ha)[a]	0.953	0.717	0.873	1.057	0.718	1.014	0.820	0.829
Rented area (ha)	1.059		1.059		1.059		1.059	
Production	kg	P	kg	P	kg	P	kg	P
Family	557	1228	303	4368	562	1984	938	1621
Share labour	270	0	63	0	121	0	274	0
Share land	230	231	154	836	183	393	426	317
Family share								
Cash cost	557	854	303	3658	562	1355	938	1253
Return								
To family cash[b] (P)	3.9		5.8		3.4		3.1	
To family labour[c] (P)	2.7		5.9		2.9		2.7	
To share labour[d] (P)	1.4		1.6		1.3		1.2	
To share land[e] (P)	565		1022		648		943	

[a] Area cropped.
[b] ((Family rice production × 1.6) + (family maize + vegetable production – family labour))/family cash input.
[c] (Total value of family production – family cash inputs)/family labour.
[d] Product value to share labour/share labour.
[e] Product value to share land/actual area share rented.

allowed to participate in a harvest. The landlord consistently gets one-fifth of the maize or vegetable crop. But there is no clear pattern regarding the sharing of production variation. On average, it was found that the five farmers managed to pass on an extra 5% of the variation in income during the 4 years under review. A detailed analysis of the 36 farmers was not done, but there is no reason to expect the results to be much different because the sharing arrangement is on a percentage basis.

Factors of Production

The next step in the analysis was the study of the factors of production for each crop. Most of the farmers adjusted their maize and vegetable crops to compensate for variation in rice yields. The correlation coefficients between rice yields and maize plus vegetable gross returns were −0.36, −0.63, +0.19, −0.89, and +0.54 for the five farmers over the 4 years. When all five farms were considered together, the correlation coefficient was −0.38. Because there were only four observations per farmer, the correlation coefficients were not statistically significant at the 5% level. Of the 25 sample farmers who grew all three crops, 16 had negative correlation coefficients between rice yields and maize plus vegetable gross returns, and nine were less than −0.5. Although not statistically significant, the trend appeared to be worth investigation. Of the 25 farms, it was found that those with a negative correlation had a mean crop gross income of P5309, whereas those with a positive correlation coefficient had a mean gross income of P8572. The difference was significant at the 1% level. The five case study farms showed the same pattern. As a further test of the hypothesis that small farmers work harder in the face of rice yield variability, a correlation was run between cash inputs for maize and vegetables and rice yields per farm over a 4-year period. The correlation coefficients were −0.94, −0.56, −0.57, −0.67, and −0.34. Again the correlation coefficients were not statistically significant due to the low number of observations. A negative sign indicates that farmers put more cash into the second season crop if they had a low rice yield. Conversely, if they got a good rice crop they did not put a lot of cash into the second season's crops.

The farmers were asked about their use of inputs following a poor rice crop. They confirmed that they would likely try for greater production in the second crops but said the final decision would depend upon market prices, particularly for the vegetables.

Although not shown statistically, the evidence indicates that income maintenance is a farmer's major goal and that there is a danger in using aggregate data when specific relationships must be understood.

Variability in Factors of Production

Farm record-keeping data are notorious for their variability. The record data of all the farmers for the 4-year period were checked to determine their variability and the distribution characteristics of their input-output coefficients. The factors associated with inputs were studied and several important problems were encountered. First, the arithmetic mean overestimated the input level for the majority of farmers. Because a few high values can bias an arithmetic mean upward, it is a biased estimator for inputs if the objective is to describe what the majority of farmers are using. The geometric mean was found to be a better estimator, while the harmonic mean biased the estimator downward when there were some very low values.

The second results of the analysis of inputs were that the kurtosis and skewness measures were unreliable. The area owned per farm showed a kurtosis of 2.71 and skewness of 0.47 with 140 observations. This met all tests of normality and yet the distribution was clearly bimodal. All 12 inputs considered were found to be normally distributed. Thus, there appears to be little value in running normality tests unless the data are plotted first. Using a chi square test of normality, eight out of the 12 inputs were found not normally distributed, suggesting that the chi square test is a better test for samples over 100. Although somewhat subjective due to the decision on class intervals, the chi square test was much more sensitive to bimodal problems than tests of kurtosis and skewness.

When the distribution characteristics of output were tested, the results were much the same. The arithmetic mean overestimated what the majority of farmers would get. The geometric mean was a better estimator and the harmonic mean showed a tendency to underestimate. The kurtosis and skewness measures were unreliable as a test for normality and the chi square test also appears to be unreliable when the number of observations falls to 20 or 30. The chi square test, for example, failed to identify a bimodal distribution of rice yields in 1974–75 when the number of observations was 27. This is mainly due to the statistical requirement that there will be at least five counts in each of the expected cells. When the number of observations increased, the chi square test became quite sensitive.

In summary, there are problems with farm record-keeping data. Because most sites will have a relatively small number of observations in the first several years there is no good test of normality. However, graphing the data will show distribution problems that cannot be found with regular normality tests. The arithmetic mean is a poor estimator, and the geometric mean should be considered for describing characteristics of inputs and products.

Independence

Checking factors of production for independence can be done by examining their correlation coefficients. Because many of these coefficients were found to be significant, the problem of interdependence needed to be examined further. One method for handling this problem is to consider a specific quantity of inputs as a package. This is what was done in this study.

Homogeneity

The basic factors of production are land, labour, and capital. In most analyses these are assumed to be homogeneous. Because this can create problems in analysis and in trying to apply the results, the assumption of land homogeneity was tested.

