Evaluating Technology for New Farming Systems: Case Studies from Philippine Rice Farms

C. Barlow, S. Jayasuriya, and E.C. Price

International Rice Research Institute

Copyrighted material

Evaluating Technology for New Farming Systems: Case Studies From Philippine Rice Farms

C. Barlow, S. Jayasuriya, and E.C Price

1983
International Rice Research Institute
Los Baños, Laguna, Philippiness
P.O Box 993, Manila, Philippines

The International Rice Research Institute (IRRI) is one of I3 nonprofit international research and training centers supported by the Consultative Group for International Agricultural Research (CGIAR). The CGIAR is sponsored by the Food and Agriculture Organization (FAO) of the United Nations, the International Bank for Reconstruction and Development (World Bank), and the United Nations Development Programme (UNDP). About 50 countries, international and regional organizations, and private foundations comprise the CGIAR.

IRRI receives support, through the CGIAR, from a number of donors including:

the Asian Development Bank
the European Economic Community
the Ford Foundation
the International Fund for Agricultural Development
the OPEC Special Fund
the Rockefeller Foundation
the United Nations Development Programme

and the international aid agencies of the following governments:

Australia
Belgium
Brazil
Canada
Denmark
Federal Republic of Germany
India
Japan
Mexico
Netherlands
New Zealand
Philippines
Spain
Sweden
Switzerland
United Kingdom
United States

The responsibility for this publication rests with the International Rice Research Institute.

ISBN 971-104-0794

About the cover

Color infrared photography enhances distinctions between crop species and land use patterns on a typical Philippine farm where cropping systems research was conducted by the International Rice Research Institute. Diverse cropping patterns suggest a complex set of technical, social, and economic relations that impinge on farm management in the Asian environment. Aerial photography courtesy of T. L. Hansen, H. T. Murphy, and J. C. O'Toole.

Contents

FOREWORD v
PREFACE vii
Chapter 1. INTRODUCTION 1
Chapter 2. BACKGROUND TO THE STUDY 5
Physical characteristics of the two sites 6
Oton and Tigbauan, Iloilo 6
Manaoag, Pangasinan 7
Farming systems and the socioeconomic environment 9
Cropping patterns 11
Farming practices 13
Off-farm and non-farm activities 17
Cash income and credit 17
The development of the model 20
Specifying the system 21
Goals 25
The range of new technologies 27
The 10 farm models 30
Chapter 3. FARM LEVEL IMPACTS OF NEW TECHNOLOGIES 35
The overall impact 35
Historical technologies 35
New technologies 36
Changes in the usage and pricing of resources 41
Labor 42
Land 45
Cash 45
Pattern selections and complementarities 46
Suboptimal choices 48
Special effects on technology selection 51
Outputs 51
Wages 53
Other effects 54
Departures from basic resource situations 57
Land 57
Labor 59
Cash 59
Some individual cases 62
Conclusions 64

Chapter 4. THE DYNAMICS OF TECHNOLOGY ADOPTION 67
Actual changes on the sites 72
Experiences with selected technologies 76
Sequential aspects 81
Farmers' behavior in adoption 83
Personal behavior 85
Wider patterns 87
Towards appropriate technologies 88
Factor and product market changes 89
Labor absorption and factor shares 93
Broader implications 94
Chapter 5. ASSESSING THE BENEFITS OF NEW TECHNOLOGIES 97
The wider assessment problem 98
APPENDIX TABLES 101
REFERENCES 103
INDEX 107

Foreword

Research to develop techniques for growing rice in combination with other crops began in 1964 under the leadership of Dr. Richard Bradfield, and by 1975 had expanded to include six fulltime scientists in four IRRI departments. The objective is to develop techniques of multiple cropping that will support more productive and profitable cropping systems on small rice farms. Sound principles of economics, ecology, energy conservation, and employment generation must be integrated into a socially acceptable cropping pattern. The problem of identifying from a number of alternate experimental cropping patterns, those that likely to be profitable to farmers is challenging. Yet the exercise is crucial for guiding research and avoiding the damage caused by introducing unacceptable technology to farmers. The authors of this book approach the problem in a *whole-farm* context, employing the method of linear programming.

Dr. Colin Barlow, senior fellow, Research School of Pacific Studies, The Australian National University, joined the IRRI Agricultural Economics Department and Cropping Systems Program as visiting scientist in January 1977. Soon afterward he was joined by Dr. Sisira Jayasuriya, initially as a post-doctoral fellow and later as economist, Cropping Systems Network. Dr. Edwin Price, IRRI agricultural economist for cropping systems research, worked with Barlow and Jayasuriya to conduct research on methods of evaluating experimental technology for small rice farms. Titled the *Whole-farm Analysis Project,* the work subjected the myriad interactions of crops and other farm activities to more careful analysis than was previously possible. With this work, economic evaluation of new multiple-cropping technology has moved fully within the context of the whole "farming system" around which the day-to-day life of a farmer and his family revolves.

The cropping systems program at IRRI is indebted to the Australian National University for supporting Dr. Barlow's work, particularly during the later stages of computer analysis, manuscript preparation, and typesetting. IRRI Visiting Editor Debrah Jefferson edited the earlier drafts of the manuscript, and later assistance was given by Ms. Gloria Argosino of the Information Services Department.

Evaluating Technology for New Farming Systems: Case Studies from Philippine Rice Farms provides a detailed view of factors that affect the adoption of techniques for multiple cropping recently developed by the IRRI Cropping Systems program. The authors provide a helpful insight on cropping systems research and the economics of small rice farms in Asia.

M. S. Swaninathan
Director General
International Rice Research Institute

Preface

In this book we analyse the economics of new agricultural technologies. We study their impact in the context of both farm households and agricultural districts, and do not confine ourselves to the usual partial analyses of direct effects on particular enterprises.

At the household level we look at the influences of new technologies on the net returns or losses of whole family groups, and also check the economic effects of these technologies on the main family activities. Such activities commonly include several cash-earning enterprises, the production of food for subsistence, and the consumption of food, education, and a range of other items. At the district level we investigate the way in which technologies spread through whole regions, and the particular characteristics of those who adopt them at successive stages from their original introduction. At both the household and district levels, we focus especially on factors constraining or accelerating the process of adoption.

We undertake our household level analyses through a detailed examination of 10 case study farms. Five of these were on the Cropping Systems site of the International Rice Research Institute (IRRI) in the province of Iloilo, Philippines, and five on a further site in Pangasinan. We undertake our district analyses through studying trends for each of these sites as a whole.

Our investigations covered three years of regular recording for the case study farms, and involved us in many personal discussions with the operators, both in the field and at their houses. Over the same period we also observed more general trends occurring on the sites as a whole.

We present this study to illustrate the importance of analysing the impact of new technologies at household and district levels. Our household methodology in particular is too complex for regular use by field workers, however, and such persons will need to apply simpler techniques in their routine analyses.

We acknowledge with very great thanks the continuing cooperation of the case study farmers, some of whom became good friends over the long period of investigation. To avoid any possible misunderstandings we iden-

tify these persons by numbers in the reporting of this book. We also express our immense debt to the many research personnel who assisted us, both at the Institute headquarters at Los Baños and at the sites themselves. Successive leaders of economics research at Iloilo were Rosalinda Servano, Nicanor Roxas, Macario Genesila, and Ramona Abatay. The work in Pangasinan was led by Crescencia Bantilan, Jose Nicolas, and Lolita Lavapiez. Programming assistance was provided by Leonida Yambao and Merito Oallares, and Constancia Maranan, Alma Tonogbanua, and Nancy Palma gave clerical support.

The dedication of these people to their work was impressive, and exceptional by all international standards. We finally mention the helpful comments and criticisms of our professional colleagues, notably John Flinn, Kwanchai Gomez, Bob Herdt, Dick Morris, and Hubert Zandstra. Needless to say, we take responsibility for the results and analyses presented.

CHAPTER 1

Introduction

New farming technologies can be a major instrument for achieving economic development in less developed countries. These countries are characterized by large rural populations engaged in small-scale farming. Their farmers operate typically under conditions of low resources, limited technology and low productivity.

Over the past two decades, efforts have been made to enhance the productivity of small farmers through research to develop new technologies. Major successes have been registered, but an enormous task still lies ahead. Large-scale adoption of new technologies has taken place, although not all such technologies have been acceptable to the farmers. What is considered an appropriate technology is subject to sociocultural and political judgment, and varies between groups of people. To be fully appropriate, technologies must not only improve productivity, but be acceptable and attractive to small-scale farmers and enhance the community's overall social welfare.

The need for assessing the appropriateness of new technologies both on the farm and in a wider social context is now accepted widely within technology-generating research institutes.

The assessment of technologies can take place at different stages in their process of generation. In cropping systems research we are interested both in assessing a technology at the design stage when it is 'notional', and later when it has undergone testing on farmers' fields for one or more years. Even this subsequent assessment precedes the possible extension of a technology to wider groups of farmers. In that sense it is an 'ex ante' evaluation.

Most assessment studies of new technologies in less developed countries have tended to be 'ex-post' evaluations, where the patterns and levels of adoption of a technology and their consequences are analyzed, and its relative benefits and costs evaluated. The findings of such studies have undoubtedly influenced the nature and direction of subsequent research. However, where inappropriate technologies have been developed and then actively pushed through large-scale programs, the social and economic costs have been considerable. Ex-ante assessment of technologies can help the researchers and policy makers avoid such costly mistakes. It may also provide useful information for the design of more appropriate systems.

Generally, ex-ante evaluations of new technologies have tended to con-

centrate on agronomic aspects. When economic considerations were taken into account, they were usually incorporated quite crudely and often did not lead to an improved assessment.

The Cropping Systems Programs of IRRI and of various Asian countries collaborate within the Asian Cropping Systems Network to develop new technologies tailored to fit specific farming circumstances. In these circumstances ex-ante assessments of technologies assume immediate importance, and have encouraged the development and use of methods for adequate evaluation.

Costs and returns analysis is the most common method used to determine the impact of a new technology. The average gross returns and variable costs per unit of land are usually determined on the basis of average market prices, while overhead inputs, such as land and sunk capital, are ignored . Profitability or benefit criteria are derived from such analysis, and returns over variable costs are probably the most frequently used criterion.

The major advantage of costs and returns analysis is its simplicity. It can be carried out by field workers with little training in economics. It is rapid and easy to undertake without relying on sophisticated computers, and gives a good initial guide to the benefits of technologies. It can also be extended and modified to incorporate an estimate of risk and uncertainty. The measurement of gross benefits over variable costs can be supplemented by the computation of returns to scarce resources, which may be valued at judgmentally derived shadow prices that more closely reflect their true scarcities. Such improvements to costs and returns analysis are discussed by Anderson (1976), Norman and Palmer-Jones (1976), and Perrin et al (1976).

Essentially, all costs and returns analyses remain *partial*, however, because they ignore the systems context in which the technologies relating to various farm enterprises should actually be evaluated. The farm is viewed as a *superstructure* of enterprises resting on a *foundation* comprising basic resources of land, fixed capital, working capital (cash), family labor, and animal power. It is assumed that individual enterprises can be varied within broad limits without affecting the cost of basic resources, which are accordingly omitted from the budgeting calculations. The partial analysis calculations merely attempt to measure the *extra* returns and *extra* (variable) costs incurred by enterprises using the technologies under consideration.

This type of analysis does not directly answer the question of whether a particular technology is feasible and desirable given the farmer's total resources. It also does not examine the implications for overall system performance of the required changes in resource use.

Where new technologies involve only minor alterations in resource use, costs and returns analysis performs particularly well. This, for example, occurs in assessing the relative benefits of directly substitutable component technologies such as fertilizers, pesticides, and seed varieties. However,

when the technologies involve major changes in resource use, the drawbacks of such analysis can be important.

When a technology involving major changes is evaluated, the interaction between its activities and the farm household resource base needs to be considered. Then the relevant price or cost of the farmer's inputs and outputs will depend on the actual demand-supply position within the farm household. In this situation, the use in analysis of overall average prices (or what are effectively zero prices where inputs or outputs are merely ignored) will lead to major inaccuracies. The market prices of some of the farmer's major resources usually do not reflect their real scarcity value to him personally. During the slack cultivation period, family labor may be relatively abundant, but at peak periods it is more scarce in terms of the demands for it. Similarly cash, family labor, animal time, and land will have different values at different times of the crop year.

As indicated above, average costs and returns analysis is sometimes refined by using seasonal factor shadow prices. But when the number of farm activities and resources is large, or the new technologies are likely to change the existing pattern of resource use, appropriate shadow pricing is difficult.

In the Cropping Systems Program it is recognized that farms are systems, because several activities are related to each other by the common use of the farm's labor, land and capital, by risk distribution, and by the joint distribution of the farmer's management capacity. Indeed, any farm is part of a hierarchy of systems. It belongs to the larger system of the rural area, and itself consists of various activities which are subsystems (Ruthenberg 1976). Farms are also goal-oriented systems. Farmers consciously attempt to achieve a multiplicity of goals within constraints imposed by resources, environment, and other factors. Decisions made at the farm level, and reflected in subsequent practices and amounts of production and consumption, can in the aggregate have important effects on higher level rural and national systems. Conversely, changes in the higher level systems can have important effects on individual farms. Similar relationships obtain between the farm and its own subsystems. In general, all these systems exist in a state of dynamic interaction with one another.

Through the development of new agricultural technologies, we seek to achieve changes in the cropping and livestock subsystems, but the consequences of such changes are not confined to or completely determined within these particular components of the whole. The acceptability of the new technologies depends on the perceptions of the farmer regarding the degree to which they will improve overall system performance and help him achieve his goals. These goals are conditioned by the sociocultural environment in which the farmer operates, and are significantly different among farmers at different points on the subsistence to commercial continuum.

Acceptance of a new technology will change the previous patterns of resource flows within the farm. It also can change the farmer's purchased inputs and sold outputs, and thus modify his relationship with the wider rural system. For example, a farmer's decision to plant two early maturing rice crops instead of one late maturing crop will change the land, labor and power use patterns, his demand for hired labor and material inputs, and the supply of his own labor to the rural markets. It also can change the amount and quality of animal fodder, level of soil fertility, etc. If a substantial number of farmers make such a change, there will be discernible and significant changes in the related rural systems, with alterations in labor wages, rice prices, etc.

As already mentioned in the preface, our study concentrates on the economic dimensions of technology evaluation at the farm-household and district levels. It reports the results and experiences of assessing new technologies developed by researchers at two locations in the Philippines, and discusses some conclusions drawn from these exercises. Thus Chapter 2 describes the physical and socioeconomic conditions and farming practices at the two locations, and explains how the farm-household systems were specified in models that enabled the use of the well-known technique of linear programming for technology evaluation in a whole farm context. Chapter 3 examines the farm household level assessments of new technologies made by using these models, and Chapter 4 analyzes the actual responses to the technologies of farmers at the 'district' levels, of the locations as a whole. Chapter 5 looks at some general implications for technology assessment accruing from the study.

CHAPTER 2

Background to the study

The IRRI Cropping Systems Program, in collaboration with the Philippine Bureau of Plant Industry (BPI), had two multidisciplinary research teams operating at two research locations or 'sites' in Iloilo and Pangasinan Provinces, from 1975 to 1980 (Fig. 2.1).

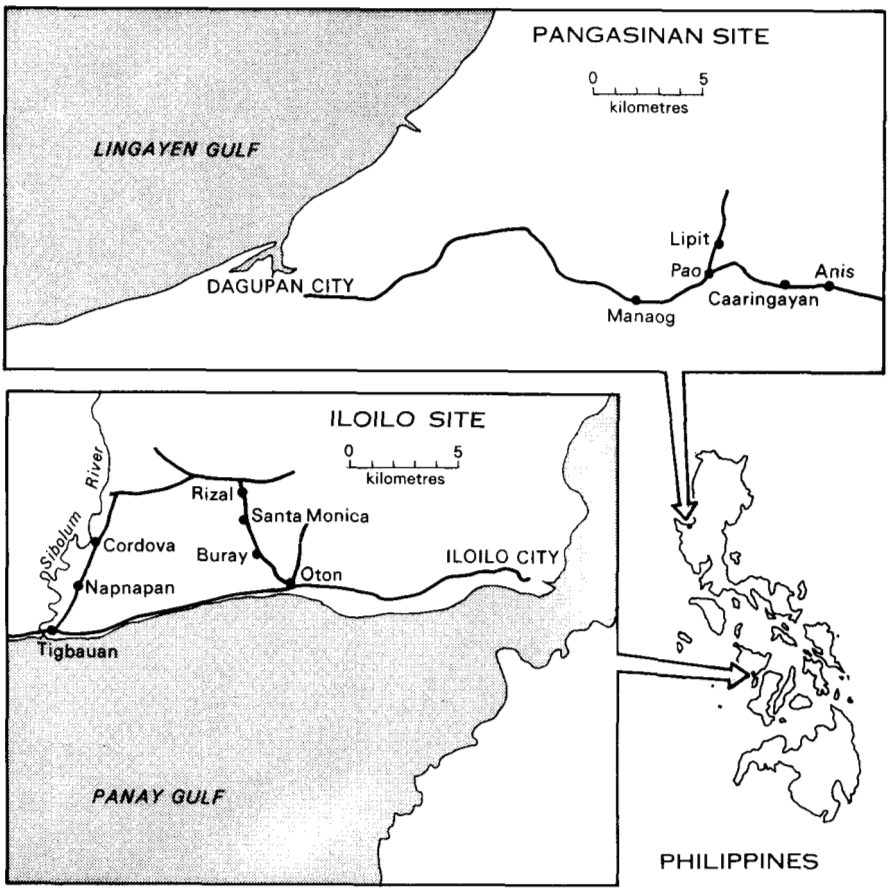
The main research objective was the development of methodology for location-specific, on-farm research in cropping systems. This objective was conceived as being intimately linked to the experience secured in attempting to generate appropriate technologies for the small rice farmers concerned. The researchers had to develop technologies which were adapted to the particular bio-physical and socioeconomic environment prevailing at each site. It was hoped that these technologies could then be extended to wider areas with similar environments.

The research activities at the sites involved monitoring and describing the existing environment and farming systems, as well as designing new technologies and testing and evaluating their impact.

The existing farmers' systems were monitored through a group of farmers ('economic cooperators') who kept daily records of all farming and household activities. The testing of new technologies was undertaken by incorporating these in cropping patterns in the fields of another group of farmers ('agronomic cooperators'). The patterns being studied were implemented on large plots (1,000 m^2), and were replicated in different farmers' fields. Monitoring these experiments yielded not only the usual data on agronomic performance, but also gave valuable clues on the farmers' ability to manage and implement the new technologies.