In the original 1973 Cale baseline study each farmer was asked to establish an area and value for each of his parcels of land. These areas were later checked and actual parcel size recorded. This resulted in three estimators for land: farm size, cropped area, and value of cropped area. Correlation coefficients can be used to test for the best estimators. The correlation coefficient for land value and crop gross returns was 0.63, but for cropped area and crop gross returns it was 0.73. Farm size was not tested because not all parcels were cropped twice, and it was assumed there was a low relationship. Thus, for aggregated data, cropped area is suggested as the most accurate estimator of land input.

A test for labour homogeneity was conducted by having three people working at the site divide the farmers into three groups according to diligence. In descending order of diligence the groups were assigned labour coefficients of 1, 0.8, and 0.6. The product of the actual hours and labour coefficient was then correlated with crop gross returns from the farm. The correlation with the labour coefficient was higher indicating that labour is not homogeneous in crop production.

The final input tested for homogeneity was cash input. Cash inputs were found to have a low correlation with crop output. Actual physical input measures gave higher correlations. This suggests that there was a wide variation between farms in costs per unit of input, and indicates the farmers' varying abilities to buy cash inputs at their lowest costs. Fertilizer makes up 90% of cash inputs.

The conclusion is that land, labour, and capital are not homogeneous on farms in one village. If a specific process is to be studied it is important that accurate estimators be used. Whenever possible, actual physical units should be used and even these may have to be subdivided on the basis of quality.

The Case Study Approach

The basic assumption in choosing a case study approach rather than an aggregate approach is that a detailed working knowledge of a few farms is of more use in making decisions on new technology than a broad overview that defines a few aggregate relationships. Economists working in the field do not have the resources to complete a detailed study of a large sample. Therefore, the key question is: Is a large sample of a few critical factors superior to a detailed study of a few farms?

The foregoing discussion has pointed out some of the problems encountered with an aggregate approach, namely:

(1) Arithmetic means are not representative of the majority of farmers. Because most frequency distributions found on a farm are skewed, there will be a continual overestimation of inputs and outputs using arithmetic means.

(2) The interactions between input-input, input-output, and output-output relationships obtained from aggregate data will not only give an inaccurate understanding of the relationships the individual farmer faces but could give the opposite sign to the relationship and thus lead the research in the wrong direction.

(3) Farm data are highly variable, nonhomogeneous, and not independent; therefore, they are unsuited to econometric procedures used in aggregate analysis.

(4) Aggregate cross-sectional analysis overestimates the variability an individual farmer faces. A small time-series study gives a more reliable understanding. However, decisions must be made in the first year at the site and cross-sectional analysis can perform a useful function in this instance.

In addition, there is another important reason for using case studies. The economist at the site acquires a fund of informal knowledge of the farm and how it works. Most agricultural economists in Asia come from the city and have little farm experience. Continual personal interaction with a small number of farmers gives them a much better understanding of farming than large-scale, impersonal interviews.

The main problem with the case study approach is selecting representative or modal farms. This problem can usually be solved by consulting people who are knowledgable about the community and the farmers and weighing their suggestions against their vested interests.

Pretesting Informal Procedures

Following the procedures discussed earlier, the first step is to compare the alternatives by using budgets. The resource requirements can then be graphed to determine any major constraints. The final step is to use program planning to determine to what extent the new technology should be adopted by the farmers.

Table 6. Comparison of experimental data for sorghum and farmers' data for maize in Cale, 1975–76 (P/ha).

	Sorghum[a]			Corn[b]		Sorghum[c]	
Cost	Cash	Imputed	CV	Cash	Imputed	Cash	Imputed
Materials							
Seed	85		45	28	38	85	
Pesticides	15		133	3		15	
Fertilizer	446		60	403		533	
Subtotal	546			434	38	634	
Labour							
Land preparation		143	50		72		171
Maintenance		22	148		51		16
Weeding		21	157		78		31
Harvesting							
Family		70	50		88		82
Hired				64			
Hired threshing	113					143	
Land rental							
Family		67			90		104
Landlord	266		85	361		416	
Total cost	925	323		859	417	1193	404
Gross return	1553		53	1803		2308	
Return							
Over cash cost	608			944		1115	
Overall cost	285			527		711	
Per peso spent	1.3			1.6		1.6	
Per hour family labour		2.1			2.8		3.4

[a] Based on 20 parcels.
[b] Based on 58 parcels.
[c] Based on 10 high-yielding plots.

Several new crops were introduced in Cale to replace maize. One of these was sorghum, which will be used in the pretest. Sorghum has the advantage that it can be harvested in 85–100 days and, if sufficient moisture is available, a ratoon crop is possible. In 1975–76, 20 parcels were planted to sorghum. The recommended agronomy practices were explained to the farmers who participated in the research.

Although the costs and returns for sorghum did not appear promising, some farmers wanted to continue production (Table 6). The main reason for this was the high yield of over 3 t/ha obtained by some farmers. They were aware that most of the low yields were due to poor stand establishment caused by inadequate land preparation. Because inadequate land preparation can be improved, it was decided to drop the 10 parcels that had low yields and compare the results of the 10 high-yielding plots with maize. The costs and returns for these 10 high-yielding plots are shown in Table 6.