The performance of new technologies on farmers' fields was compared to that of farmers' existing technologies. The research process was therefore interactive with each farmer as a participant, providing feedback to the scientists for refining, modifying, or discarding the originally designed new technologies. This cropping systems research methodology is discussed in detail by Zandstra et al (1981).

The first section of this chapter describes the physical characteristics of the two sites. The second section discusses the nature of the farming systems, and the socioeconomic environment when the research process was initiated in 1975. Finally, the third section outlines the development of



2.1. Location maps of the Iloilo and Pangasinan (Philippines) Cropping Systems sites.

qualitative and quantitative farm-household models which enabled us to study and assess the potential impact of the new technologies.

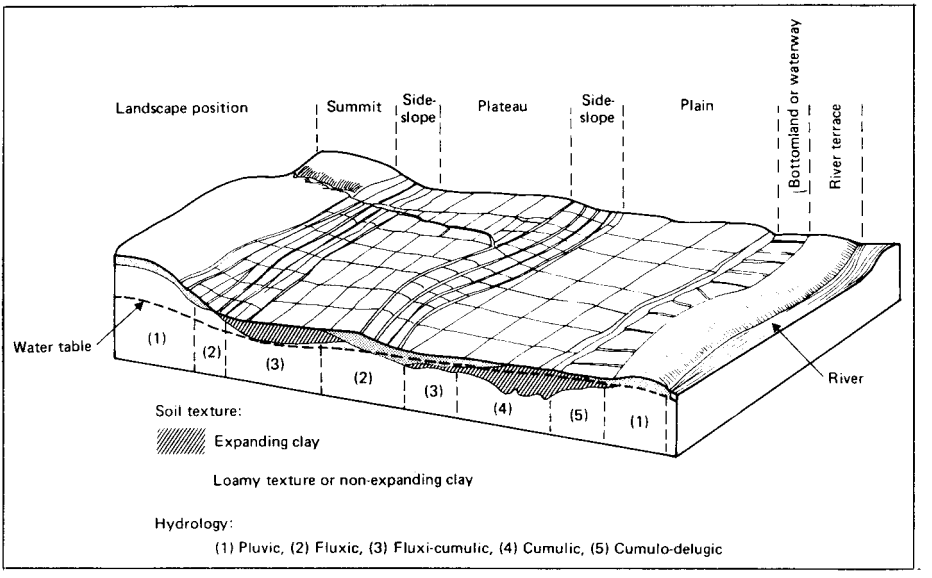
PHYSICAL CHARACTERISTICS OF THE TWO SITES

1

Oton and Tigbauan, Iloilo

This site is located in the municipalities of Oton and Tigbauan, in the Iloilo Province of Panay Island, about 400 km south of Manila. It encompasses the six villages or barangays of Cordova Norte, Cordova Sur, Napnapan Norte, Napnapan Sur, Rizal, Santa Monica, and Buray (Fig. 2.1).

The land system is derived by erosion of an old terrace. The result is a landscape sequence of beach ridges to marine plains, to dissected low terraces, to colluvial intermediate terraces, to high relic terraces, and to foothills (Fig. 2.2).



2.2. Schematic presentation of geomorphic and pedologic conditionson the Iloilo (Philippines) Cropping Systems site (Source: Raymundo 1978).

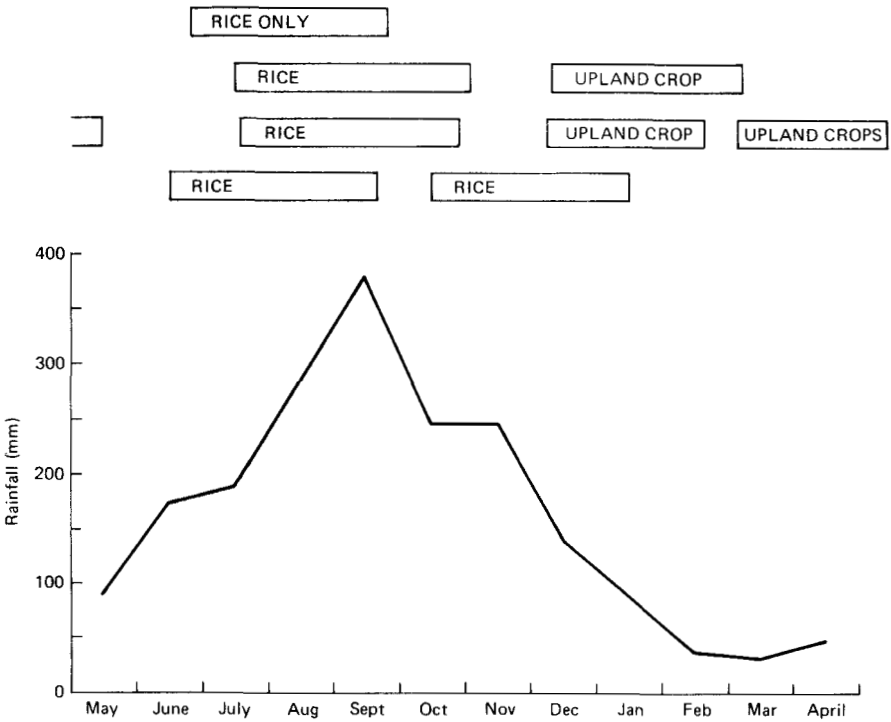
Soil surface materials are generally moderate to slightly acid clay or silty clay material. According to a recent classification the taxonomically predominant soils are Pelluderts, Eutropepts, and Tropofluvents (Moorman et al 1976).

The annual rainfall pattern is unimodal. On the average, it involves 2-4 consecutive dry months with less than 100 mm of rainfall, and 4-5 consecutive wet months with 200 mm of rainfall. The rainfall begins towards the last week of April. It usually peaks in August, and declines rapidly after October. There is little or no rain from December to March (Fig. 2.3).

The Iloilo site has numerous serviceable roads and good transport facilities. Oton and Tigbauan are small towns with markets. The capital of Iloilo Province, Iloilo City, is 11 km from Oton and is the largest and most important city on Panay Island.

2
Manaoag, Pangasinan

This site is located in the municipality of Manaoag in Pangasinan Province, approximately 200 km NNE of Manila on Luzon Island (Fig. 2.1).



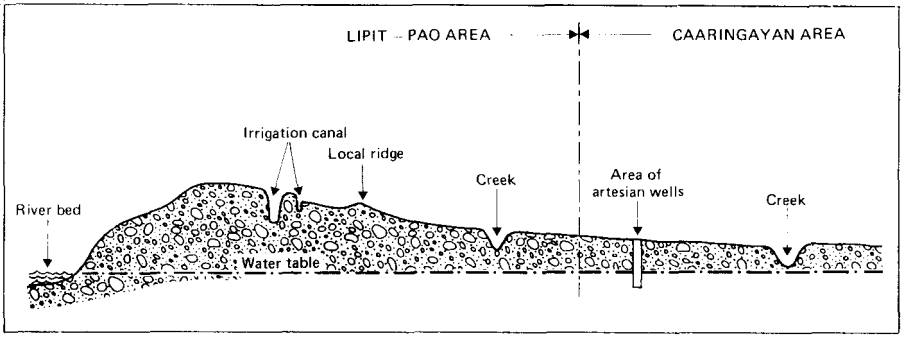
2.3. 26-year monthly rainfall average and farmers' cropping patterns in the mid seventies, Iloilo, Philippines

The area has many main and feeder roads, and contains the important urban centers of Urdaneta and Dagupan.

The research area is divided into two significantly different rice production complexes. The first is a level plateau with a deep water table. It covers the three contiguous villages of Pao, Lipit Sur, and Lipit Norte. The second complex is a level plain with a shallow water table, and covers the two contiguous villages of Caaringayan and Anis. Figure 2.4 presents a schematic cross section of the areas of Lipit Sur and Caaringayan.

As shown in Figure 2.4, the land system comprises a flat plain on the river terrace subsystem, and levees of an alluvial subsystem. The water table in the Caaringayan-Anis area is shallow enough to permit free-flowing wells along the lower portions of the landscape, except during the drier months.

Taxonomically, most site soils fall within the Eutropept Great Group. Soil



2.4. Schematic cross section of Cropping Systems project areas at Caaringayan and Lipit Sur, Manaoag, Pangasinan, Philippines (after Moorman et al 1976).

pH ranges between 6.7 and 7.9 with a mean of 7.4. The modal surface soil texture is clay loam.

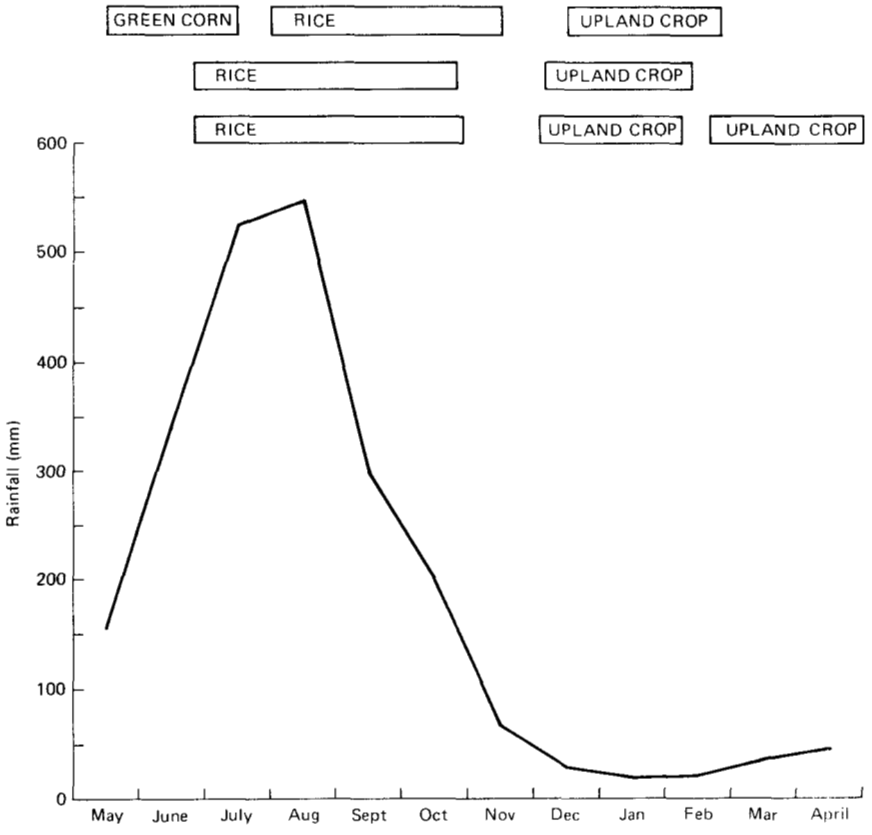
The annual rainfall pattern is unimodal (Fig. 2.5). On the average there are 6 consecutive months with less than 100 mm of rain, and 4 consecutive wet months with more than 200 mm of rain. Rainfall usually exceeds 500 mm in at least one of the wet months. The rains begin in April, peak in July-August, and end about October. The months of November to March have little or no rain.

FARMING SYSTEMS AND THE SOCIOECONOMIC ENVIRONMENT

Initial information on farming systems and socioeconomic conditions at the two sites came from secondary sources. A baseline survey of 200 farmers at each site was then conducted in 1975. More detailed data on farm practices came subsequently from the daily records of economic cooperators. The data mentioned in this section focuses largely on the situation in the mid-seventies, prior to the introduction of new technologies under study.

Tables 2.1 and 2.2 detail some characteristics of farm households at the two sites in 1975, but the situation portrayed broadly persists today. The farms are small, semisubsistence units, with wetland rice cultivation as the main agricultural activity.

In Iloilo, owners or part-owners are dominant, with the balance being share-tenants. In Pangasinan share-tenants are dominant, with significant proportions of both owners and amortizing owners (Table 2.2). The tenurial arrangements between landlords and share-tenants vary greatly. The most



2.5. 26-year monthly rainfall average and farmers' cropping patterns in the mid seventies. Pangasinan. Philippines.

common arrangement, however, consists of the farmer paying a fixed harvest share (usually 1/6th in rice cultivation) to the landlord, who provides no material inputs.

Lowland paddies cover most of the farmland, but many farmers at both sites also have small, upland dry cultivation areas. The relative proportion of the wetland and dryland areas within the farms varies, and in some villages at the Pangasinan site the latter are quite substantial. However, the farming activities at both sites essentially center on lowland rice cultivation.

Livestock raising is common, and consists mainly in raising a pig and some poultry, as well as a work animal which is usually a water buffalo (carabao).

When research activities commenced in 1975, *little or no irrigation* was

Table 2.1. Characteristics of farm households, Iloilo and Pangasinan, Philippines,[a] 1975.

Characteristics	Iloilo	Pangasinan
The farmer		
Age (yr)	51.6	48.7
Educational attainment (yr)	5.1	4.8
Farm experience (yr)	22.0	23.2
Size of household (no. of persons)	5.5	5.5
The farm		
Parcels per farm (no.)	2.1	3.0
Average area per parcel (ha)	1.5	0.6
Average area per farm (ha)	3.2	1.7
Cropping patterns		
Cropping intensity[b] (%)	118	163
Dominant patterns	Rice – fallow (81%)	Rice – mungbean (54%)

[a]The 1975 and 1974-75 figures in Table 2.1, 2.2, and 2.3 come originally from baseline surveys of 205 farmers in the selected villages of Iloilo, and of 200 farmers in Pangasinan. Figures for subsequent years (including those in Table 2.4) come from record keeping studies of 45 farmers (economic cooperators) at Iloilo and 36 at Pangasinan record keeping farmers were selected randomly from the baseline lists. [b]Cropping intensity = (total area of all crops) ÷ (total area available for cropping) × 100.

Sources: See note 'a'. Also Nicolas (1977) for Pangasinan; Palada et al (1976) for Iloilo.

available at either site. All crop cultivation depended on rainfall. Over the next few years this changed rapidly, and irrigation facilities of varying degrees of reliability and adequacy were made available with government help at both sites. By 1978-79, 25% of the lowland area at Pangasinan, and 34% of the area at Iloilo, had some degree of irrigation.

Cropping patterns

The major cropping patterns practised by the farmers are strongly influ-

Table 2.2 Farmer tenure status at Iloilo and Pangasinan, Philippines, 1975

Tenure	Farmers (%)	
	Iloilo	Pangasinan
Share-tenants	44	53
Owner cultivator	37	8
Part-owner	19	25
Others[a]	–	14

[a]Leased, amortizing owner.
Sources: See note 'a' of Table 2.1. Also Nicolas (1977) for Pangasinan; IRRI (1981) for Iloilo.

Flooding prior to cultivation. Water is now building up in these rainfed parcels, and in some parcels cultivation has started. Note the terracing.

enced by rainfall. Figures 2.3 and 2.5 show these patterns superimposed on the average rainfall distributions at the sites. Table 2.3 denotes the relative importance of different cropping patterns on the Iloilo site over the years 1974-79. Some of the changes shown are due to annual variations in rainfall, and others to the introduction of new irrigation facilities.

Table 2.3. Percentage of cropland in various cropping patterns, Iloilo, Philippines, 1974-79.

Cropping pattern	Cropland (%)				
	1974-75	1975-76	1976-77	1977-78	1978-79
2 or more rice	5	20	38	49	45
1 rice + 1 or more upland crop	11	28	30	17	31
2 or more upland crops	2	5	12	6	8
1 rice + fallow	82	47	20	27	14
1 upland crop + fallow	-	-	-	1	2

Sources: See note 'a' Table 2.1 Also Genesila et al (1979).

In 1975 a cropping intensity of 148 at the Iloilo site compared with 163 at Pangasinan (Table 2.1). At Iloilo most farmers left their lowland paddies fallow, after growing a single transplanted rice crop during the rainy season. At Pangasinan a low management mung crop usually followed the transplanted rice, which was occasionally preceded by maize. Where some supplementary irrigation was available at Pangasinan (from dug wells, pumps, etc.) and soils were suitable, tomato, squash, melon, and vegetables were grown in limited areas mainly for the early market. Farmers sometimes shifted from rice to sugarcane and back in response to changing prices.

On the upland areas of both sites, maize was the most widely grown crop, and still remains so. This is harvested both green and dry, and is followed by other crops such as vegetables, bananas, sweet potatoes, cassava, and peanuts (grown mainly on small plots for home consumption). At Pangasinan, some farmers also grow cotton with credit and marketing facilities extended by the Philippine Cotton Corporation.

Farming practices

Farmers at the two sites have a history of adopting new farming practices, crops, and varieties. Significant changes in rice cultivation techniques in Iloilo over the last century have been documented by Price (1977). During the post-World War II period, considerable advisory efforts were directed at

farmers by the Bureau of Agricultural Extension. New improved rice and other crop varieties, together with modem farming methods including those of crop establishment and maintenance, were brought to the farmers' attention. However imperfect the extension system may have been, major alterations in farming practices took place which were attributable to its influence.

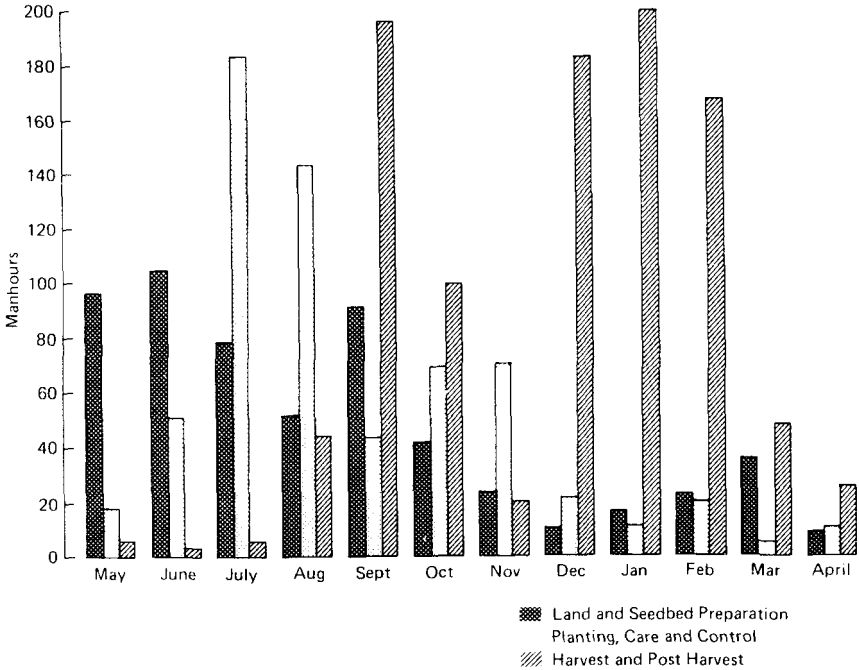
The most important changes in rice farming related to varieties grown and methods of crop establishment. While substantial areas remained under local varieties, improved varieties were also quite common. BE3, a photoperiod-sensitive material from Burma, was introduced in the late 1950s. University of the Philippines at Los Baños (UPLB) varieties and early IRRI varieties appeared in the 1960s. Direct seeding of rice, which had been the common practice at Iloilo until the early 1950s, was subsequently replaced almost completely by transplanting as the method of crop establishment in lowland paddies.