Budgets

Using the data from Table 6, a partial budget was used to compare the feasibility of replacing maize with sorghum (Table 7). Sorghum costs more to grow than maize because added costs are greater than reduced costs. However, the added income from sorghum is greater than the reduced income from the maize it would replace. The economic advantage was greater than the disadvantage by only P198/ha; therefore, the analysis would normally stop here because the advantage appears insufficient to expect the farmers to adopt sorghum. However, as the farmers had indicated an interest, further analysis was justified.

Table 7. Partial budget to compare maize with sorghum; based on 58 parcels of maize and 10 of sorghum, Cale, 1975–76 (P/ha).

	Cash	Imputed		Cash	Imputed
Added costs			Reduced costs		
Materials	634		Materials	434	38
Labour		300	Labour		289
Threshing	143		Harvesting	64	
Landlord	416		Landlord	361	
	1193	300		859	327
Reduced income			Added income		
	1803	0		2308	
	2996	300		3167	327
Economic disadvantage	3296		Economic advantage	3494	

Graphs

The next step in the procedure was an analysis of labour use to compare the two crops following a rice crop (Table 8). (The main purpose of Table 8 is to show a comparison of corn and sorghum labour requirements to determine if sorghum is better than corn in the cropping system; however, labour for rice and vegetables must be shown because of their importance to the farmer.) Sorghum required more land preparation than maize for all farmers, and it required it at a time when most farm families were busy harvesting rice and planting vegetables. There would be pressure on the farmers to do hurried, most likely inadequate, land preparation for sorghum so they could work on the vegetables. As seen in the preceding paragraphs, this results in poor yields. Thus, although the labour requirement did not actually exceed the labour available, it should be considered a limiting factor. Harvesting sorghum is more laborious than maize, but because there is little other work at that time, this is no problem.

Table 8. Comparison of rice and vegetable (RV), sorghum (S), and corn (C) labour use (hours) at planting for five farmers in Cale.

	Farmer 18			Farmer 20			Farmer 24			Farmer 32			Farmer 50		
Week	RV	S	C	RV	S	C	RV	S	C	RV	S	C	RV	S	C
34	65	—	—	—	—	—	15	—	—	83	—	—	15	—	—
35	5	—	—	5	—	—	45	—	—	686	—	—	157	—	—
36	25	—	—	10	—	—	15	—	—	60	—	—	40	—	—
37	50	—	5	20	—	—	40	—	—	20	30	10	5	—	—
38	5	—	—	210	—	—	70	—	—	30	40	5	20	5	30
39	20	—	—	20	—	—	20	—	5	25	30	15	55	15	5
40	35	—	5	25	—	—	25	20	—	15	40	5	30	30	—
41	5	35	30	—	45	25	30	10	—	20	40	25	30	15	5
42	30	20	10	—	20	45	5	10	—	30	10	5	55	—	—
43	20	20	5	5	40	10	10	—	—	30	—	30	45	—	—
44	15	10	5	20	10	5	5	—	—	30	—	10	—	—	—
45	—	—	—	20	—	—	25	—	5	65	—	5	—	—	—

Program Planning

The next procedure is program planning. In Table 9 an initial matrix is shown using mean data for maize and for the best 10 sorghum plots. The constraints are those found on an average farm. To ensure that both maize and sorghum could come into the solution, the data were calculated on 50 m^2 land units. Solution B uses all sorghum. As more maize is added, gross margin falls, but so do cash expenditures. Finally, in solution F, all maize is planted, and the loss in gross margin is compensated for by the reduced cash expenditure. It would appear from this analysis that the average farmer would gain nothing from planting sorghum and would be facing a larger risk due to the higher cash and labour input.

Each of the five case study farms was then used to compare maize and sorghum (Table 10). Only farms 18 and 24 required program planning analysis because the other three farms had maize gross margins higher than sorghum and nitrogen costs were the same or lower; therefore, there was no possibility sorghum could enter the solution. Farmer 18 would not plant all the maize area to sorghum, because he had a land preparation constraint in weeks 42 and 43 (Table 11). There was a possibility of moving the land preparation to other weeks to plant the remaining area. By planting various combinations of maize and sorghum he could get a slightly higher gross margin, but it seems likely he would grow all maize (solution F). If the farmer could get more money, he could plant an additional 240 m^2 and get P1.4 for each peso spent on sorghum (solution C).

Table 9. Program planning comparing mean data for maize and sorghum data, Cale, 1975–76.

	Gross margin	Land[a]	Cash	Labour/land preparation	Limits
Initial matrix					
Activity					
Sorghum	4.46	1	2.54	0.684	39.37 (cash)
Maize	3.77	1	1.89	0.288	40 (land)
Resources		40	100	30	
Solution B					
Sorghum	175.59·	39.37	100	26.93	
Solution C					
Sorghum	156.10	35	88.90	23.94	
Maize	18.85	5	9.45	1.44	
Resources	174.95	40	98.35	25.38	
Solution D					
Sorghum	133.8	30	76.2	20.52	
Maize	37.7	10	18.9	2.88	
Resources	171.5	40	95.1	23.40	
Solution E					
Sorghum	89.2	20	50.8	13.68	
Maize	75.4	20	37.8	5.76	
Resources	164.6	40	88.6	19.44	
Solution F					
Maize	150.8	40	75.6	11.52	

[a] Assuming 2000 m^2, and one unit of land 50 m^2.

Farmer 24 proved to be the one farmer who could gain from growing sorghum (Table 12). In 1975–76 he used more nitrogen on maize than the average for sorghum, so nitrogen was not a constraint. Sorghum had a definite advantage over maize for him as the gross margin for sorghum was 55% higher than maize. In solution B he would grow all the sorghum he could until he hit the week 41 labour constraint. For each additional hour of labour he could use in week 41, he would gain P15.5. He could easily hire labour for less than this. Thus, sorghum shows a real potential for farmer 24.