Land preparation for rice is undertaken at the onset of the rainy season. It consists of a number of plowings and harrowings with draft animal power. Small farmers usually do not hire labor or power, although this is common practice for larger farmers. When hiring is done, a man-animal team is normally taken. Rice seedbeds are also established at the beginning of the

Table 2.4. Average labor utilization by source, Iloilo, Philippines, 1975-76 to 1978.

Source	Labor utilization						
	1975-76[a]	1976-77		1977-78		1978[b]	
	%	Average monthly man-h/farm	%	Average monthly man-h/farm	%	Average monthly man-h/farm	%
Operator	30	43	24	27	19	34	27
Family member	18	27	15	19	13	18	14
Hired	50	106	58	92	65	70	54
Exchange	2	5	3	5	3	7	5
Total	100	181	100	143	100	129	100
Total man-h/year[c]		97,391		76,733		52,246	
Average man-h/month[c]		8,116		6,394		4,354	
Average man-h/ha		85		68		62	

[a]Figures on total labor utilized not available in this period. [b]Average for 9 months. [c]For all surveyed farms.
Sources: See note 'a' of Table 2.1.

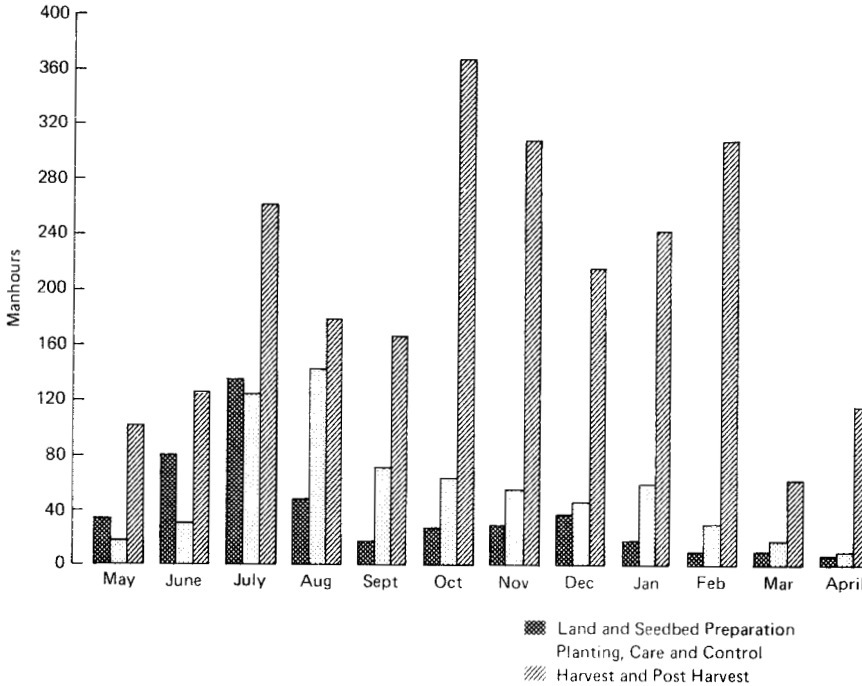


2.6. Average monthly labor use by major operations (all crops), existing farming system, 45 economic cooperators at the Iloilo. Philippines Cropping Systems site. 1976-77 crop year

rainy season. Rains in Pangasinan commence before those in Iloilo, and most cropping activities are accordingly 2 to 3 weeks earlier. The peak transplanting from seedbed to field is during July and August on both sites, but its effect in heightening labor use in the mid seventies was particularly marked at Iloilo (Figs. 2.6 and 2.7). The distribution between operators, family members, and outsiders of average labor use by economic cooperators at Iloilo from 1975-76 to 1978 is given in Table 2.4.

Transplanting is a highly labor intensive operation, and takes around 20 man-days/ha. While land preparation is done exclusively by males, both sexes participate in transplanting. Family labor alone is almost never sufficient for this work, because it has to be done within a comparatively short time when the land is ready and the moisture level suitable. Even small farmers are forced to hire labor in this situation. Since 1975 transplanting at Iloilo has been extensively replaced by the less labor-intensive wet seeding, as described subsequently.

Whilst exchange labor use was at one time widespread in transplanting, it was almost insignificant by 1975 (Table 2.4). With the increasing monetiza-



2.7. Average monthly labor use by major operations (all crops), existing farming system, 36 economic cooperators at the Pangasinan, Philippines. Cropping Systems site, 1976-77 crop year.

tion of village economies, it had given way to hiring labor for a cash wage supplemented with meals.

Once the rice crop had been established in the mid seventies, few resources were spent on it. Occasionally, some hand weeding was done. Fertilizer use was widespread, particularly on the modern varieties, but the amounts applied were very low (Nicolas 1977, Roxas et al 1978). In 1975 the Masagana 99 program, which had been initiated in 1973 to provide credit facilities for rice cultivation, was facilitating higher levels of cash inputs. Its full effects had not yet been felt, however.

With transplanting in July and August, rice harvesting starts in October, but is mostly undertaken from November to January, when the rainy season ends. Like transplanting, harvesting also requires hired labor to supplement family workers, even on smaller farms. Harvesting is done manually, and this remains true today. At Iloilo in 1975, threshing was also done manually, with foot threshing being the commonly used method. The harvesters also did the threshing, and were paid 1/6th of the crop. At Pangasinan there was substantial mechanical threshing and the 'Tilyadora', a large threshing

machine operated by several persons, had been commonly used for three to four decades. The harvesters paid for the mechanical threshing from their share of the crop. The combined payment for harvesting and threshing at Iloilo and Pangasinan was generally 1/6th of the crop, but it appeared from farm interviews that this arrangement was new. It had come down from a 1/5th share, which had been paid when rice yields were lower.

Rice yields at both locations in the mid-seventies were still low. They averaged 1.5 to 2.0 metric tons per hectare, with Iloilo having somewhat higher yields than Pangasinan. The mungbeans grown after rice in Pangasinan were either relayed into the rice crop, or established with low levels of tillage. No fertilizer and little pesticide were used with mung, and yields were very low indeed, averaging 200 kg/ha. Mungbean was both a cash and a food crop, and was sometimes grown at Iloilo.

In the upland areas, land preparation starts earlier than in the lowland paddies. The maize crop grown there is important because it gives both food and cash during the lean months before wetland rice is harvested. While rice is the preferred main staple, and almost all farmers aim to grow the quantity they need for household consumption, maize is often eaten as a substitute or as a supplement. Again in the mid-seventies, the levels of inputs and of management were not high, and average yields were low.

Both maize harvesting and dry maize shelling, which is a very labor-intensive activity, are done for a crop share. In Pangasinan the maize crop is often sold to a contract buyer, who pays for the unharvested crop and bears harvesting and transport expenses. A similar arrangement exists for sugarcane.

Off-farm and non-farm activities

An active labor market exists in both locations, and in 1975 hiring labor for transplanting, harvesting, and threshing was common. Nearly all small farmers worked as hired laborers during the peak labor periods to supplement their cash and rice stocks. Yet even small farmers hired labor during these periods for their own transplanting and harvesting, because of the need for timeliness in these operations.

Some members of farm households engage in occupations such as tricycle driving, or in small business ventures such as operating a local store. Some smaller farmers also have the additional activities of tuba or coconut sap gathering, and (particularly in some Pangasinan barrios) of handicrafts such as basket weaving.

Cash income and credit

Even within the same site, farmers exhibit substantial differences in the nature and level of their cash flows over the year. In 1975-76, the total annual cash incomes per farmer at Iloilo ranged from US$97 to 2,051

(assuming here and elsewhere that US$l.00. = ₱7.5). All farmers also have a large subsistence food component in their agricultural production.

Typically at the two sites, crop sales constitute the major source of cash incomes. In 1975-76, Iloilo farmers derived an average 41% of their total cash incomes from crop sales, mainly of rice. In Pangasinan, little rice was sold, and sugarcane, cotton, maize, and vegetables were the important cash crops.

In addition to crop sales, many operators augment their cash incomes by marketing livestock. As already mentioned, they often manage to raise a pig, fed mainly with rice bran and kitchen refuse. In the mid-seventies, the sale of a pig brought a substantial income of around $100.

Wet seeded parcels at Iloilo. The near area is quite level, and germination is proceeding well.

While most farmers depend on farming activities for their cash incomes, contributions from family members employed outside the village are a major, and sometimes even dominant, source of revenue. When a member works overseas, contributions are often relatively large, and enable the family to purchase land, build houses, and generally become rich farmers.

The major items for which cash expenses are incurred are a) hiring of labor and power and purchase of farm inputs, b) food (fish, cooking oil, etc.), fuel and clothes, c) children's education, d) celebrations (especially

the village fiesta), and e) medical services. Children's educational expenses are considered by farmers as an essential item of expenditure. This reflects the high value placed on education in rural Philippine communities.

Where dependence on crop sales for cash is high, the farmers go through a lean period with acute cash shortages. This is the case with the majority of smaller farmers. The lean period begins with the land preparation and crop establishment phases of rice cultivation, when considerable cash expenditure is needed. Because of the cash shortage much of the first crop, such as maize in Pangasinan, has to be sold on harvesting at the beginning of the dry season for comparatively low farm gate prices. The National Grain Authority (NGA) has purchasing depots for procuring rice close to the two sites, but at Iloilo the major outlet for farmers' rice remains the local buyers. This is because there are problems of quality control and assessment at the NGA depot. In addition, the local buyers offer transportation facilities and provide credit during lean months.

Some farmers carry stocks of grain which they sell at the beginning of the rainy season when the main farming expenses are incurred. However, the smaller farmers are commonly forced to borrow money at this time of the year, often right up to the time their major crop is harvested and sold.

Both institutional and non-institutional sources of credit are found in both study areas. From 1973-76, the Masagana 99 program gave substantial institutional credit through the local rural banks to farmers organized in groups or 'cells'. Informal credit comes from local traders, middlemen, landlords, friends and relatives, as well as from professional money-lenders.

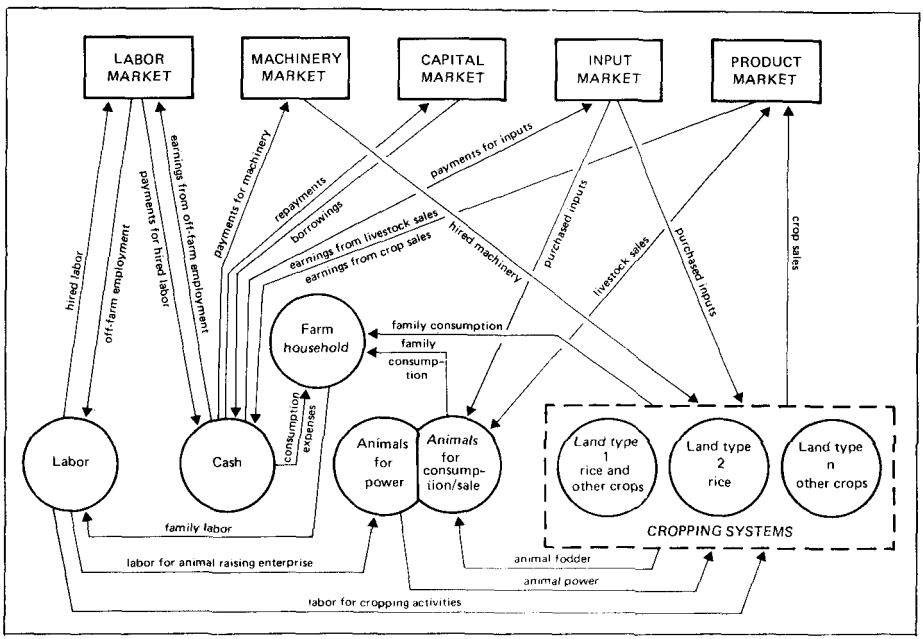
The interest rates and conditions for credit differ widely across the various sources. The Masagana 99 program extends credit at 12%/annum, and is conditional on the farmers concerned accepting a package of new technologies. These include high yielding varieties, fertilizers, other cash inputs and related farming practices, whose implementation is supervised by Bureau of Agricultural Extension technicians. In the informal lending sector, the terms and conditions depend on the type and size of loan, as well as on creditor-debtor relationships. Borrowing from friends and relatives is usually interest-free, while interest rates of 100%/annum are common for credit from professional money-lenders. Sometimes landlords extend interest-free credit for material inputs, and occasionally for other farm expenses. In the late seventies farmers could obtain up to $40 of credit from the Rural Bank, with their buffalo as collateral.

The smaller farmers found it difficult to obtain institutional credit even when the Masagana 99 program operated actively in their areas. Later these difficulties increased when some farmers defaulted on their loans. This deprived other farmers belonging to the same cell from access to Masagana credit. Thus by 1980, Masagana 99 was no longer a significant source of funds at the two study sites.

THE DEVELOPMENT OF THE MODEL

To model the farm-household system, we need to: a) specify the goals of the farm household, and b) quantify the major resource flows and specify their relationships and interactions.

The broad outline of the small-scale farm-household systems in most South and Southeast Asian countries is captured in the schematic diagram of Figure 2.8.



2.8. Resource flows in the farming system.

The relative importance and magnitude of the components of this system vary, depending on location, type of farm, etc. The farm household operates within a given bio-physical and socioeconomic environment, and attempts to achieve its goals to the maximum extent possible. Its resource allocation decisions, including those on what crops to grow, are nonetheless taken within the fixed framework shown.

Small farms are complex systems. They operate in an environment of risk and uncertainty, and are oriented towards satisfaction of multiple goals. Any attempt to build a model which simulates these systems must recognize that incorporation of more detail and realism results in a bigger, more complex model. This is often very cumbersome to manipulate. The model

and its data requirements should be kept as simple as possible, while incorporating the important features of the actual system.

Our aim is to study the impact of changes in cropping technologies on farm-household systems. We use the mathematical programming approach termed linear programming (LP) for system modeling. LP has been used widely to model and study farm households in many less developed countries. The technique itself is described in numerous publications (Clayton 1965, Heyer 1972, Thodey and Rapeepun Sektheera 1974, Hardaker 1975, Low 1975, Benito 1976, and Wardhani 1976.) An excellent review of its advantages and limitations, as well its possible extensions in modeling small, semisubsistence type farms, is given by Hardaker (1975).

Specifying the system

In using LP, we specify and quantify in a matrix the relationships between the activities of the farm household and its base of resources. Table 2.5 shows the broad outlines of the matrix used in our study. This matrix is essentially an attempt to quantitatively specify many of the relationships shown in Figure 2.8.

Table 2.5. Outline of the farm-household model

Activity / Resources	Crop production[a] (ha)[b] [357][c]	Crop consumption (t) [4]	Crop sale ($) [7]	Other earnings ($) [1]	Household expenditure ($) [1]	Loans ($) [13]	Family labor transfer (h/wk) [52]	Labor hiring (h/wk) [52]	Carabao labor hire (h/wk) [52]	Cash saving hire ($/wk) [52]	Cash surplus ($/wk) [52]
Land (diff. types, wkly) (ha) [156]	$^{+}P_{mk}$[d]	0[e]	0	0	0	0	0	0	0	0	0
Labor (diff. types, wkly) (h) [104]	$^{+}P_{mk}$	0	0	0	0	0	$^{+}P_{mk}$ $^{-}P_{mk}$	$^{-}P_{mk}$	$^{-}P_{mk}$	0	0
Carabao time, wkly (hrs) [52]	$^{+}P_{mk}$	0	0	0	0	0	0	0	0	0	0
Cash supply, wkly ($) [52]	$^{+}P_{mk}$	$^{+}P_{mk}$	$^{-}P_{mk}$	$^{-}P_{mk}$	$^{+}P_{mk}$	$^{+}P_{mk}$ $^{-}P_{mk}$	0	$^{+}P_{mk}$	$^{+}P_{mk}$	$^{+}P_{mk}$ $^{-}P_{mk}$	$^{+}P_{mk}$
Credit maxima ($) [2]	0	0	0	0	0	$^{+}P_{mk}$	0	0	0	0	0
Household expenditure minima ($) [1]	0	0	0	0	$^{+}P_{mk}$	0	0	0	0	0	0
Other earnings, maxima ($) [1]	0	0	0	$^{+}P_{mk}$	0	0	0	0	0	0	0
Crop balances (t) [7]	$^{-}P_{mk}$	$^{+}P_{mk}$	$^{+}P_{mk}$	0	0	0	0	0	0	0	0
Consumption minima (t) [2]	0	$^{+}P_{mk}$	0	0	0	0	0	0	0	0	0
Carabao availability (h) [1]	0	0	0	0	0	0	0	0	$^{+}P_{mk}$	0	0
Surplus per unit of activity ($)	0	0	0	0	0	0	0	0	0	0	$^{+}c_{k}$

[a] These crop production vectors occupy about half the matrix area and account for most of its density. [b] Items in parentheses () are units in which the relevant vector is measured. [c] Items in brackets [] are numbers of vectors in each category in the model for farmer 1 at Iloilo, including both historical and new technology vectors. [d] $^{+}P_{mk}$ / $^{-}P_{mk}$ indicates that the input-output coefficients P_{mk} in this particular submatrix are positive or negative. Where both $^{+}P_{mk}$ and $^{-}P_{mk}$ are together both positive/negative input-output, coefficients may occur. [e] 0 indicates that all P_{mk} are zero.

The model of Table 2.5 covers a year of operations for the farm-household unit. This year comprises a number of time periods, which enter into the specification of all activities and resources. Weekly time periods are used in the Iloilo models, and fortnightly periods in the Pangasinan models. Experience shows that the simpler nature of computations and manipulations associated with a fortnightly model compensates for its less detailed consideration of time constraints. Indeed, the results of applying weekly and fortnightly models to the same problem are substantially similar.

The farms at the two sites are predominantly engaged in crop production. This is reflected in the model. Each type of crop production activity (defined with 1 ha as the unit) has differing requirements for the various restricted farm resources. These resources include land, labor, draft animal time, and cash.

As indicated in the discussion on farming systems, land is not homogeneous within farms at the two sites, and this is recognized in the model. Land parcels differ not only in their classification as upland or lowland, but also in their water regimes (rainfed, partially irrigated, or fully irrigated), tenure status (fully owned, share-tenanted, etc.,), and sometimes in their position in the landscape (plateau, plain, sideslope, bottomland). The physical differences between parcels are reflected in the expected performances of crop production activities. The tenure status of parcels determines the proportion of the product that will accrue to the farmer, and will therefore influence his allocative decisions.