Although the group data showed little advantage for sorghum, individual analysis showed a definite advantage for one farmer. It is likely that this farmer was typical of the few farmers who were interested in sorghum.

Comparison of Linear Programing and Informal Procedure Solutions

The final test of the informal procedure is to compare its solution with linear programing based on data from two other sites, Iloilo and Pangasinan. A detailed description of the linear programing model and the assumptions used is given in Barlow et al. (1979). Their matrix had 378 rows and 643 columns. The main activities were: crop production, crop consumption, crop sale, other earnings, household expenditures, loans, family labour, transfer

Table 10. Comparison of five farmers' actual maize data with sorghum experimental data for the same area, Cale, 1975–76.

	Farmer 18		Farmer 20		Farmer 24		Farmer 32		Farmer 50	
	Maize	Sorghum	Maize	Sorghum	Maize	Sorghum	Maize	Sorghum	Maize	Sorghum
Area (ha)	0.397	0.397	0.485	0.485	0.225	0.225	1.004	1.004	0.339	0.339
Planting date (week)	42	42	43	43	45	45	42	42	43	43
N (kg)	43	48	37	59	31	27	113	120	10	41
N cost (P)	180	201	157	250	135	118	407	432	52	213
Land preparation (hours)	15	65	31	83	0	38	45	172	0	58
Cultivation (hours)	6	0	4	0	7	0	11	0	4	0
Weeding (hours)	0	8	0	10	2	7	0	31	0	11
Harvest (hours)	47	85	105	109	40	51	116	227	26	76
Yield	747	939	1126	1189	414	613	3142	2473	760	831
Gross returns	747	837	1126	1070	414	552	3142	2225	760	748
Over cash	567	636	969	820	279	434	2735	1793	708	535
To landlord	142	159	242	205	70	109	689	448	177	134
To family	425	477	727	615	209	294	2056	1345	531	401
To labour (hours)	6.25	3.02	5.19	3.04	4.27	3.06	11.92	3.13	17.7	2.76

labour, hiring, water buffalo hire, cash saving, and cash surplus. The resources were: three categories of land, two categories of labour, cash, water buffalo, and a set of constraints relating to family needs. Two sets of technology were defined: farmers' technology, which was the practices used

Table 11. Program planning for farmer 18 comparing sorghum with current maize production, 1975–76.

	Gross margin	Land[a]	Cash	Labour by week 41	42	43	44
Initial matrix							
Activity							
Sorghum	12.7	1.0	4.0	0.30	0.40	0.40	0.17
Maize	11.3	1.0	3.6	0.36	0.10	0.08	0.02
Resources available		50.0	180.0	25	15.00	21.00	20.00
Solution B							
Sorghum	476	37.5	150	11.25	15.00	15.00	6.385
Solution C							
Sorghum	381	30.0	120	9.00	12.00	12.00	5.10
Maize	188	16.7	60	6.00	1.70	1.33	0.33
Resources	569	46.7	180	15.00	13.70	13.33	5.43
Solution D							
Sorghum	355.6	28.0	112	8.40	11.20	11.20	4.76
Maize	213.4	18.9	68	6.80	1.90	1.50	0.38
Resources	569.0	46.9	180	15.20	13.10	12.70	5.14
Solution E							
Sorghum	317.5	25.0	100	7.50	10.00	10.00	4.25
Maize	251.1	22.2	80	8.00	2.20	1.77	0.44
Resources	568.6	47.2	180	15.50	12.20	11.77	4.69
Solution F							
Maize	565	50.0	180	18.00	5.00	4.00	1.00

[a] One unit of land is 80 m^2.

Table 12. Program planning for farmer 24 comparing sorghum with current maize production, Cale, 1975–76.

	Gross margin	Land[a]	Labour by week 39	40	41	42	45	46
Initial matrix								
Activity								
Sorghum	8.7	1	0.0	0.36	0.2	0.2	0.00	0.00
Maize	5.6	1	0.1	0.00	0.0	0.0	0.12	0.12
Resources		45	12.0	14.00	6.0	26.0	19.00	17.00
Solution B								
Sorghum	261.0	30	0.0	10.80	6.0	6.0	0.00	0.00
Maize	84.0	15	1.5	0.00	0.0	0.0	1.80	1.80
Resources	345.0	45	1.5	10.80	6.0	6.0	1.80	1.80

[a] One unit of land is 50 m^2.

by the farmer in 1975–77, and new technology, which was the methods being tested by the IRRI cropping systems team during the same period. The coefficients used were arithmetic means from the agronomy experiments and case study farm data. The linear programing model was designed to first obtain a given amount of rice and then to maximize the net surplus (Jayasuriya 1979). Five case studies were run in Iloilo and Pangasinan with data from 10 individual farms.

To ensure that the solution from the informal procedure was comparable with the linear programing solution, data were taken from the working tables used to develop the linear programing model. There was no way the informal procedure could handle the great mass of data used in the model. In consultation with research assistants who had worked at the sites, assumptions were made regarding the critical factors. It was decided to: (1) use only two land classifications — upland and lowland, (2) use only the first date when land preparation can start, (3) use only land preparation hours, (4) consider only fertilizer and chemicals in cash costs, and (5) use highest gross return as the decision criteria. Two of the largest labour use activities were not used in the analysis, because it is a common practice to hire labour for transplanting and harvesting.