Animal production activities are not dealt with in detail in the model because of their relatively minor importance, except as sources of draft power, within the systems investigated. Competition between animal and crop production activities is not of major importance at the two sites. However, the role of activities like pig raising as important sources of cash is taken into account.

Crop production activities use resources, and contribute yield to a crop balance row. This is the net yield that is retained by the farmer after making all appropriate deductions from the gross harvest, such as landlord's, harvester's, and thresher's shares.

Crop consumption activities take quantities of crops out of the crop balance row. The sales activities also take from this row, which contributes crop sale proceeds to the cash supply.

Other earnings contribute to the farm cash supply, while household expenditure takes cash away from it. Loan activities augment the cash supply when the loan is obtained, but reduce the cash supply when the loan is paid back with interest. Labor (and power) hiring activities augment the available labor (and power) supply, but reduce the cash supply.

The model accordingly takes into account the basic interrelationships that exist between all production and consumption activities in the farm house-

hold, through their dependence on a common resource base. It puts into matrix form the direction and nature of the resource flows shown in Figure 2.8.

Quantification of these relationships needs data on time specific resource requirements and outputs of all activities. In the model we distinguish between two types of crop production activities. These are the historical technologies (HT) and the new technologies (NT). Historical technologies are crop production practices which farmers followed prior to adopting the technologies developed and tested at the sites.

The basic data for the historical technologies come from daily farm records maintained over 3 years by those economic cooperators selected as case study farmers. However, a number of problems arose in specifying the full range of planting possibilities. The data from only 3 years of farming operations did not always cover the full range of planting dates. The farmers' technologies had been changing over the 3 years in terms of varieties used, input levels, etc., and many technologies were not replicated over time. Given the limited number of observations on each technology, the daily record keeping data were inadequate for providing the information to specify activity vectors to cover the entire feasible range. Therefore, we specified the full range of activity vectors in verbal consultation with both the site researchers and the farmer concerned.

In this procedure, crop production methods that differ in any important characteristic such as variety, level and timing of input use, planting date, etc. are specified as separate activity vectors for modeling purposes, as shown by the example in Table 2.6. The activity vectors for each type of technology are defined to cover the full range of planting dates, with corresponding expected yields.

For the specification process described we also found it useful to use 'activity statements' as a step in gathering the required data. These involved the farmer in stating to an experienced enumerator his expected inputs and outputs for a particular crop activity on a particular parcel. Since the farmers had usually used historical technologies for a lengthy time period, it was often possible to obtain satisfactory data on their average performances quite easily and rapidly.

Specifying the crop production vectors for new technologies also introduced problems. Generally, the number of observations available for experimental technologies was very limited. Certainly, it was not possible to obtain observations on a particular technology for the full range of planting dates that might be anticipated in a single year. In attempting to specify the NT vectors for particular parcels on case study farms, it was also necessary to consider differences in the micro-environment.

We visited the case study farmers and obtained their assistance in specifying the new technologies appropriate for their various land parcels, In

securing the input requirements and yields of these new technologies, the historical performance of crops on their parcels and the performance of the same technologies on similar land were taken into account. The advice of researchers working on the particular new technologies was also sought, and their recommendations and expectations were discussed with the farmers. Farmers' yield expectations from particular new technologies ranged from very pessimistic to highly optimistic. We arrived at judgmentally derived most favored estimates for use in the modeling exercises, which subjectively took into account the farmers' own historical performances. Because most available linear programming computer packages allow sensitivity analysis to be conducted quite readily with varying yields and input levels, the particular estimates used have not been unduly restrictive.

Transplanted BE 3 at Iloilo. The 3-week old seedlings are planted quite evenly, but not in rows.

When farmers adopted new technologies they often modified the recommendations of the researchers, in particular reducing the levels of cash inputs. To allow the model sufficient flexibility to choose such modified new technologies if they were more appropriate for a farmer's resource situation, additional new technology vectors with lower levels of inputs were also specified. Table 2.6 presents an example of a specified new technology vector for farmer number 5 at Pangasinan.

Table 2.6. Resource requirements of a crop production activity vector (new technology): farmer no. 5, Pangasinan, Philippines.

Crop: TPR, IR42, 1st crop, with 4 bags urea and machine threshing
Parcel: No. 4, lowland rainfed, fully owned (0.70 ha).

Week no.[a]	Operation	Labor (man-h)	Animal (h)	Cash ($)
06	Plowing – animal	65	65	
06	Seedbed preparation	15	15	
06	Sowing	2		17.73 – Seeds
07	Plowing – tractor	3	–	
07	Harrowing tractor	3	–	
07	Pulling seedlings	46		
07	Transplanting	105		
09	Fertilizing	7		22.27 – 2 bags urea
12	Fertilizing	7		22.27 – 2 bags urea
16	Harvesting	300		
16	Bundling	90		
16	Hauling	20		
16	Threshing – machine	15		
16	Measuring	20		
		698	80	
Yield	500 kg			

[a]See Appendix Table 3.1 for details.

The whole array of crop production activities entered in the model for this same farmer is shown in Table 2.7. It should be recognized here that the mode of entry is quite flexible, and that with most linear programming packages, assumptions made regarding input requirements and expected performances of technologies can be changed easily.

The major resource constraints in the various models include land of different types, family labor, animal draft power, and the maximum credit available. Physical differences as well as differences in tenurial status determine the returns the farmer can obtain from different parcels within the farm. Hence, land constraints must be specified according to such variation. Changes in family labor supply over the year must also be taken into account, and different types of credit recognized.

Goals

Once the system is specified qualitatively and quantitatively in an LP framework, it is necessary to stipulate the goals it attempts to achieve. It is

Table 2.7. Crop production activity vectors included in the model: farmer No. 5, Pangasinan, Philippines.

Parcel	Historical technology	New technology[a]
Parcel 1, upland, rainfed, fully owned (0.142 ha)	Maize, 1st crop	DSR, IR36, 1st crop, zero fertilizer
	Cowpea, 2d crop	DSR, IR36, 1st crop, with fertilizer
		Cotton, 2d crop
Parcel 2, upland, rainfed, share-tenanted (0.213 ha)	Maize, 1st crop	DSR, IR36, 1st crop, zero fertilizer
	Cotton, 2d crop	DSR, IR36, 1st crop, with fertilizer
	Maize, 3d crop	DSR, IR36, 1st crop, with weedicide
		DSR, IR36, 1st crop, with hand weeding only
		DSR, IR36, 1st crop, with fertilizer and herbicide
		DSR, IR36, 1st crop, without herbicide/hand weeding
Parcel 3, lowland, partly irrigated, share-tenanted (0.517 ha)	TPR, IR1561, 1st crop,	
	machine threshing[b]	TPR, IR36, 1st crop, machine threshing, 1 bag urea
	hand threshing	TPR, IR36, 1st crop, hand threshing, 1 bag urea
	TPR, IR28, 1st crop,	
	machine threshing	TPR, IR36, 1st crop, machine-threshing 2 bags urea
	hand threshing	TPR, IR36, 1st crop, hand threshing, 2 bags urea
	Eggplant and ampalaya, 2d crop	TPR, IR36, 1st crop, machine-threshing, zero fertilizer
	Mung, 2d crop, minimum tillage	
	plow – animal	TPR, IR36, 1st crop, hand threshing, zero fertilizer
	plow – tractor	TPR, IR36, 1st crop, machine-threshing, 3 bags urea
	Cotton, 2d crop	TPR, IR36, 1st crop, hand threshing, 3 bags urea
	Cowpea, 2d crop	DSR, IR36, 1st crop, with weedicide
		DSR, IR36, 1st crop, with hand weeding
Parcel 4, lowland, rainfed, fully owned (0.700 ha)	TPR, Wag-wag-aga, 1st crop,	
	machine threshing	DSR, IR36, 1st crop, without weedicide
	hand threshing	DSR, IR36, 1st crop, with weedicide
	Mung, 2d crop, minimum tillage	
	plow - animal	TPR, IR42, 1st crop, machine-threshing, zero fertilizer
	plow - tractor	TPR, IR42, 1st crop, hand threshing, zero fertilizer
	Cowpea, 2d crop	TPR, IR42, 1st crop machine-threshing, 2 bags urea
		TPR, IR42, 1st crop, hand threshing, 2 bags urea
		TPR, IR42, 1st crop, machine-threshing, 2 bags urea
		TPR, IR42, 1st crop, hand threshing, 4 bags urea
		Mung, 2d crop
		Mung, 3d crop

[a]DSR = dry-seeded rice, TPR = transplanted rice. [b]Hand threshing in this area is by the hampas method, and involves beating out the grains by hand.

recognized widely that small farmers typically have a multiplicity of economic and non-economic goals. LP usually maximizes a certain objective function subject to specified constraints, including those of resource availabilities, and the optimal solution selects the combination and levels of activities which maximizes the specified objective function.

In this study, we assume that the major allocative decisions pertaining to farming practices can be explained under the postulate that farmers operate with a primary and dominant goal of meeting subsistence requirements, particularly of rice, and a secondary goal of maximizing the net cash earnings or cash surplus once their subsistence food requirements are met. Mathematical programming models, including modifications and extensions of the basic linear programming model, are capable of handling more complex multiple goal situations (Thambapillai, 1978; Flinn et al 1979). However, we feel that the two goals outlined are in most cases adequate when we use the models for technology evaluation. Therefore we include meeting subsistence requirements in the constraints set in the LP models, and formulate the objective function as one of maximizing the cash surplus.

Our use of linear programming and our simplified assumptions concerning goals impose certain other limitations. The technique here is basically deterministic, because risk and uncertainty factors are not explicitly incorporated. In reality, both the resource requirements of different technologies and the yields of crops are subject to variability. This is particularly the case in rainfed agriculture, where uncertain rainfall distribution over the year crucially affects all farming activities. Thus, land preparation for a rice crop may involve varying amounts of draft power depending on the incidence and strength of rainfall. A prolonged drought may drastically reduce crop yields. We usually use the average or most likely expected values to specify the crop production vectors. However, small farmers are normally risk averse and their actual farming practices and choices of technologies reflect their risk management strategies. Where technologies differ in the degree of riskiness, the models tend to overestimate the adoption of higher risk actions.

To take into account the risk aversion behavior of farmers we used cutoff dates. These limit the feasible planting dates for various production technologies, and were obtained from interviews with farmers. They reflect the earliest and latest dates which farmers felt were acceptable for use of particular technologies. Before or after these dates, the risk of low yields was considered too high. These dates are based on farmers' long years of experience in the particular environment, including their expectations regarding the nature of rainfall distribution and its effects on crop production.

By constraining the set of feasible planting dates, we were constraining the available choices for the acceptable set of technologies. We may accordingly argue that decisions on the optimal combination of technologies within this set were less affected by risk considerations. Where the technologies being tested were relatively new to the farmer, such cutoff dates were difficult to obtain. In these cases the analysis of crop performance by planting date and technology using rainfall probabilities (Zandstra and Morris 1978) provided some useful guidance.

The range of new technologies

In designing new technologies for farmers at Iloilo and Pangasinan, cropping systems researchers concentrated on developing methods to increase cropping intensity. In particular, the emphasis was on achieving a change from single to double rice cropping under rainfed conditions.

A major constraint to double rice cropping was the transplanting of the first rice crop, which could be done only after a period of sustained rainfall. Land preparation, seedbed establishment and accumulation of sufficient water in the bunded paddies pushed the planting date well into the second, third, or even fourth month of the rainy season. Harvesting of this crop was

therefore possible only near the end of, or after, the rainy season. At best in normal circumstances, an upland crop could be established after the rice harvest, and a second rice crop was quite infeasible.

Direct-seeding techniques, which had been generally replaced by transplanting by the early 1950s, now acquired a new potential. Researchers saw direct seeding as a method that enabled earlier establishment of a first rice crop. This method then took advantage of the short maturity period of the new nonphotoperiod-sensitive, high yielding varieties for establishing a second rice crop before the rains ended. Where this was not possible, the favorable soil moisture conditions following early establishment of the first rice crop enabled a more productive upland crop to be grown after rice.

Two direct seeding methods, dry seeding and wet seeding, were studied at the sites, with most work on wet seeding being concentrated at Iloilo. In dry-seeded rice (DSR), ungerminated seeds are sown on dry soil at the beginning of the rainy season. The seeds germinate after the first rains, and harvesting takes place earlier than with transplanted crops. In wet-seeded rice (WSR), seeds are sown on puddled soil. The establishment date tends to be later than with DSR, but the method is more suitable when rapid water accumulation takes place in the paddies. Some of the soil and rainfall characteristics at Iloilo favor WSR over DSR as methods of crop establishment, but the reverse is the case in Pangasinan (IRRI 1978). Both DSR and WSR significantly reduce the labor requirements for land preparation and crop establishment.

In addition to securing two rice crops through these methods, upland crops can be established in areas where sufficient soil moisture is still available. Most research on upland crops, particularly in the later years of work on the sites, was concentrated on rice-based patterns. Sometimes an upland crop such as maize is feasible before the rice crop, but more commonly upland crops follow rice. The new technologies developed for upland crops involved new methods of establishment (different levels and methods of tillage and seeding), better varieties, the use of fertilizer, and plant protection techniques involving pesticides. Thus, new varieties of mungbean, cowpea, and maize, for example, were tested at the sites, and substantial efforts were spent on testing tillage practices for legumes following rice (see IRRI 1978a, 1979a).

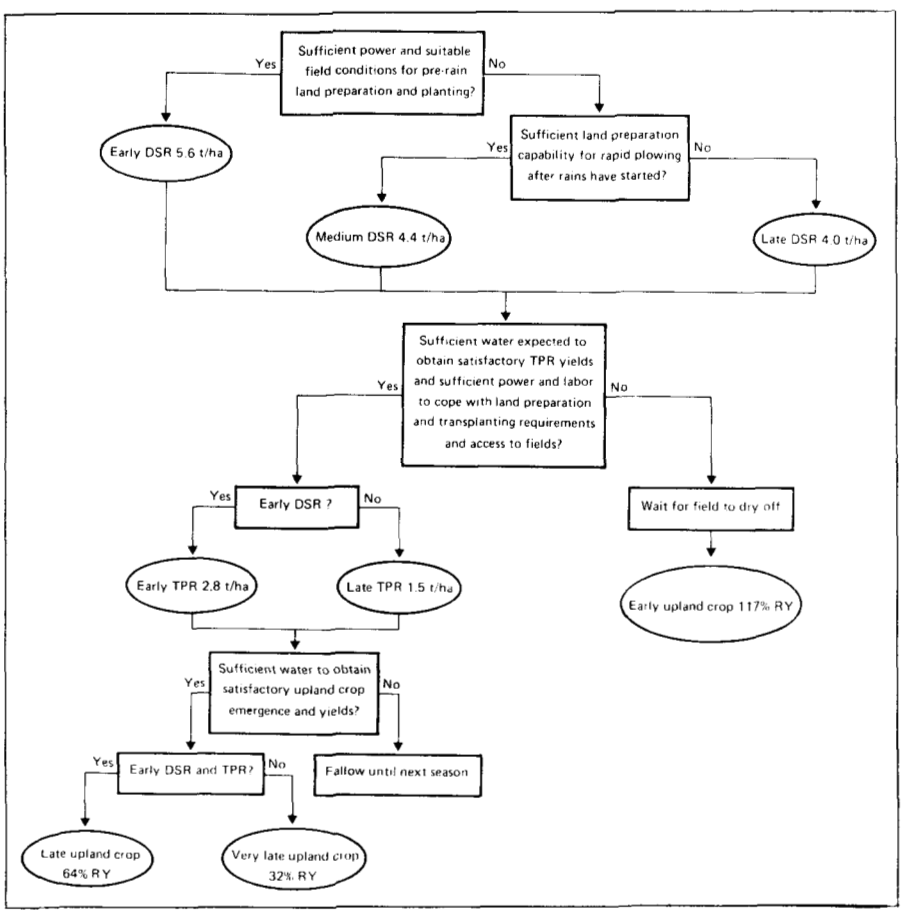
Attempts to fit two rice crops into the rainy season push them into less favorable weather conditions at the beginning and end of the season, and expose them to risks from erratic rainfall.

With dry-seeded rice, some major problems observed were:—

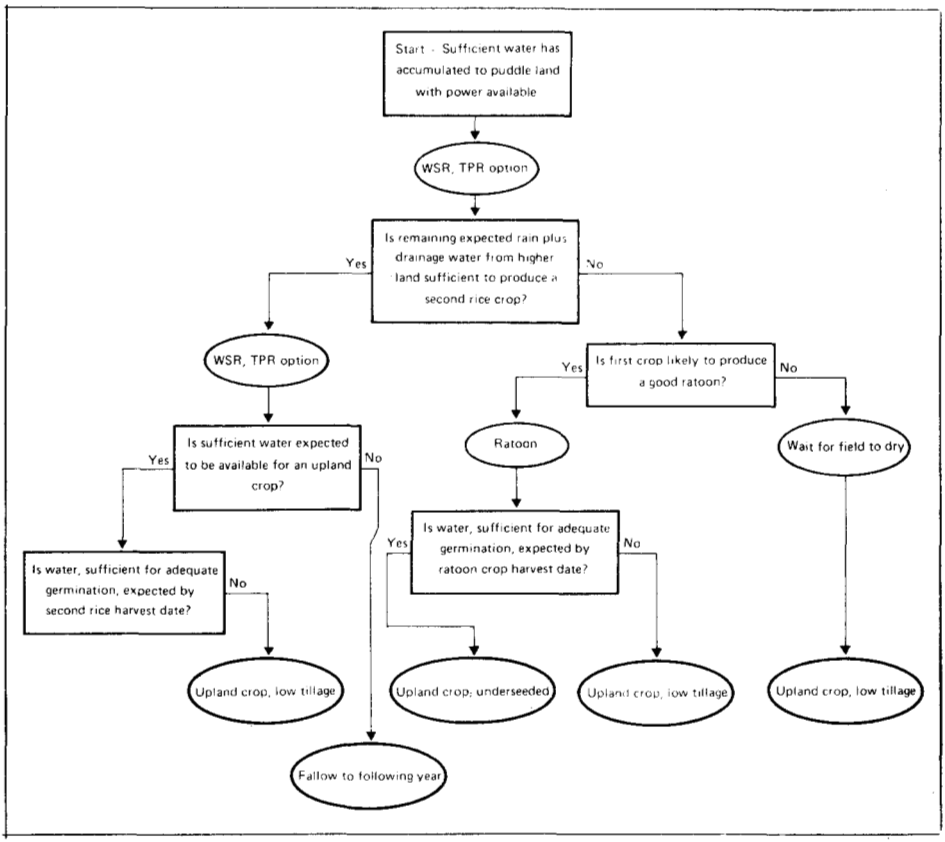
(a) Severe weed growth,
(b) Uneven germination, with subsequent uneven maturity,
(c) Initial stunting and slow growth or complete crop failure, if a dry spell occurred after initial germination.

In the case of the second rice crop, later planting dates lowered the probability of good yields. Bolton (1980) estimated that each day's delay in planting the second crop could lead to yield losses of up to 140 kg/ha.

In practice, farmers engage in sequential decision making. The cropping decisions they make change with their observations of climatic factors, and particularly those of rainfall over the crop year (Huysman, 1981). Morris (1978) has developed schematic diagrams showing the sequential decision making processes of farmers at the two sites in relation to rice seeding methods and upland cropping, and these are presented in Figures 2.9 and 2.10.



2.9. A schematic diagram to determine which pattern (DSR-UC, DSR-TPR. or DSR-TPR-UC) will be planted in a rainfed field at Pangasinan. Philippines (DSR - dry seeded rice. TPR — transplanted rice. UC — upland crop, RY — yield relative to that expected from planting at the usual time) (source. Morris 1978).



2.10. A schematic diagram to determine which pattern (rice-UC. rice-ratoon-UC. rice-rice, or rice-rice-UC) will be planted in a rainfed field at Iloilo. Philippines (source. Morris 1978)

Generally, the new technologies demand higher levels of inputs, particularly of cash. In certain instances, however, possibilities for factor substitution exist. With dry-seeded rice, the use of chemical herbicides, for example, may be reduced by more intensive land preparation and greater manual weeding.

The 10 farm models

The five case study farmers at each site were selected from among the wider group of economic cooperators mentioned earlier. These cooperators had participated in a daily farm record keeping project implemented by the Cropping Systems component of the Agricultural Economics Department at IRRI.

The primary and initial objective of working with economic cooperators

was to monitor the farmers' existing systems, so that historical technologies could be compared with the new technologies being introduced. However, over the 4 years of the record keeping project, the economic cooperators also provided valuable information on changes within the agricultural communities on the sites. The adoption or rejection of technologies which were being tested by researchers on agronomic cooperators' fields gave further useful insights into their potential success or failure.

The economic cooperators kept detailed records on all their farming activities. They recorded labor allocations on each crop and operation, the use of hired labor and power, crop yields, and incomes and expenses by source. They were visited twice a week by a 'barangay assistant' who checked and verified the records, distributed new forms, and tabulated and summarized the data. Thus, comprehensive data on farmers' historical practices and general information about the whole farm (size, labor and power availability, income, expenditure and consumption patterns, cash flows, credit use, etc.) were available. It was possible from records to trace the farmers' cropping decisions, practices, and allocative decisions from 1975 to 1979. The number of economic cooperators who continuously participated in the project was 45 at Iloilo and 36 at Pangasinan.

The performance of new technologies under farm conditions was also monitored through cropping pattern trials on the fields of the agronomic cooperators. Together, the data from economic and agronomic cooperators constituted a rich source for whole farm modeling.

The 10 case study farmers were selected to represent the range of resource endowments and farm types found at each site. At both sites, we wanted to study farmers at each end of the asset-wealth spectrum among small rice farmers. At Iloilo, the presence of irrigation facilities was also an important differentiating factor and we chose case study farmers with differing percentages of irrigated lowland.

At Pangasinan, we chose farmers representing the two distinct production complexes, differentiated mainly by the depth of the water table. The sample was also selected to cover varying types of land and the different tenure statuses.

Table 2.8 shows some characteristics of the case study farmers. Farmer 1 in each case was an affluent person with few cash constraints, and farmer 5 was generally considered a poor operator in the community.

At Iloilo, farmers 1 and 2 had irrigation facilities for most of their lowland paddies, while farmers 4 and 5 had only rainfed land. Farmer 3 had approximately equal irrigated and rainfed areas. In Pangasinan, three farmers (1, 4, and 5) were from the low-water table villages, while the other two came from the high-water table villages. Normally, farmers in the high-water table areas have higher farm incomes (Maranan 1980). However, farmer 1 was one of the richest small farmers in the area because a son-in-law remitted

Table 2.8. Resources of the 10 case study farmers, Iloilo and pangasinan, Philippines.

Farm location	Farmer	Farm size (ha)	Low-land (%)	Irri-gated[a] (%)	Owned (%)	Typical family labor available (man-h/wk)	House-hold expenses ($/yr)	Other earnings ($/yr)	Rice consumption (t/yr)	Present credit used ($/yr)	Work animals[b] (no.)
Iloilo	1	3.7	50	100	86	64	565	320	1.81	200	1
	2	3.5	100	100	0	84	841	353	3.96	160	1
	3	2.5	86	55	14	190	457	160	2.51	307	1
	4	3.4	100	0	0	190	356	168	3.61	107	3
	5	1.6	35	0	72	100	320	93	1.14	107	1
Pangasinan	1	2.4	51	81	20	50	1267	173	2.88	0	1
	2	2.7	78	44	36	112	247	400	2.16	320	1
	3	3.7	74	79	11	100	400	800	4.40	293	1
	4	3.9	66	19	15	90	280	293	1.44	0	1
	5	1.6	78	43	45	48	233	140	3.06	40	1

[a]Percent of lowland that is irrigated. [b]These are all buffalo, or 'carabao' as they are called locally.

Wet seeded IR36 in the foreground. Behind it is a parcel of BE 3, past the booting stage, and showing its characteristically thick growth.

considerable earnings from work in a Middle Eastern country. The poorer farmers and some of their family members at both sites worked on other farms during peak periods. Farmer 5 at Iloilo supplemented his earnings by regularly tapping, collecting, and selling tuba from his coconut trees. While this income amounted to only a few pesos a day and was often interrupted by rains, it was an important source of cash for meeting his basic daily household expenses.

Other major differences between our case study farmers were availability of family labor, use of credit, and other earnings. The farmers' cash flow patterns over the year also varied substantially, and this affected their credit needs. The farmers' asset positions, on the other hand, largely determined their access to credit. In Iloilo, Farmer 1 had no difficulty in obtaining adequate institutional credit. Farmer 1 in Pangasinan had a very high non-farm income, and did not need any. At the other extreme Farmers 5 in Iloilo and Pangasinan had problems in obtaining any institutional credit for rice cultivation. Other farmers were in intermediate positions.

All farmers except Farmer 4 at Iloilo had only one work animal. None of the farmers owned tractors or mechanical threshers. However, by 1978

farmer 3 in Pangasinan had free access to a hand tractor owned by his brother.

There were also considerable differences in attitude and managerial ability between our selected farmers. Thus despite his high asset status, Iloilo farmer 1 was a relatively conservative person compared with farmer 2, who in any international comparison would be rated outstanding in his enthusiastic investigation and cleverly practical adoption of new technologies. In contrast Iloilo farmer 5 was a most cautious person, whose observed technical coefficients indicate relatively low operational efficiency. Even farmer 5 however, demonstrated an ability to learn slowly about new technologies, and to apply them with increasing efficiency over time.

Information that was not readily available from farm records was obtained through visits and interviews. We developed close relationships and good rapport with all 10 farm families over the two years of our case study. We gained an intimate and detailed knowledge of their farm household systems, decision-making processes and relationships to wider social institutions. By attempting to faithfully model their system in detail, we were forced to confront and tackle problems that illustrate how farm household systems function in reality. This work enabled us to observe, at first hand, the process of technology adoption by small farmers.

We used the collected data to establish the input-output relationships associated with each production technology. We also determined the farmers' resource bases, their sources of credit and maximum borrowable levels, their off-farm activities, cash flows, minimum subsistence requirements of rice and other crops, and household expenditures. Once this was done, the farm models were specified in a linear programming format using the MPSX 370 (IBM) mathematical programming computer package.

CHAPTER 3

Farm-level impacts of new technologies

Our 10 farm models may now be used to project the economic impact of introducing new technologies. We have built these models to reflect the major resource endowments and other characteristics of the actual situation within each of the case study farms (Table 2.8). In this chapter we explore the simulated effects and implications of introducing new technologies to these varied circumstances.

The diversity of conditions across case study farms does not necessarily imply that many new technologies must be made available to enhance productivity and income. In practice the farmers at each site have chosen only a few key technologies, which in turn have been utilized in numerous crop combinations. Our models help to explain how differences in the quantity and quality of resources at a farmer's disposal cause differences in the economic optimum combination of technologies which maximizes profit. Our aim in this chapter is to present some important results of modeling, and to draw some broad conclusions regarding the projected acceptance of new crops and patterns.

THE OVERALL IMPACT

In our general assessment of the impact of new technologies we use the models to compare two basic situations. These are the *'historical'* situation of the mid-seventies, in which only the historical technology vectors are included in each model, and the 'new' situation where all appropriate new technology vectors are also included.

Historical technologies

The chief cropping patterns of Iloilo and Pangasinan in the early seventies have already been described. At Iloilo in lowland areas they were basically a crop of photoperiod-sensitive transplanted rice, sometimes followed by relayed mungbean and a ratoon. At Pangasinan in lowland areas they were transplanted rice followed by an upland crop, or maize followed by transplanted rice and mungbean. At both sites there were also several upland

crops on the upland rainfed areas. All these crops are included in our models as historical technology vectors.

Thus some typical Pangasinan crops and patterns in the 1976-77 crop year are specified among the historical technology vectors for farmer 5 (Table 2.7). These vectors include some of the earlier technologies developed by IRRI, with IR1561 and IR28 already being cultivated by farmer 5 in his lowland irrigated parcel. The more traditional Wag-wag-aga was still the only variety grown in the lowland rainfed parcel, however.

The optimal farm plans obtained from running the models with historical technology vectors only were compared with the actual farm plans adopted by each farmer in the historical situation of 1976-77. In general the results were quite encouraging, as the major crop combinations in the optimal solutions proved quite similar to those actually adopted. When important discrepancies were observed, the farmers were consulted and their response to the indications of the model elicited. This often led to better specification of the models through the incorporation of factors earlier overlooked.

New technologies

The main new technologies available to farmers were dry-seeded IR36 for the first crop, wet-seeded and transplanted IR36 for the first and second crops, and minimum tillage improved mungbean as the second or third crop. They also included some improved maize for upland rainfed areas. All these technologies are incorporated as vectors in the models, each vector being specified as a package including complementary inputs of labor, fertilizers, pesticides, etc. (see Table 2.6). As mentioned earlier, provision is also made in some cases for higher and lower levels of inputs and outputs.

Tables 3.1 and 3.2 show the projected overall impacts of introducing new technologies. They indicate that higher cash surpluses are generated in all models. This improvement is not uniform over all farms, however, denoting that the new technologies are better adapted to some situations than to others. In addition, the degree of adoption of improved technologies was already quite high in some historical situations, and the further gains were consequently less. This was true of farmers 2 in Iloilo and Pangasinan, both of whom were very progressive. A rise in total area cropped is seen in some cases, and a small decline in others.

Increases in total family and hired labor use occur for all Iloilo farmers (Table 3.1), and for two of the Pangasinan farmers (Table 3.2). Labor use dropped owing to the introduction of hand tractors by Pangasinan farmer 2, and of machine threshers (instead of foot threshing) by farmers 3 and 5. Yet while our farmers earn higher cash surpluses through adopting new technologies, their relative returns on use of scarce resources are not necessarily larger. Indeed, a comparison of randomly selected historical and new technology vectors in terms of the ratios of total value of output to total

Table 3.1. Broad effects of introducing new technologies, Iloilo, Philippines, case study farmers.

Farmer	Technologies[a]	Total cash surplus[b] ($)	Total cash surplus[b] ($/ha)	Total cropped area (ha)	Total FL and HL[c] (h)
1	HT	1124 (1228)	307	7.32	3227
	HT & NT	2044 (2148)	558	7.32	4110
2	HT	448 (935)	130	6.39	1746
	HT & NT	702 (1189)	204	6.89	1879
3	HT	618 (914)	252	4.09	4695
	HT & NT	1540 (1836)	627	4.83	4997
4	HT	277 (464)	81	7.27	3811
	HT & NT	531 (719)	157	6.86	4034
5	HT	211 (360)	133	2.95	2704
	HT & NT	457 (607)	288	2.99	2894

[a]HT = historical technology, NT = new technology. [b]Cash surplus = total cash income minus total cash expenditure. Outputs and inputs not paid for in cash (e.g. output consumed at home and family labor income) are not included. Figures in parentheses are total cash surplus plus household expenditure minus other nonfarm earnings. [c]Excluding share labor. FL = family labor, HL = hired labor.

Table 3.2. Broad effects of introducing new technologies. Pangasinan, Philippines, case study farmers.

Farmer	Technologies[a]	Total cash surplus[b] ($)	Total cash surplus[b] ($/ha)	Total cropped area (ha)	Total FL and HCL[c] (h)
1	HT	483	198	7.32	1154
	HT & NT	1020	425	7.27	1477
2	HT	490	184	6.39	2824
	HT & NT	520	192	6.89	2552
3	HT	438	129	4.09	3216
	HT & NT	663	179	4.83	2192
4	HT	598	158	7.27	3288
	HT & NT	1643	421	6.55	3985
5	HT	75	48	2.95	1697
	HT & NT	158	99	2.99	1358

[a]HT = historical technology, NT = new technology. [b]Cash surplus = cash income minus cash expenditure. Outputs and inputs not paid for in cash (e.g. output consumed at home and family labor income) are not included. [c]Excluding share labor. FL = family labor, HL = hired labor.

variable costs (at average market prices) shows that these vary relatively little (Table 3.3).

Table 3.3. Total values of output and total variable costs. Farmer 1, Iloilo, Philippines.

Technologies	Gross returns (GR) ($/ha)	Total variable costs (TVC)[a] ($/ha)	GR TVC ratio
Historical			
IR28, TPR, 1 crop	274	141	1.9:1
BE3, TPR, 1 crop	210	144	1.4:1
Kapopoy, TPR, 1 crop	220	98	2.2:1
IR20, TPR, 2 crops	210	106	2:1
New			
IR36, DSR, 1 crop	336	175	1.9:1
IR36, TPR, 1 crop	409	198	2:1
IR36, TPR, 2 crops	364	190	1.9:1
IR36, WSR, 2 crops	346	163	2.1:1

[a]At average prices of $0.90/h for labor and $0.22/h for buffalo (including driver) time. In fact, prices may vary considerably around these levels, as discussed in the text.

Changes in the area of rice also differ between farms with adoption of new technologies (Tables 3.4 and 3.5). Total rice production rises in all cases, but sometimes the rise is only slight and here the rice area also declines substantially through omission of the second rice crop. Such declines are largely offset by increased areas of upland crops, which under the circumstances assumed are more profitable than a greatly enhanced rice production. Thus, once the basic requirements of rice for subsistence have been met, greater additions to the total cash surplus are often secured by growing a second crop of mungbean. In yet other cases, the rice area is extended through addition of a second crop. It should be noted that the new technologies are not necessarily adopted according to recommended patterns. The combinations specified by the model vary considerably according to the particular environmental situations assumed.

A general phenomenon in the introduction of new technologies to case study farms on both sites is the wide substitution of IR36 for more traditional varieties. At Iloilo, wet seeding becomes relatively more important as a method of establishment for all but farmer 2, whose circumstances are especially favorable for dry seeding and whose projected yields from this

Table 3.4. Total area upland and rice crops, and total rice production, Iloilo, Philippines, case study farmers.

Farmer	Technologies[a]	Total area (ha)					Total rice production (t)
		Upland[b]	DSR[c]	WSR[d]	TPR[e]	All rice	
1	HT	3.69	0	1.60	2.03	3.63	6.9
	HT & NT	4.71	0	1.35	1.26	2.61	8.0
2	NT	0.54	0	2.68	3.18	5.86	20.5
	HT & NT	0.54	1.47	1.71	3.18	6.36	22.2
3	HT	0.69	0.35	0.94	2.11	3.40	9.5
	HT & NT	0.69	0	4.14	0	4.14	13.7
4	HT	2.86	1.02	0.65	2.74	4.41	6.8
	HT & NT	3.39	0.62	2.00	0.85	3.46	11.8
5	HT	2.05	0	0	0.90	0.90	1.4
	HT & NT	2.28	0	0.15	0.56	0.71	1.8

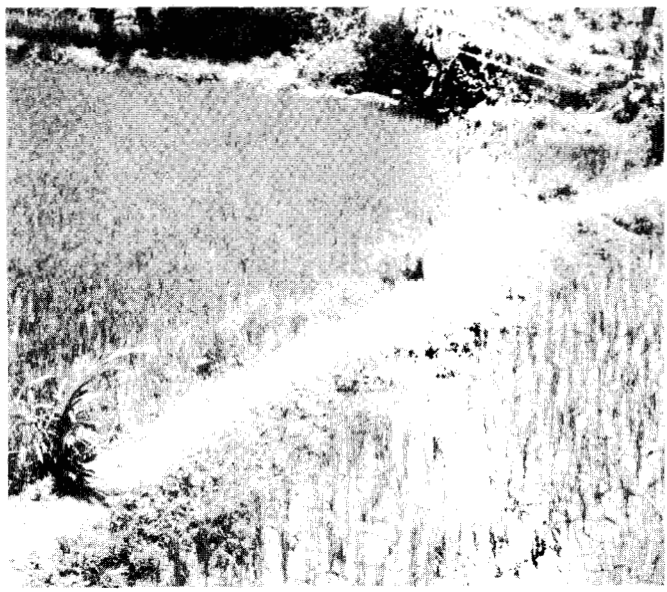
[a]HT = historical technology, NT = new technology. [b]This includes upland crops on both upland areas and lowland areas (where they are grown as second and third crops to rice). Upland crops grown as relays (as with mungbean sown before rice harvest) are not included. [c]Dry-seeded rice. [d]Wet-seeded rice. [e]Transplanted rice.

Table 3.5. Total area of upland and rice crops, and total rice production, Pangasinan, Philippines, case study farmers.