One factor that complicated the analysis more than would normally occur was the large number of farmers and new technologies that had to be compared. The linear programing model included all crops the farmer had grown as well as all experimental crops. The budgeting phase of the procedure was, therefore, much larger than would be the case if a specific new technology could be compared with the specific farmers' technology it was to replace. In this case all farmers and all new technology had to be compared for one land classification at one planting period. In many cases this meant 40 crops from which to select. The first step was to discard all crops that had low gross margins and high land preparation or cash requirements. The crops that remained were put in a budget comparison table.

Detailed Analysis of One Farmer

The process followed in the procedure will be discussed for farmer 1, Iloilo. Those crops that were not clearly unprofitable were listed along with their critical factors in a budget comparison (Table 13). Each crop was given a code to facilitate analysis, with F for farmers' technology and N for new technology. The crops are divided into farmers' and new technology, upland and lowland, and first or second crop period. Because rice is the main crop considered, rice cultivars are shown by their letter and number codes. The two letters in parentheses following the rice cultivar's name indicate seeding method. Transplanting (TP) is the traditional technology; wet seeding (WS) and dry seeding (DS) are new technology. In the first year of testing dry seeding and wet seeding, séveral farmers adopted it and in the classification it was recorded as farmers' technology in the record-keeping. The land preparation start week is the first week plowing can begin.

The initial matrix and solution for the first crop period are shown in Table 14. F-6, F-7, and N-8 were the three crops selected for the upland area. The upland area was 1 ha of five parcels of 2000 m^2, which appeared to be the average parcel size for most farms. Therefore, the solution could easily be interpreted into number of parcels.

Table 13. Budget comparison of farmer's and new technology, farmer 1, Iloilo (per hectare).

	Land preparation start week	Land preparation (hours)	Cash (P)	Gross revenue (P)
Farmer's technology				
Upland (UL)				
First crop				
F-6 Maize	16	94	117	1390
F-7 Maize	16	94	0	610
Second crop				
F-8 Maize	45	221	0	469
F-9 Maize	45	221	117	1044
F-10 Maize	32	330	0	2455
Lowland (LL)				
First crop				
F-1 IR5 (TP)[a]	23	124	177	1469
F-2 Kapopoy (TP)	21	203	187	1537
F-4 BE 3 (TP)	23	203	335	1926
Second crop				
F-5 BE 3 (TP)	34	244	218	934
New technology				
Upland				
First crop				
N-8 Maize	16	145	252	1877
Lowland				
First crop				
N-1 IR36 (WS)	18	138	404	2009
Second crop				
N-3 Maize — yam bean[b]	41	255	110	3077
N-5 IR36 (TP)	36	190	420	1699
N-7 Mung	41	88	257	723
N-4 IR36 (TP)	36	38	84	579

[a] TP = transplant; WS = wet seeded.
[b] Can only be grown in 2000 m^2.

A more precise solution could be achieved if 1 m^2 was used as the basic land area, but that would entail working with a lot of small decimals that would have little meaning to researchers. By using a typical parcel area, the researchers can check their calculations with the experience gained from working with the farmers. Gross returns, cash, and land preparation hours from the per hectare budget data were all divided by five before they were entered in the program planning matrix. The land preparation hours column and the weeks in which they could be used were separated.

The land preparation weeks are those during which the researchers found the farmer had been or could carry out land preparation. After the weeks shown, the farmer would get substantially reduced yields or, in the case of lowlands, the fields might be flooded and no crop could be grown. The land preparation hours shown, or multiples of them, can be used in any of the weeks shown. The possible crops for the lowland are shown below the upland crops. In this case, there are only three units, or 6000 m², of lowland available. In the "resources" row, the value for cash, P350, and the 48 hours/week are for both upland and lowland areas. Using the same procedure described for comparing sorghum and maize, a new optimal solution was found. The solution is shown at the bottom of Table 14. The upland area was planted to 6000 m² N-8 and 4000 m² F-7. The lowland area had 4000 m² N-1 and 2000 m² F-2. These crops gave a gross return of P2131, used P349 in cash costs, and used all the land preparation hours available for 4 weeks and most of the fifth.

The selection of crops for the second period becomes a little more complicated, because the duration of the first crop must be taken into consideration. Because the first crop was usually rice or maize, it is not a major problem. The initial matrix and solution for the second crop period are given in Table 15. Both cash and land preparation time became major constraints and brought the farmer's traditional early maize with no fertilizer into the solution.

The solutions for first and second crop periods are combined to show the cropping pattern solution in Table 16. The solution shows upland (UL) all planted to maize. All of the lowland (LL) is planted to rice except for one parcel in a maize/yam bean intercrop. The solution shows 50% of the land in

Table 14. Initial matrix and solution for first crop period, farmer 1, Iloilo.

	Gross revenue (P)	Land[a]	Cash (P)	Land preparation (hours)	Land preparation (week) 16	17	18	19	20
Initial matrix									
Activity									
Upland (UL)									
F-6	255	1	23	19					
F-7	122	1	0	19					
N-8	325	1	50	29					
Lowland (LL)									
N-2	274	1	81	40					
N-1	321	1	81	34					
F-1	258	1	35	32					
F-3	198	1	43	40					
F-4	318	1	67	50					
F-2	270	1	37	50					
Resources		UL 5 LL 3	350		48	48	48	48	48
Solution									
Upland									
N-8	975	3	150		48	39			
F-7	244	2	0					37	1
Lowland									
N-1	642	2	162			9	48	11	
F-2	270	1	37						37
Resources	2131	UL 5 LL 3	349		48	48	48	48	38

[a] One unit of land is 2000 m².

Table 15. Initial matrix and solution for second crop period, farmer 1, Iloilo.

	Gross revenue (P)	Land[a]	Cash (P)	Land preparation (hours)	Land preparation (week) 32	33	34	35	36	37	38	39	40	41
Initial matrix														
Activity														
Upland (UL)														
F-9	185	1	23	44										
F-10	491	1	0	66										
F-5	143	1	44	49										
Lowland (LL)														
N-3	830	1	22	51										
N-4	688	1	114	38										
N-5	387	1	84	38										
N-6	365	1	84	40										
N-7	149	1	51	18										
Resources		UL 5 LL 3		350	48	48	48	48	48	48	48	48	48	48
Solution														
Upland														
F-10	491	1	0		48	18								
F-9	740	4	92						2	48	48	48	30	
Lowland														
N-3	830	1	22										18	4
N-4	1376	2	228			30	48	48	46					
Resources	3437	UL 5 LL 3	342		48	48	48	48	48	48	48	48	48	4

[a] One unit of land is 2000 m^2.

Table 16. Informal cropping pattern solution, farmer 1, Iloilo.

Crop	Land in: New technology (N)	Land in: Farmer's technology (F)	Rice land: Dry seeded or wet seeded	Rice land: Transplant	Gross margin
First crop period					
N-8 Maize UL[a]	3				975
F-7 Maize UL		2			244
N-1 Rice LL	2		2		642
F-2 Rice LL		1		1	270
Second crop period					
F-10 Maize UL		1			491
F-9 Maize UL		4			740
N-3 Maize/yam bean LL	1				830
N-4 Rice LL	2			2	1376
Total	8	8	2	3	5568

[a] UL = upland; LL = lowland.

new technology and 67% of the rice being seeded by a new method. The new technology does appear to have a place in this farmer's cropping system.

The same process was used on the other four farms in Iloilo and on four additional farms in Pangasinan. One farm was omitted because it had grown a considerable area of sugarcane and there was not sufficient information to justify an analysis.

The Iloilo Site

A comparison of the program planning and linear programing solutions for Iloilo in Table 17 shows there was little difference in family income from crops. The differences for Iloilo were 11, 17, 17, 2, and 20%, respectively. However, this is of limited value because the linear programing model was able to give a far more complete picture by including off-farm income, family cash expenses, rice consumption, and hired labour in its final solution.

The main objective of the procedure is to find if the new technology will fit into the farm and if so to what extent. A comparison of the two procedures for percentage of area in new technology shows similar patterns. Farmer 2

Table 17. Comparison of informal procedure and linear programing for Iloilo and Pangasinan.

	Percentage area in new technology		Percentage rice area dry seeded or wet seeded		Family income from crops (P)	
	IP[a]	LP	IP	LP	IP	LP
Iloilo						
Farmer 1	50	82	67	21	5568	6264
Farmer 2	100	100	100	52	16989	20230
Farmer 3	75	71	79	100	15605	18706
Farmer 4	67	25	100	50	18770	18327
Farmer 5	71	59	12	75	11783	9825
Pangasinan						
Farmer 1	38	5	40	4	15424	9034
Farmer 2	63	66	100	18	9573	4690
Farmer 3	100	37	75	56	13908	11358
Farmer 5	9	32	10	0	15307	12509

[a] IP = informal procedure; LP = linear programing.

would use all new technology and farmer 3 would use new technology on about three-quarters of his land. The differences come with farmer 1 and 4. In the case of farmer 1, the limit on cash was partially removed by credit and off-farm income in the linear programing solution, and this allowed more new technology. Farmer 4 had high family cash expenses that limited the cash available for new technology in the linear programing solution.

The percentage of area direct seeded or wet seeded showed more diversity particularly for farmers 1 and 5. In all cases the major cause of difference was the family requirement for rice, which was included in the linear programing solution but not in the informal procedure.

The results of the informal procedure would lead to the same conclusions as linear programing. The new technology would benefit most of the farmers. With the prices and technologies considered, most of the farmers would use new technology on over one-half of their cropped area. Direct or wet seeding would be used on over one-half of most farmers' rice area.

The Pangasinan Site

A comparison of the two procedures for Pangasinan shows a very different situation. Solutions from the informal procedure have a higher family income from crops (Table 17). Farmer 2 only worked part-time, and so labour was a major constraint in the linear programing solution. Generally, labour constraints and outside activities caused the major differences. For farmer 1, the informal procedure solution used much more new technology and pushed the cash surplus higher. The linear programing solution shows that new technology will not play a major role in the majority of these farms. The informal procedure solution shows the same thing. In a comparison of direct- and wet-seeding area, the informal procedure was far higher. Farmer 2, who only works part-time, had a major difference. However, the informal procedure indicated that the new seeding methods would not be generally accepted and more research was needed. The conclusions from both procedures are that the new technology does not fit well and that more research is needed before general adoption will occur.

The results from the informal procedure for Pangasinan are not as accurate as those for Iloilo, because the author was not as familiar with this site as he was with those at Cale and Iloilo. As previously indicated, when using the informal procedure, familiarity with the site is essential.