Farmer	Technologies[a]	Total area (ha)					Total rice production (t)
		Upland[b]	DSR[c]	WSR[d]	TPR[e]	All rice	
1	HT	4.23	0.38	0	0.86	1.24	7.3
	HT & NT	3.51	1.37	0	1.04	2.41	12.0
2	HT	3.18	0	0	2.10	2.10	5.1
	HT & NT	3.29	0.08	0	2.02	2.10	5.9
3	HT	3.65	0	0	2.80	2.80	5.7
	HT & NT	4.08	0	0	2.80	2.80	9.5
4	HT	2.89	0.88	0	2.78	3.66	10.6
	HT & NT	2.85	1.60	1.63	0.87	4.10	20.1
5	HT	1.26	0	0	1.64	1.64	5.0
	HT & NT	1.62	0.21	0	0.96	1.17	5.9

[a]HT = historical technology, NT = new technology. [b]This includes upland crops on both upland areas and lowland areas (where they are grown as second and third crops to rice). Upland crops grown as relays (as with mungbean sown before rice harvest) are not included. [c]Wet-seeded rice. [d]Dry-seeded rice. [e]Transplanted rice.

approach are relatively high (Table 3.4). Transplanting still remains quite prominent at Iloilo, however, especially for the second crop; here it is expected to produce a higher yield, and to enable the field period to maturity to be reduced by the initial time of 2-3 weeks in the seedbed. Dry seeding is only significant for farmer 2. In Pangasinan the superior yield and performance of transplanting mean that it is still the chief projected method in the new technology situation for all but farmer 5 (Table 3.5). For this farmer both wet and dry seeding become important, owing to the special condition of a high water table. In both Iloilo and Pangasinan minimum-tillage improved mungbean enters some solutions as a second crop, but relay sown traditional mungbean also remains important. These general effects are discussed further below.



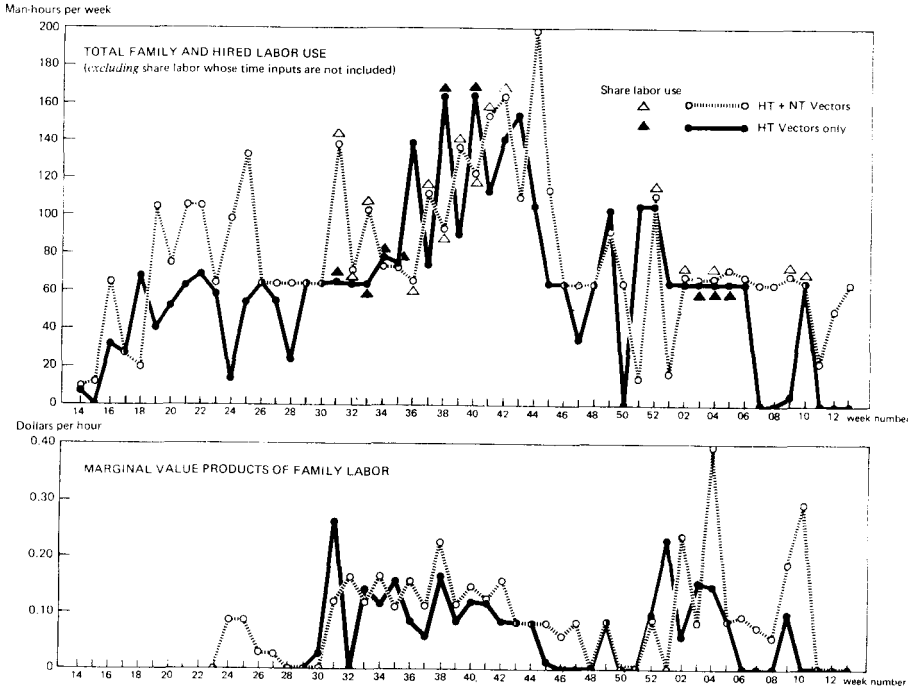
Padi on the sideslope. The planting on the right has already dried up, and is now unlikely to give any crop.

A feature common to the new technology solutions for both locations is the usually much higher projected use of inputs in lowland irrigated than in lowland rainfed areas. This is due to the higher productivity of inputs when applied in conjunction with an ample water supply. Thus, although all case study farmers are projected to adopt IR36, the intensity with which this new technology is used varies considerably. There are some exceptions to this irrigated versus rainfed generalization, however, notably for rainfed bottomland parcels with a more assured water supply.

As indicated previously, direct risk measures are not employed in our deterministic linear programming model, and are broadly reflected by a lower expected yield being assigned in more risky situations. Again, while two rice crops are always stipulated for irrigated areas in the new technology solutions, projected second rice cropping on rainfed areas always remains limited owing to constraints imposed by moisture availability late in the season. These constraints are incorporated in the models by assuming cutoff dates for second rice planting, beyond which no further rice growing vectors are included.

CHANGES IN THE USAGE AND PRICING OF RESOURCES

We now examine how the use of farm resources is changed with introduction of new technologies. We also study the parallel variations in resource prices.

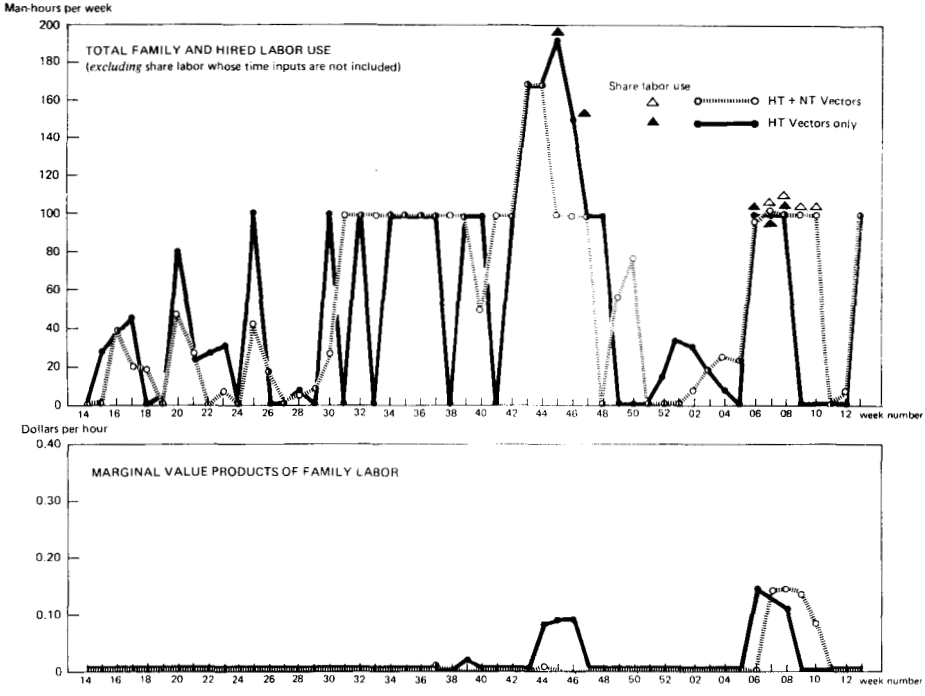


3.1. Labor use and marginal value products, Farmer 1, Iloilo, Philippines (HT = historical technology, NT = new technology).

Labor

The common finding of our models is that adoption of new technologies spreads labor demand more evenly through the year. In doing so it may also redistribute labor use away from peak periods. These aspects are illustrated by comparing the employment of family, hired, and share labor in the historical and new technology situations of farmers 1 and 5 at Iloilo (Figs. 3.1 and 3.2).

With farmer 1 in the historical situation, two main peaks in labor use occur. The first and most major is between weeks 36 and 44 (3 September to 4 November, Appendix Table 3.1). This is when the first crops of upland maize and rice are being harvested and threshed, and cultivations for second crops are taking place (Table 3.6). Some share labor is also employed for harvesting at this time. The second but more minor peak occurs from weeks 49 to 06 when the harvest of the second rice crops, and of the maize segment of the maize/yambean intercrop, is undertaken. Share labor is again employed towards the end of this period, when the family labor force is reduced by the return of children to school. A rather similar distribution of



3.2. Labor use and marginal value products, Farmer 5, Iloilo, Philippines (HT = historical technology, NT = new technology).

Table 3.6. Cropping patterns under historical and new technologies. Farmer 1, Iloilo, Philippines.[a]

	Parcels	Historical technology	New technology
1	Upland rainfed and fully owned (1.847 ha)	Maize, 1 crop FL (16-31 to 19-35): 1.241 ha SL (16-31 to 14-32): 0.606 ha Maize/yambean, 2 crops FL (37-03 to 44-09): 0.235 ha SL (39-07 to 44-09): 1.612	Maize DMR FL (16-32 to 26-42): 1.013 ha SL (18-34 to 26-42): 0.834 ha Maize/yambean FL (37-03 to 44-09): 0.355 ha SL (38-08 to 44-09): 1.492 ha
2	Lowland irrigated and share-tenanted (0.520 ha)	TPR, IR20, 2 crops FL (39-04 to 39-06): 0.520 ha WSR, IR28, 1 crop FL (23-38 to 27-42): 0.520 ha	WSR, IR28, 1 crop FL (20-35 to 21-36): 0.041 ha WSR, IR36, 1 crop FL (19-38 to 21-40): 0.392 ha SL (19-38 to 20-39): 0.087 ha TPR, IR36, 2 crops/cowpea FL (39-15 to 41-17): 0.308 ha WSR, IR36, 2 crops/cowpea FL (37-02 to 40-05): 0.212 ha
3 & 4	Irrigated and fully owned (0.275 ha)	WSR, IR28, 1 crop FL (23-38): 0.114 ha SL (24-39): 0.088 ha TPR, IR28, 1 crop FL (26-43): 0.073 ha TPR, IR20, 2 crops FL (39-06): 0.073 ha SL (39-05): 0.202 ha	WSR, IR36, 1 crop SL (19-38 to 20-39): 0.275 ha WSR, IR36, 2 crops/cowpea SL (39-04 to 40-05): 0.216 ha TPR, IR36, 2 crops/cowpea SL (39-15): 0.059 ha
5 & 6	Lowland rainfed and fully owned (1.019 ha)	TPR, IR28, 1 crop FL (25-41): 0.137 ha SL (24-39): 0.005 ha WSR, IR28, 1 crop FL (21-36 to 23-38): 0.325 ha SL (20-35 to 21-36): 0.552 ha TPR, IR20, 2 crops FL (24-52 to 38-04): 1.017 ha SL (32-50 to 39-06): 0.002 ha	TPR, IR36, 1 crop/ratoon FL (22-47): 0.058 ha SL (22-47 to 23-48): TPR, IR36, 1 crop FL (28-43 to 29-44): 0.339 ha WSR, IR36, 1 crop FL (29-46): 0.130 ha Mungbean, 2 crops FL (46-08 to 49-11): 0.099 ha

[a]FL = harvesting with family labor, SL = harvesting with share labor, WSR = wet-seeded rice, TPR = transplanted rice. Figures in parentheses denote ranges of weeks during which ground is used by the particular technology (from first plowing to threshing).

labor inputs occurs with the historical technology situation of farmer 5 (Fig. 3.2), although the two peaks are shorter and occur somewhat later.

With farmer 1 in the new technology situation (Fig. 3.1), an extra peak in labor utilization occurs early in the year, from week 19 to week 25. This is because the labor (and animal) requirements for maize cultivation are now added to by work in preparing for a first crop of wet-seeded rice (Table 3.6). In the historical technology situation, cultivations for the first rice crop do not begin until week 23, well after the planting of maize is completed. Again, the peak associated with first crop harvests and second crop cultivations begins somewhat earlier in the new technology situation (in week 31), and continues somewhat later (week 45). The very high labor utilization in week 44 is due to pressures from the harvesting of transplanted IR36 in parcels 5 and 6. Finally in the new technology situation, the late season peak of

farmer 1 is more sustained in the early weeks of the new year. For the crop as a whole, considerably more share labor is required.

With farmer 5 in the new technology situation (Fig. 3.2), the early peaks of labor use are actually reduced. This is because the succession of two rice crops on rainfed land in the historical situation (transplanted Kapopoy followed by transplanted BE3) is replaced by the more profitable combination (under these circumstances) of one higher yielding rice crop (transplanted IR36) followed by mungbean. On the other hand, the mid-year utilization of labor by farmer 5 with new technologies is more sustained with new than with historical technologies, although his peak utilization is less and he accordingly avoids the use of share labor entirely. Late in the year rather higher yields of yambeans and a rescheduling of the harvest mean that the peak of labor utilization is more prolonged, and his need for share labor enhanced.

These changing requirements for labor may have important effects on its *marginal value product* (MVP) to the farmers concerned (lower sections of Figs. 3.1 and 3.2). The MVP is the extra value of product forthcoming by using one more unit of labor (or any other resource). It is also the cost of labor at the margin, and is sometimes referred to as its *shadow price.* In our model, the MVP's of family labor are taken as zero as long as its utilization is below its total availability; within this limit there is no shortage of labor, which is freely available for all farm activities. Such a situation applies for Iloilo farmer 1 over the period up to week 23, and additions to the family labor supply have no effect on the projected cash surplus. Beyond this week, however, the family labor supply is generally insufficient to carry out projected activities, and labor becomes a constraint. It is then necessary to hire labor (for cultivation activities) or to use share labor (for harvesting and threshing), and an appropriate price must be paid. This price is also the MVP of family labor, which is no longer in ample supply and has an opportunity cost to the farmer. Thus in week 38, the the average increase in cash surplus which would accrue if one further hour of family labor became available. This increase would spring from the reduced use of share labor in harvesting wet-seeded IR36 on irrigated share-tenanted and irrigated fully owned land (Table 3.6).

With farmer 1 the MVP of labor is generally higher in the new than in the historical technology situation, since labor demand is greater and more sustained, and family labor is a constraint (Fig 3.1). This is to some extent true of the other case study farmers at Iloilo, but not of farmer 5 whose family labor supply is relatively plentiful (Table 2.8); except for one short period near the close of the year there is no constraint, and the MVP remains at or close to 0 (Fig. 3.2).

These varying MVP's are directly accounted for in the modeling process, which is taken to simulate the decision making process of each farmer. As

already explained, this process chooses those combinations of crops and patterns which maximize the overall cash surplus subject to the constraints (and consequent MVP's) of labor and other resources used.

Land

Since introducing new technologies makes land more productive, the demand for it generally rises in relation to availability. The MVP of land accordingly tends to increase, and this is true of all case study farm situations. Such increases are subject to constraints in complementary resources of cash and labor, however. This is illustrated by the maximum MVP's of rainfed land for farmers 2 and 3 at Iloilo, both of which actually fall with the advent of new technologies (Table 3.7). In these cases most available cash is used to support the introduction of the new technologies in the irrigated parcels of each farm, where they can add most to total cash surplus. Less productive technologies which absorb less cash are correspondingly employed in the rainfed sections.

The MVP's of land are the increases in total cash surplus which would be secured through addition to this resource. Thus for farmer 5 in week 38 of the new technology situation, additional fully owned rainfed land would enable more transplanted IR36 to be grown, and an extra surplus at a rate of $115 per hectare to be earned (Table 3.7). These marginal value products vary considerably between farms, and reflect substantial differences in the productivity and profitability of technologies available to our farmers. Thus farmer 4 (maximum MVP of $81 with new technologies) has relatively low yields owing to poor soils, indifferent management, and a lack of cash for material inputs; farmer 1 (maximum MVP of $244) has good yields owing to better soils and management and a higher material input level.

Cash

With the advent of new technologies using higher material inputs, more cash is required. Since cash is often scarce in the early part of the crop year, its MVP's are frequently high then and become higher as new technologies are introduced (Table 3.7).

Once the first substantial crop has been sold, however, the inflow of cash much reduces the relative scarcity of this resource, whose MVP drops sharply (Fig. 3.4).

Once again the situations of our case study farmers vary considerably. While the maximum MVP of $1.03/$ for Iloilo farmer 1 (Table 3.7) in the new technology situation is very low, and denotes that cash is quite plentiful in relation to other resources, the much higher maximum of $7.41/$ for Iloilo farmer 4 shows that a more productive (but more cash intensive) technology could be adopted for the first crop if further cash was available. Cash is also scarce in the new technology situations of Iloilo farmers 2, 3, and 5.

Table 3.7. Maximum marginal value products[a] of rainfed lowland and cash, Iloilo, Philippines, case study farmers.

Farmer	Technology[b]	Marginal value products ($)	
		Lowland rainfed ($/ha)	Cash ($/$)
1	HT	109 (33)	1.00 (14-13)
	HT & NT	244 (49)	1.03 (14-31)
2	HT	160 (40)	3.60 (14-25)
	HT & NT	151 (52)	3.69 (14-25)
3	HT	253 (46)	1.00 (14-31)
	HT & NT	213 (25)	1.72 (14-25)
4	HT	56 (41)	1.25 (14-44)
	HT & NT	81 (47)	7.41 (14-44)
5	HT	97 (41)	1.09 (14-31)
	HT & NT	115 (38)	5.97 (14-31)

[a]The highest weekly shadow price in the particular solution. Figures in brackets are week numbers or ranges of week numbers in which the maximum shown applies. See Appendix Table 3.1 for details. [b]HT = historical technology, NT = new technology.

PATTERN SELECTIONS AND COMPLEMENTARITIES

Most models show that after introducing new technologies a mix of cropping patterns and establishment methods is specified in the optimum solution. This indicates complementarities between different technologies which, in the context of the whole farming system, can be quite important in enabling the farmer to reach a higher overall cash surplus. These complementarities are particularly to be noted, as all too often comparison and evaluation of technologies tend to be one sided, and often implicitly recommend the wholesale adoption or rejection of a particular technology.

Such a selection of cropping pattern mixes is well illustrated by the solutions for Iloilo farmer 1 in Table 3.6. We take for more detailed discussion the selection of new technologies by the model in the new

technology situation on 1.109 ha of fully owned rainfed land [‘parcels’ (5) and (6)], whose labor requirements are further analyzed in Table 3.8. The costs and returns analysis of the various new technology vectors specified for this parcel shows that IR36 TPR/ratoon followed by minimum tillage mungbean is likely to be superior in total net returns (Table 3.9). The actual model selection includes several other patterns, however.

Table 3.8. More detailed labor requirement for the HT and NT solution on 1.019 ha of rainfed land, parcels (5) and (6)_, Farmer 1, Iloilo Philippines

	Labor requirements (man-h)									
	TPR IR36 1 crop		TPR IR36 1 crop ratoon		WSR IR36 1 crop	Mungbean 2 crops				
Week	0.072 ha[a]	0.265 ha	0.227 ha	0.325 ha	0.130 ha	0.244 ha	0.223 ha	0.227 ha	0.325 ha	Total
21[b]			6 (c)							6
22			20 (c)	3 (c)						23
23			17 (c)	28 (c)						45
24			54 (t)	25 (c)						79
25				77 (t)						77
26			16 (w)							16
27	1 (c)			23 (w)						24
28	6 (c)	2 (c)								8
29	5 (c)	20 (c)			11 (c)					36
30	17 (t)	21 (c)			10 (c)					50
					2 (t)					
31		63 (t)								63
32	5 (w)									5
33		19 (w)			13 (w)					32
34										-
35					8 (w)					8
36			17 (h)							17
37			17 (h)	24 (h)						41
38				25 (h)						25
39										-
40										-
40										-
41										-
42	5 (h)									5
43	6 (h)	20 (h)								26
44		20 (h)								20
45					10 (h)					10
46			17 (h)		10 (h)	11 (c)				44
						6 (c)				
47			17 (h)	24 (h)		4 (t)	10 (c)			51
							6 (c)			
48				25 (h)			4 (t)	10 (c)		45
								6 (c)		
49								4 (t)	15 (c)	19

[a]Figures in this row are areas of parcels involved in each case. Letters in parentheses in body of table are codes for operations: c = rice cultivation; h = rice harvesting and threshing; t = transplanting, pulling, and handling; w = hand weeding; e = initial cultivation for mungbean. [b]For transplanted IR36, work on the seedbed commenced in week 21, but coltivation work on the parcel itself began in week 27. This table only indicates the weeks over which the land of the parcel itself is used.