In summary, the analysis indicates that the informal procedure lead to the same conclusions as linear programing. In one case the new technology was acceptable, and in the other it was not likely to be adopted. This was the conclusion for both procedures. Although not as precise as linear programing, it does appear that the informal procedures were as accurate. With practice, the informal procedure should help economists make a greater contribution to cropping systems research.

Conclusions and Recommendations

The economic component of the current cropping systems research program was found to involve analytical techniques that were not well suited to the cropping system sites. More data were being collected than could be effectively analyzed. Therefore, an improved procedure was required, both in terms of the data collected and in the analytical procedures, and it had to be more compatible with the expertise, time constraints, and facilities at the sites.

Although enough trained manpower was available to carry out the economic studies at most sites, the economic methodology was causing frustration among the economists and their team members. First, the economic analysis was usually completed too late to be of use for decision-making. Second, in many cases, the results were incomplete. The economists felt they were not developing useful skills in their profession and were not contributing sufficiently to the team effort. The conclusion was that less time should be spent in collecting farm record data and more time should be spent on analysis.

Collection of less data requires a choice between a larger sample of fewer factors or a smaller sample involving more factors. The traditional approach has favoured the large sample. This traditional approach was found to be unsatisfactory for effective evaluation of new technology in cropping systems research. Cross-sectional studies overestimate the input and output variability that the individual farmers face — by 300% when compared with time-series studies of individual farmers. Another problem is that a false understanding of the interaction of enterprises can be formed. For example, aggregate data showed a positive relationship between gross returns of the first and second crop periods, but a majority of individual farms showed a negative relationship. Thus, research based on aggregate analysis would start from a false premise. Arithmetic means, the basis for nearly all analysis in the traditional approach, overestimate input and output levels of the majority of farmers. Because most input and output calculations are ratios, i.e., kg/ha, the geometric mean is a better estimator for the majority. Kurtosis and skewness measures are unreliable tests for normality, particularly in the case of bimodal distributions; therefore, graphs of the frequency distribution should be used, and if there are over 100 observations, a chi square test of normality should be considered. The three main factors of production (land, labour, and capital) are not homogeneous or considered independent by farmers; thus a package of inputs is of more use in analyzing farm data for comparison with agronomy research results.

When a comparison between the farmers' existing technology and new technology is to be made at a typical site, a case study approach is superior. Studying a small number of farms in detail gives a better understanding of the farms. The case study approach has several other advantages. First, it allows a continuous interaction between the farmer and the researcher. Through this interaction the researcher understands the actual operational procedures and organization on a farm and the reasons why certain decisions are made. Thus, he builds his informal knowledge of farming, and this can be used in the design phase of the research. Second, the interactions between enterprises can be studied. Unless a complete set of records is available for a farm, these interactions can be overlooked and, even if noted, cannot be analyzed. Third, by understanding the researcher's objectives, the farmer can contribute much more effectively to the research program. Fourth, by selecting a small number of farmers to study in detail, the researcher can plan his work so time is available to do special studies on problem areas.

One of the roles of the economist is to develop a framework for understanding and analyzing the farmer's cropping system. A schematic diagram of the stock and flow of resources and products on a farm gives all members of a cropping system research team a better picture of how the farmer is using his resources and where the products are going. It can serve as a framework to plan research, and as a model to test the effects of introducing new technology. The same type of diagram can be used to show a subsystem of a farm, such as a cropping system or cropping pattern.

By the time an economist has collected detailed data on a few farms and worked through a couple of schematic diagrams he should have sufficient understanding of the farming operation to begin evaluating the effects of new technology. It is important that the person who has collected the data and gained the informal knowledge does the analysis. This is particularly true for the informal procedure.

Partial budgets are an effective tool for evaluating the likelihood of acceptance of new technology in an existing farm operation. They can be completed quickly, and other team members can easily understand the procedure and results. Partial budgets are an efficient first step in the informal procedure and can be used to weed out technologies that are inferior to those on the farm and to retain those that show promise.

Graphs are an effective method of finding constraints in resource use for a new technology that is found to be profitable. Graphs of resources use over time can be quickly and easily constructed and understood, and they can show periods when resources are underutilized. This information can be used in designing new technology to make more efficient use of the farmers' resources.

Partial budgets and graphs can, thus, be used to assess the probable acceptance of a new technology. However, for a more complete analysis, program planning was found to be effective. Using the results of partial budgeting and graphing, program planning can be used to demonstrate to what extent the new technology is likely to be adopted. It also supplies a set of shadow prices that can be used in designing research for new technology. Although not as simple as partial budgets and graphs, program planning solutions can be obtained with the use of a hand calculator. Because program planning relies on the skill and knowledge of the researcher it should only be undertaken by someone familiar with the farms under study.

The informal procedure led to the same conclusions as linear programing in predicting the acceptance of new technology. At the Iloilo site, for example, both procedures predicted general acceptance of the new technology under review. This was borne out by farmers' actions. At

Pangasinan the conclusion from both procedures was that the new technology would not be generally accepted without further research, which proved to be the case.

In summary, the overall conclusion was that a case study approach helps ensure that the researcher will not collect more data than he can analyze and utilize. Use of the informal procedure of partial budgets, graphs, and program planning will allow analysis to be completed within 1 month at a typical cropping systems site. This helps to ensure that economic results from the testing phase will be available for use in the design phase of cropping systems research. The following are the overall recommendations:

(1) A case study approach on a small number of typical farms at a site should be used. Each of the farms should be analyzed individually and the potential adoption of a new technology should be tested on each farm.

(2) The analysis of cropping systems research should be conducted at the site to ensure interaction with farmers and other team members.