The major reason for specifying this mix of technologies is that they use labor at different times. The solution provides a staggering of crops, such that their labor resource requirements complement one another. Thus land preparation and transplanting for IR36 begin in weeks 21 and 22, and again in weeks 27 and 28. Land preparation for wet seeded IR36 begins in week 29. In the interval between these times there is also the initial cultivation and planting of maize in the upland parcel of 1.847 ha (Table 3.6). One reason why dry seeding is not selected by the model is that it conflicts with labor requirements for maize in weeks 19-23. It also produces lower yields than other seeding methods and (in the particular configuration of resources and shadow prices that rule) is less profitable. On the other hand, times of heavy

Table 3.9. Net returns and returns to labor of selected new technologies on rainfed land. Farmer 1, Iloilo, Philippines.

Crop[a]	Net returns[b] ($/ha)	Returns to labor[c] ($/man-h)	Returns to cash[d] ($/$)
DSR, first crop	229	0.52	5.25
WSR, first crop	277	0.59	6.15
TPR, first crop	287	0.49	6.31
WSR/cowpea	525	0.53	8.10
TPR/cowpea	508	0.46	7.86
TPR/ratoon	518	0.51	8.14
Mungbean, minimum tillage, 2d crop	311	0.62	10.07

[a]All rice crops are IR36, DSR = dry-seeded rice, WSR = wet-seeded rice, TPR = transplanted rice. [b]Gross returns minus all variable costs. [c](Gross returns minus material input costs) divided by total labor hours. [d](Gross returns minus labor and animal costs) divided by material input costs.

labor requirement for transplanting are different from times for weeding wet-seeded rice. Further, the periods of harvesting are dovetailed (from week 36 to week 48) so that there is no exceptional labor requirement in any one week. On these rainfed parcels (5) and (6), the turnaround period between rice harvesting and the subsequent establishment of minimum tillage mungbean ranges from 3 to 4 weeks. It is shorter in the imgated parcels (2), (3) and (4) (Table 3.6), where there is more need for timeliness owing to the limited growing season.

A similar dovetailing applies to the other parcels of farmer 1 (Table 3.6), and avoids high peaks of labor utilization over the period from week 36 to week 46 (Fig. 3.1). Such dovetailing of labor, land, and cash use is of course a feature of all normal farm operations, and reflects the farmer's actual decision-making process whereby he consciously balances his use of resources, and chooses his technologies, so as to minimize his resource cost and maximize his *overall* cash surplus. Thus the resources and environment of the *whole* farm dictate the particular cropping patterns that are chosen from the agronomically feasible set of patterns in each situation. A higher family labor supply, or a smaller upland parcel, or a greater household expenditure (and resultant shortage of cash) in certain periods, may all determine substantially different optimum mixes of technologies. One major advantage of the newer over the older technologies is that they enable a greater spreading of activities over time, and an accordingly greater use of resources in periods of relatively lower opportunity cost.

Suboptimal choices

The costs to Iloilo farmer 1 of moving from his optimum solution for new

Harvesting IR36 at Iloilo. The workers use sickles, and later bundle the cut material into sheaves prior to threshing.

technologies on rainfed land are shown in Table 3.10. This quotes the 'marginal' or extra 'opportunity costs' per hectare of taking some of the suboptimal choices available to him. These costs will subtract from the overall cash surplus.

For technologies actually included in the optimal solution, these marginal opportunity costs are zero. This is true, for example, of TPR, first crop ratoon, beginning its period of land use in week 22. As soon, however, as this pattern is begun in week 23, it incurs an extra cost at the rate of $9 per hectare, owing to the higher shadow price of labor. If it is planted over the period weeks 24-49, it incurs the very much higher additional charge of $209 per hectare, which is the surplus otherwise derived from minimum tillage mungbean; the latter may only be established up to week 49, after which it is considered too late to secure a worthwhile crop. Such conflicts between possible crops are resolved in the model (and to a great extent in practice) by choosing that course which is expected to lead to the greatest overall farm surplus.

The figures of Table 3.10 also serve to indicate other possible cropping pattern combinations which are close to optimum. Thus the cost of zero for DSR, first crop, beginning its land use in week 20, denotes that a similar cash

Table 3.10. Marginal opportunity costs of selected new technologies on rainfed land. Farmer 1, Iloilo, Philippines.

Crop[a]	Marginal opportunity costs ($/ha) and range of weeks crop occupies the ground[b]													
DSR, first crop	13	0	59	101	95									
Wks	19-35	20-36	21-37	22-38	23-39									
WSR, first crop		64	57	37	30	27	24	10	8	0	45	28	255	256
Wks	20-37	21-38	22-39	23-40	24-41	25-47	26-43	27-44	28-45	29-46	30-47	31-48	32-49	33-50
TPR, first crop	17	54	27	6	0	0	0	0	1	0	42	17	179	180
Wks	22-37	23-38	28-39	25-40	26-41	27-42	28-43	29-44	30-45	31-46	32-47	33-48	34-49	35-50
WSR, first crop/cowpea	17	73	22	18	0	0	82	12	153	59	0	35	32	67
Wks	20-48	21-49	22-50	23-51	24-52	25-01	26-02	27-03	28-04	29-05	30-06	31-07	32-08	33-09
TPR, first crop/cowpea	83	115	52	42	26	32	102	55	176	109	59	75		
Wks	22-96	23-47	24-48	25-99	26-50	27-51	28-52	29-01	30-02	31-03	32-04	33-05		
TPR, first crop/ratoon	0	9	209	180	160	167	165	203	211	223	225	199		
Wks	22-47	23-48	24-49	25-50	26-51	27-52	28-01	29-02	30-03	31-04	32-05	33-06		
Mungbean, minimum tillage, 2d crop	0	0	0	0	0	0								
Wks	44-06	45-07	46-08	47-09	48-10	49-11								

[a]All rice crops are IR36. [b]For key to week numbers, see Appendix Table 3.1.

surplus could be earned by following this option. It would involve some rescheduling of maize planting in the upland parcel (Table 3.6), and an accordingly lower area of transplanted or wet-seeded rice; this, however, would have a minimal effect on the surplus. Again, the zero (or minimal cost) of TPR, first crop (without ratoon), up to the beginning of week 32 (as compared to the actually specified solution of planting from weeks 28 to 29) (Tables 3.6 and 3.8), indicates that there is some flexibility in planting times here. With this particular rice pattern the conflict with minimum tillage mungbean occurs much later (in plantings beginning in week 34), since no ratoon is involved and the period over which it occupies the ground is much shorter.

It should nonetheless be mentioned that the flexibility indicated for some crops through the Table 3.10 figures should not be overestimated. These figures essentially refer to small adjustments from the technology balance indicated in the optimal solution. Large adjustments from this optimum will usually encounter further resource limitations which may very substantially change the cost picture indicated.

SPECIAL EFFECTS ON TECHNOLOGY SELECTION

Once the operations of a case study farm are modelled in the way outlined, the major items involved may be varied from our prior assumptions. Such parametization allows us to depart from the confines of specific case study farm situations, and to undertake wider analyses. In particular, we may wish to check the extent to which certain technologies remain profitable or 'robust' under different conditions. In this section we examine the effects of varying outputs, wages, inputs, ownership status, and weather conditions.

Outputs

Table 3.11 describes the projected effects of changes in expected yield on optimum crop combinations for the 1.109 ha of rainfed lowland fully owned by Iloilo farmer 1. Situation 1 is in fact the same as that described in Table 3.6. Its complementarities have already been discussed. It represents the optimal solution of the model assuming the average yield expectations of farmer 1 for each new technology. These expectations were elicited in the manner described in Chapter 2, and featured a higher average yield per hectare for transplanting (2,925 kg) than for wet seeding (2,750 kg) or dry seeding (2,400 kg). A relatively high yield of 800 kg is also taken for the ratoon, which is cut 10 weeks after the first harvest of transplanted crop. Under these yield expectations, and in the light of farmer 1's relatively plentiful cash resources which enable him to employ hired or share labor at

a low shadow price, the largest area of first crop is transplanted. All the second crop area is under minimum tillage mungbean, which in this instance has the high expected yield of 600 kg / hectare.

Table 3.11. Effects of yield changes on 1.019 ha of rainfed and fully owned land , Farmer 1, Iloilo, Philippines.

Crop	Total surplus[a] ($)	Yield (kg/ha)	Weeks[b]	Area (ha)
Situation 1: Yields expected by farmers				
IR36, TPR, 1st crop	2044	2925	28-43 to 29-44	0.339
IR36, TPR, 1st crop/ratoon		2925 + 300	22-47 to 23-48	0.552
IR36, WSR, 1st crop		2750	29-46	0.130
Mungbean, minimum tillage, 2d crop		600	46-48 to 49-11	1.019
Total				2.040
Situation 2: Yields equalized[c]				
IR36, TPR, 1st crop	2049	2925	27-43	0.071
IR36, TPR, 1st crop/ratoon		2925 + 800	22-47 to 23-48	0.453
IR36, WSR, 1st crop		2925	27-44 to 29-46	0.495
Mungbean, minimum tillage, 2d crop		600	45-06 to 19-10	1.019
Total				2.038
Situation 3: Yields equalized, half those in situation 2				
IR36, TPR, 1st crop	1843	1462	28-43	0.173
IR36, TPR, 1st crop/ratoon		1462 + 400	22-47	0.338
IR36, WSR, 1st crop		1462	27-44 to 31-48	0.508
Mungbean, minimum tillage, 2d crop		300	45-06 to 49-10	1.019
Total				2.028
Situation 4: Yields equalized, one and a half those in situation 2				
IR36, DSR, 1st crop	2266		19-35 to 20-36	0.259
IR36, TPR, 1st crop		4388	28-43	0.044
IR36, TPR, 1st crop/ratoon		4388 + 1,200	22-47	0.470
IR36, WSR, 1st crop		4388	27-44 to 29-46	0.246
IR36, WSR, 2d crop		4388	36-02 to 37-02	0.259
Mungbean, minimum tillage, 2d crop		900	46-07 to 49-10	0.760
Total				2.038

[a]Earned from the whole farm including all types of land. [b]For key to week numbers, see Appendix Table 3.1. [c]At level of TPR.

In situation 2, equal yields (2,925 kg/ha) are assumed for all rice seeding methods on our rainfed parcel (but not on the irrigated parcels of the farms where a higher yield from transplanting is still postulated). Transplanting without a ratoon is then almost completely omitted in the optimal solution, being replaced by wet seeding (Table 3.11). Transplanting followed by the ratoon is substantially retained in the most profitable solution, however. Even at this higher expected yield dry seeding is not included, largely because the continued specification of the profitable second crop of mungbean does not require particularly early planting of the first rice crop. In

addition, the early cultivation for dry seeding conflicts with that for the more profitable and relatively high yielding DMR 2 maize (2.4 t/ha), which is specified for the upland parcel of farmer 1 (Table 3.6).

In situation 3, equal yields are again assumed for all seeding methods, but reduced to half those in situation 2 (i.e., to 1,462 kg, /ha). Here the emphasis on transplanting is retained, but ratooning is reduced and confined to the earlier weeks 22-47. The labor released from harvesting the ratoon is more profitably employed to harvest a somewhat larger area of much higher yielding second crop transplanted rice in the irrigated parcel. The wet-seeded area in that parcel is accordingly lowered.

Finally in situation 4, the equal yields are raised to one and a half times those in situation 2 (i.e. to 4,388 kg/ha). Dry seeding from weeks 19 and 20 is now introduced on part of the area occupied by wet seeding in previous situations, and accordingly makes possible the subsequent cultivation of a second wet-seeded rice crop on the same area. The much higher rice yields make it profitable to displace some upland maize (which is now planted in later weeks) and some minimum tillage mungbean.

Similar yield change exercises were carried out in relation to rainfed parcels of other case study farmers, and similar complementarities between activities were observed. These complementarities applied both to other activities *within* the rainfed area and *across* parcel boundaries to activities in *other* irrigated upland areas of each farm.

The most common expectations of our other Iloilo case study farmers regarding IR36 were for a low yield from dry seeding, and for higher but similar yields from transplanting and wet seeding the first crop. Transplanting the second crop was expected to give superior yields to wet seeding, however, and also to occupy the field for a shorter time. Ratooning was not thought to give particularly good yields. Under these expectations dry seeding was only projected by the models in special circumstances, and a mixture of wet seeding and transplanting (sometimes with a ratoon) was normally specified by the models for the first crop. Transplanting was generally indicated for the limited conditions where second rice crops were profitable. Cultivators other than farmer 1 at Iloilo expected relatively low yields of minimum tillage mungbean, and the models accordingly indicated more of the traditional relayed mungbean or cowpea, or mere fallow. For the case study farmers at Pangasinan, transplanting was commonly thought to give superior yields, as mentioned earlier, and was accordingly projected as the chief method of establishment for both first and second rice crops.

Wages

It is also relevant here to check the implications for transplanting of raising the assumed wage of outside workers. Hiring of labor to supplement family labor resources is almost inevitable, since the transplanting operations have

to be done in a comparatively short time. Where many farmers engage in transplanting over the same period, and the community supply of labor is limited, its price will naturally be bid up. Our assumptions in the modeling exercises of a hired labor wage of $0.09 per hour is relatively low in this competitive situation, and may accordingly lead to overspecifications of transplanting.

When yields from wet seeding and transplanting the first crop at Iloilo are equalized, and a higher wage rate for transplanting is specified, wet seeding tends to dominate transplanting as the preferred method of establishment. The choice of wet seeding or transplanting, where a second rice crop is undertaken at the higher wage rates, does not show a uniform pattern across the models, however. This is because the shorter maturity period of a transplanted second crop leads to higher yields compared with a wet-seeded crop planted at the same date; a rapid decline in yield for crops harvested beyond week 52 is assumed in the models. Much depends here on the specific situation, and notably on relative yields, the supply of family labor, and the availability and shadow price of cash to pay hired workers. Again in the situation at Pangasinan, the marked superiority in yield from transplanting the first and second crops means that this approach is broadly maintained, even at higher wage levels.

Other effects

Further modeling exercises examined the introduction of new technologies with lower material input requirements, and accordingly lower outputs. For our farmers these represent a compromise between the normal new technology vectors used in previous modeling, and the historical technology vectors with their much lower input and output levels (Table 3.3). Vectors involving 75% of normally specified material inputs, and 90% of outputs, were found to be adopted quite strongly in the first crop by farmers with short cash and high shadow prices of credit. These modified vectors are in fact representative of the kinds of adjustment often imposed by farmers on introduced new technologies as they seek to fashion them to their own limited cash situations.

Differences in the ownership status of parcels, and thus of the farmer's share of the return to limited resources, may often affect the level of material inputs used. Thus, Pangasinan farmer 5 is the poorest of the case study farmers there, and must operate with very limited costs. His total farm area is 1.57 ha, of which 1.22 ha is lowland (Table 3.12). This latter comprises a partially irrigated and share-tenanted parcel of 0.52 ha, and a rainfed and fully owned parcel of 0.70 ha.

The new technologies considered for his partially irrigated parcel include transplanted IR36 with different levels of fertilizer and dry-seeded IR36 with different levels of fertilizer and chemical weedicides. On the basis of

Table 3.12. Cropping patterns under new technologies. Farmer 5, Pangasinan, Philippines.

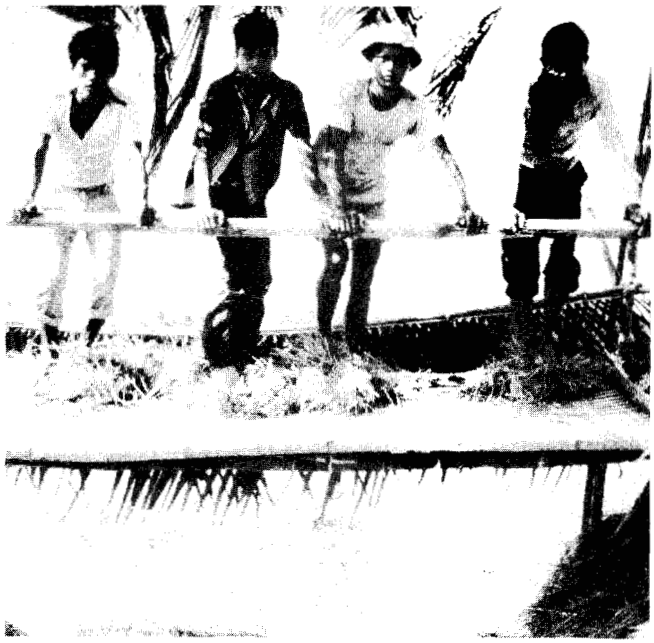
Parcels[a]	Cropping pattern
(1) Upland rainfed and fully owned (0.14 ha)	Maize -- cotton
(2) Upland rainfed and share-tenanted (0.21 ha)	IR36 DSR (no fertilizer) -- cotton
(3) Lowland partially irrigated and share-tenanted (0.52 ha)	IR36 TPR (no fertilizer) -- no cotton
(4) Lowland rainfed and fully owned (0.70 ha)	IR42 TPR (4 bags urea) /mung, 0.62 ha IR42 TPR (4 bags urea) /cowpea, 0.08 ha

[a]Total farm area is 1.57 ha (0.35 ha upland and 1.22 lowland).

average costs and returns analysis, transplanted IR36 with 3 bags of urea is shown to be the most profitable, giving a net return of $273. However, the linear programming solution indicates transplanted IR36 with zero fertilizer to be optimum (Table 3.12). Under costs and returns analysis this gives a net return of only $40. The selection of this apparently much less profitable activity is related to the optimum technology indicated by the solution for his fully owned lowland rice parcel. Here the technology with the highest net returns, transplanted IR42 with 4 bags of fertilizer, is chosen. In this situation of full ownership, the returns from investing his limited cash in a cash intensive technology which gives high returns are greater.