(3) The evaluation of new technology should start with partial budgets to determine if the new technology is profitable. Graphs should then be used to find the constraints in resource use. Program planning should follow to evaluate likely adoption rates.

(4) New technology should not be evaluated using aggregate farm data in the testing phase of cropping systems research.

References

Allaby, Michael. 1972. World food resources: actual and potential. London, U.K., Applied Science Publishers, 418 p.

Anderson, Jack R., Dillon, John L., and Hardaker, J.B. 1977. Agricultural decision analysis. Iowa, USA, Iowa University Press, 344 p.

Banta, Gordon R. 1977. Information requirements for description of cropping systems. In: Symposium on cropping systems research and development for the Asian rice farmer, 21–24 September 1976. Los Baños, Philippines, IRRI, pp. 151–166.

Barlow, C., Jayasuria, S., Cordova, V., Roxas, N., Yambo, L., Bantilan, C., and Maranan, C. 1979. Measuring the economic benefits of new technologies to small rice farmers. Los Baños, Philippines, IRRI, Research Paper Series 38.

Bhattacharjee, J.P. 1978. External assistance for food and agricultural development in the Third World. In: Sinha, R., ed., The world food problem. Glasgow, Scotland, Pergamon Press, pp. 636–638.

Bradfield, Richard R. 1964. Some unconventional views about rice culture in Southeast Asia. Los Baños, Philippines, IRRI, Saturday Seminar, 16 April 1964, mimeo.

Buringh, P. and Van Heemst, H.J.D. 1977. An estimation of the world food production based on labour-oriented agriculture. Wageningen, The Netherlands, Centre for World Food Market Research, 49 p.

Castillo, Gelia T. 1975. Diversity in unity: the social component of change in rice farming in Asian villages. In: Changes in rice farming in selected areas of Asia. Los Baños, Philippines, IRRI, p. 358.

Dessler, Gary. 1979. Management fundamentals. Virginia, USA, Reston Publishing Co.

Dillon, John L. 1976. The economics of systems research. In: Spedding, C.R.W., ed., Agricultural systems, vol. 1. London, U.K., Applied Science Publishers, pp. 5–22.

Dorfman, Robert, Samuelson, Paul A., and Solow, Robert M. 1958. Linear programming and economic analysis. New York, USA, McGraw-Hill Book Co., Inc.

Ebersohn, J.P. 1976. A commentary on systems studies in agriculture. In: Spedding, C.R.W., ed., Agricultural systems, vol. 1. London, U.K., Applied Science Publishers, pp. 173–184.

FAO (Food and Agriculture Organization of the United Nations). 1977. FAO production yearbook, 1977. Rome, Italy, FAO, 31, 291 p.

Fellows, Irving F. 1960. The basic theory and assumptions underlying use of the budgeting technique. In: Fellows, Irving F., ed., Budgeting. Connecticut, USA, University of Connecticut, Bulletin 357.

Harwood, Richard R. and Price, E.C. 1976. Multiple cropping in tropical Asia. In: Stelly, M., ed., Multiple cropping. Wisconsin, USA, American Society of Agronomy, Special Publication No. 27, p. 12.

Heady, E.O. 1973. Allocation of colleges and economists. American Journal of Agricultural Economics, 54, p. 941.

Heady, E.O. and Candler, Wilfred. 1958. Linear programming methods. Iowa, USA, Iowa University Press.

Heady, E.O. and Dillon, John L. 1961. Agricultural production functions. Iowa, USA, Iowa University Press.

Heady, E.O. and Jensen, H.R. 1964. Farm management economics. New Jersey, USA, Prentice-Hall Inc., p. 6.

Hopper, W.D. 1977. The politics of food. Ottawa, Canada, International Development Research Centre, IDRC-100e, 24 p.

Hsieh, S.C. 1963. Management decisions on small farms in Taiwan. Journal of Agricultural Economics, 1(15).

IFPRI (International Food Policy Research Institute). 1976. Meeting food needs in the developing world: the location and magnitude of the task in the next decade. Washington DC, USA, IFPRI, Research Report No. 1, 64 p.

IRRI (International Rice Research Institute). 1978. Annual report for 1977. Los Baños, Philippines, IRRI, 112 p.

Jayasuriya, S. 1979. New cropping patterns for Iloilo and Pangasinan farmers: a whole farm analysis. Los Baños, Philippines, IRRI, mimeo.

Jensen, Harold R. 1978. Farm management and production economics, 1946–1970. In: Martin, Lee R., ed., A survey of agricultural economics literature, vol. 1. Minnesota, USA, University of Minnesota Press.

Muller-Merbach, Heiner. 1974. Heuristic methods: structure, applications, computational experience. In: Cattle, R.W., and Krarup, J., ed., Optimization methods. London, U.K., English University Press.

Petersen, T.A. 1976. Alberta agriculture training course, Red Deer, Alberta. 14 September, mimeo.

TAC (Technical Advisory Committee, Consultative Group on International Agricultural Research). 1978. Farming systems research at the International Agricultural Research Centres. Rome, Italy, Agriculture Department, FAO, pp. 8–12.

Vincent, Warren H. 1962. Economics and management in agriculture. New Jersey, USA, Prentice-Hall Inc.

Zandstra, H.G. 1977. Cropping systems research for the Asian rice farmer. In: Symposium on cropping systems research and development for the Asian rice farmer, 21–24 September 1976. Los Baños, Philippines, IRRI, pp. 11–31.