It is thus evident that the limited cash circumstances of farmer 5 dictate a technology which is nonoptimum on a *plot* basis for parcel 3, but optimum from the *whole farm* viewpoint. Similar differences between single plot and whole farm optima have been indicated in our discussions of other farm situations. Further analysis of farmer 5's case shows that, if his credit facilities are improved, higher fertilizer rates are also applied to the share-tenanted parcels.

The effect of changing weather conditions was also simulated in the Iloilo farm models. This was done by pushing forward the dates of first possible cultivation from week 19 (early May) for wet seeding and transplanting, and from week 16 (late May) for upland maize. These were the starting weeks assumed in the budgeting work reported above, and in fact represent conditions in a fairly early year. The dates for wet seeding and transplanting were first changed to week 24 (mid-June), and then to week 27 (early July), and the upland crop dates were also adjusted accordingly. A start in early



Foot threshing on a raised platform at Iloilo. The work is hard on the feet and very time consuming.

July would represent a late year. No adjustments were made to the stipulated end of the cropping season.

Broadly these exercises tended to increase the projected proportion of the first crop wet seeded, since doing this served to reduce what would otherwise have been an exaggerated peak of labor use where first upland maize, and then transplanted rice, were established in a relatively shorter period. Where cultivation began in week 24 and second crops were still possible, the emphasis on transplanting the second crop was enhanced, since this enabled the crop to be in the ground for a shorter period. Where cultivation began in week 27, no second rice crop at all could be grown. Thus while it had been postulated that the collapsing of available time would lead to greater peak demands on available labor, this did not occur since the farmers were still able to avoid such peaks and the concomitant high marginal value products of labor by staggering their labor utilization.

One feature highlighted in our study of how particular changes affect optimum combinations of crops is the relatively small impact which all but very drastic changes (such as the very late deferment of initial cultivation) have on the total estimated cash surpluses. This is illustrated by the relatively small variations in the total surplus earned in the different situations of

Table 3.11, and is due to the scope which exists for balancing adjustments throughout the whole farm enterprise. Such adjustments serve to minimize particular effects within given parcels or sectors. This theme of continuing adjustment, which is a very real feature of each farmer's practical situation, is carried further in Chapter 4.

DEPARTURES FROM BASIC RESOURCE SITUATIONS

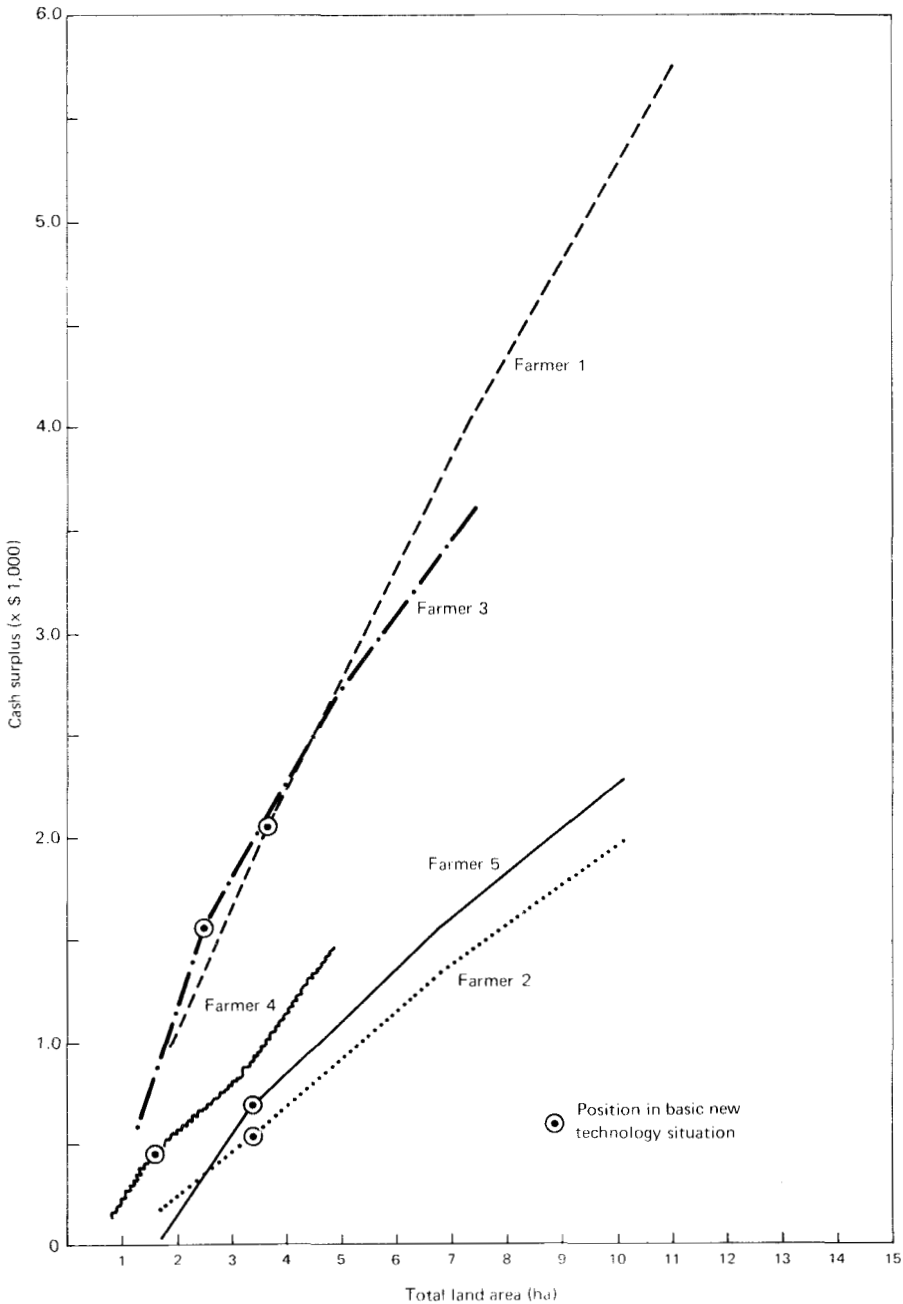
We may also use our models to estimate the effects on overall cash surpluses, and on optimum crop combinations, of relative changes in the quantities of land, family labor, and credit available to the case study farmers. Our goal here is to simulate the positions of farmers with differing relative resource endowments, and to discern whether any broad generalizations can be made. Our procedure is to start from the basic resource situation of each case study farmer in the presence of new technologies, and to add to this in turn successively increasing quantities of one of the three major resources, the other two being held constant. We also examine the results of increasing land and credit simultaneously. A key to our various resource levels appears in Appendix Table 3.2.

Land

Figure 3.3 describes the effects of raising available land areas on the cash surpluses of Iloilo case study farmers. These rises are taken to include the same proportionate mixes of upland, rainfed, and irrigated parcels as exist in the basic situations. Table 3.13 presents some effects of such changes on the crop combinations of three Iloilo farmers.

It is notable how farmers 1 and 3, each of whom has irrigated land some of which they own personally (Table 2.8), are both able to earn relatively large extra surpluses from additions to their land area. Their MVP's from extra land are high, as already shown in Table 3.7. In contrast, farmer 2, all of whose land is irrigated, cannot earn such a high extra product. This is partly because he is very short of cash for material inputs, as reflected in his high MVP of cash (Table 3.7). He must also as a tenant remit a share of his crop to his landlord. Farmers 4 and 5 also have lesser MVP's from land, owing largely to their less productive rainfed areas.

The additions to land area cause a fall in cropping intensity on all farms: the proportion of total area double-cropped drops from 100% or more in the basic situation to from 82 to 95% where the land supply is tripled and other resource availabilities are held constant (Table 3.13). This trend is of course due to the growing relative shortage of other resources. There is also some decline, which varies considerably between farmers, in the proportion of the



3.3. Variation of total cash surplus with total land area Results of models based on case study farmers, Iloilo, Philippines.

total crop area occupied by rice. This reflects both the lower cash requirements of upland crops, especially mungbean, and the greater profitability of these crops on rainfed areas once the basic consumption needs of farmers have been met. The proportion of new technologies in the optimum plan also falls on all farms, and parallels the increasing adoption of crop activities which require lower material inputs and less work. While it could again be expected that wet seeding being less labor intensive would be increasingly adopted as land increased in relation to labor and credit availability, no clear trend is evident. Indeed, the situations of all rice seeding methods vary greatly from farm to farm (Tables 3.4 and 3.5), and are determined by special factors in the manner explained below. It is pertinent to note that no allowance is made in these or other resource addition exercises for the fact that farmers' consumption would certainly increase with rising profits. A likely income elasticity of consumption for our farmers is around 0.8; this would substantially reduce the rise in cash surplus illustrated, and constrain the cash available for material input purchases in the second crop.

Labor

The projected effects on cash surplus of raising family labor availability are minor for all Iloilo farmers except farmer 1. Since these other farmers have relatively ample family workers (Table 2.8), their marginal value products of labor are generally low, and in adjustments from the basic situations soon reach zero. In the few and restricted peak labor use periods many additional workers are needed, so the extra availability of family labor projected here does not greatly reduce these peak requirements. In addition, at times of peak cultivation on these farms, an important further constraint is posed by the limited availability of carabao. For cultivation purposes men and animals are complementary, and adjustments which only provide extra labor at these times will have a low MVP. Thus additions to family labor supply where other resources remain constant have little effect on cropping intensity, the relative importance of rice, or the use of new technologies. There are nonetheless some substantial effects on rice seeding methods, which vary in nature between farms.

The rise in cash surplus from the basic situation of farmer 1 is somewhat greater, and reflects the fact that the marginal value products of his labor are positive for most of the cropping season (Fig. 3.1). This rise is assisted by the relatively ample cash supply of this farmer, which allows him to secure extra hired and shared labor without paying high interest rates. His low shadow price of cash has already been noted in Table 3.7.

Cash

Except for farmer 1 who has quite plentiful cash, all Iloilo farmers sustain some increase in surplus through additions to available credit. Except for

Table 3.13 Changes in crop selections and shadow prices of cash with variations in land and labor availability, Iloilo, Philippines, case study farmers.

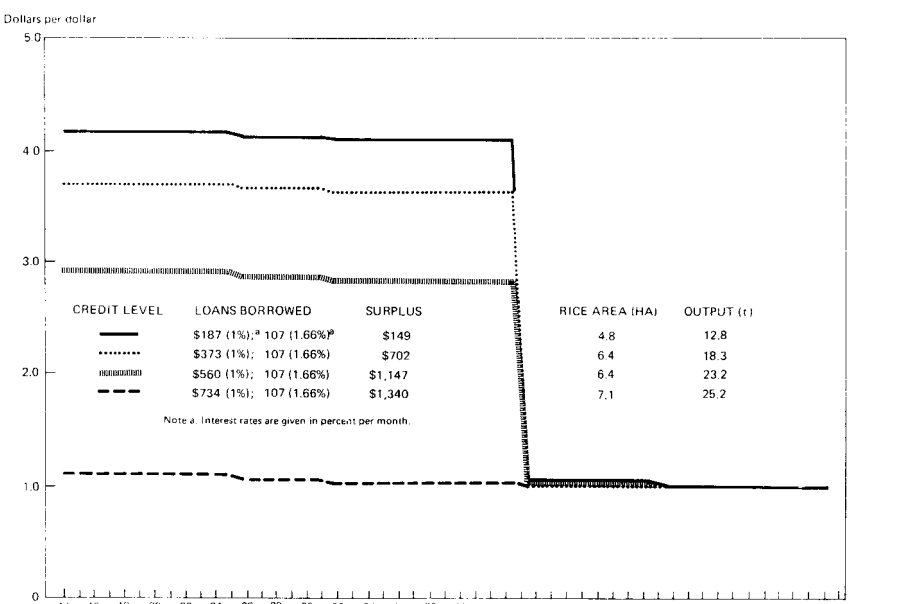
Farmer and characteristic		Land level[a]			
		0.5	1.0	2.0	3.0
1	DSR (%)[b]	0	0	0	0
	WSR (%)[b]	30	51	55	52
	TPR (%)[b]	70	49	45	48
	Rice area (%)[c]	36	35	36	33
	Rice area (ha)	1.31	2.57	5.22	7.01
	Double crop (%)[c]	100	100	100	95
	N.T. (%)[d]	75	74	48	46
	Cash shadow price ($/$)[c]	1.03	1.03	1.92	3.60
3	DSR (%)[b]	0	0	2	0
	WSR (%)[b]	100	100	76	63
	TPR (%)[b]	0	0	22	37
	Rice area (%)[c]	86	86	80	85
	Rice area (ha)	2.11	4.22	7.48	9.82
	Double crop (%)[c]	100	98	94	85
	N.T. (%)[d]	81	72	53	46
	Cash shadow price ($/$)[e]	1.71	1.22	3.95	4.60
4	DSR (%)[b]	33	18	38	49
	WSR (%)[b]	23	58	41	29
	TPR (%)[b]	44	24	21	23
	Rice area (%)[c]	60	51	43	39
	Rice area (ha)	2.53	3.46	5.07	6.48
	Double crop (%)[c]	125	97	87	82
	N.T. (%)[d]	83	72	63	62
	Cash shadow price ($/$)[e]	1.09	7.42	4.53	4.00

[a]For information on actual levels, see Appendix Table 3.2. [b]Of total rice area. [c]Of total crop area. [d]Of new technologies in total crop area. [e]Maximum price for early part of year.

farmer 2, however, such additions soon encounter zero marginal value products. This is owed essentially to the process whereby farmers consciously adjust their technologies to their basic resource situations. All Iloilo farmers except farmer 2 had specified new technologies which were almost within their ability to implement with their existing resources of cash. Only relatively small increases in credit availability were necessary to enable them to adopt the technologies in full.

Farmer 2, on the other hand, is a highly innovative and entrepreneurial farmer whose very productive technologies could fully absorb considerable increases in amounts of available credit. A more graphic illustration of the projected effects of various credit levels on his marginal value product of cash, together with his cash surplus, total rice area, and rice output, is given in Figure 3.4.

Yet in the course of the 'learning process' for new technologies, even less innovative farmers may also be expected to increase their use of cash and credit facilities. Once this learning process has reduced their assessment of risk to an acceptable level, they are likely to increase their purchases of material inputs in the expectation of good profits from doing so. In this sense the marginal value products of additional cash supply are likely to be higher



3.4. Marginal value products of cash at 4 credit levels, Farmer 2, Iloilo, Philippines.

than forecast from our model. We discuss the learning process further in Chapter 4.

In these discussions we have dealt with situations where one major resource was increased, while others were held constant. This imposed major constraints on the farmers, who in the models allocated their use of resources to make most effective use of those becoming scarcer. Increases in cash surplus are also much limited in these situations. Where resources may be increased together, however, such constraints are not so important, and much larger increases in cash surpluses are secured. The effects on projected cash surpluses of joint increases in land and credit availability are shown for Iloilo farmers 1 and 2 in Table 3.14.

Some individual cases

We may finally review in more detail some interesting effects of resource level variations for particular farmers (Table 3.13).

Thus with farmer 1 , the relative proportion of wet seeding to transplanting increases up to the stage where the land area is doubled. Although transplanted IR36 is expected to produce higher yields in farmer 1's situation, maintaining its proportion would involve payment of a very high shadow price for labor at peak transplanting and harvesting periods. Introducing more wet seeding reduces the transplanting peak, and permits a greater staggering of the harvest. When the land area is tripled, on the other hand, the proportion of transplanting rises again slightly. This is due to some substitution within rainfed areas of transplanted traditional varieties, which have lower inputs and lower outputs than IR36; scarce inputs may then be concentrated on the much more productive transplanted IR36 in irrigated areas. The cash scarcity in the tripled land situation is highlighted by a rise in its shadow price to $3.60/$ in early months of the year (Table 3.13).

A further interesting effect is that of land area increases for farmer 3, who has a combination of irrigated and rainfed parcels (Table 2.8). In this case wet seeding IR36 is expected to produce higher yields than transplanting, and is accordingly the preferred technology where resources are plentiful. It is optimal on 100% of the rice area in both the basic and the halved land situations (Table 3.13). Yet as the area of land is doubled and then tripled, increasing proportions of transplanting are indicated (Table 3.13). This transplanting largely involves the traditional variety BE3 in rainfed areas. Here again we have a situation of increasingly scarce credit and labor. Introduction of a historical technology which has relatively lower material input levels, and requires labor for transplanting after the period of peak utilization for wet seeding, allows concentration on the most productive technology of wet-seeded IR36 in the irrigated portions of the farm.

We may lastly consider the case of farmer 4, whose area is entirely rainfed. This is the only Iloilo farm where substantial dry seeding is indi-

Table 3.14. Cash surplus at different levels of land and cerdit availability.[a] Farmers 1 and 2, Iloilo, Philippines.

Credit level	Cash surplus ($) at land levels		
	1	2	3
	Farmer 1		
1	1720	3542	4837
2	1721	3783	5599
3	1721	3790	5765
4	1721	3790	5812
5	1721	3790	5812
	Farmer 2		
1	187	612	1253
2	874	1800	2514
3	1172	2769	3607
4	1172	3415	4531
5	1172	n.a.[b]	n.a.[b]

[a]For information on actual levels, see Appendix Table 3.2. [b]n.a. = not available.

cated in the optimal solutions of our model. Here there is a decline in the proportion of dry seeding from the situation with halved land to the basic situation, followed by an increase in proportion as land area rises further. With this farmer, the best yields per hectare are expected from transplanting, with yields from wet and dry seeding being successively lower.

In the situation of halved land with an emphasis on intensive cropping, use of dry seeding allows two productive rice crops to be grown on the bottomland. These then go far to meeting the relatively high minimum rice consumption requirement for this farmer of 3.6 t (Table 2.8). Once land supply is doubled to the basic situation, however, there is no difficulty in meeting this requirement, and mungbeans following transplanted rice are specified as most profitable for bottomland. As the land area rises further, labor and particularly credit become very scarce. A mix of dry and wet seeding, with some transplanting on the most productive areas, are then specified as allowing these latter resources to be used optimally. The increasing proportion of area under dry seeding is largely Kapopoy, a traditional variety with low material input requirements and relatively low yields.

These varying effects of resource level changes in individual farm situations further illustrate the complex nature of resource allocation within the whole farm context, and the complementarities which exist between various segments of the whole. Analytical models intended to serve the purpose of identifying optimum crop technologies must take cognizance of these wider aspects, if they are to have real meaning at the practical farm level.

CONCLUSIONS

We may now summarize some major implications emerging from our study of case study farm situations.

Our analyses help to substantiate the picture of a farm-household complex in which there are many important relationships, often involving complementarities, between the various cropping enterprises and consumption activities of the farm family. They clearly show that economic optima based on a whole-farm assessment may frequently differ from optima based only on appreciating the conditions of a limited plot. They denote how the introduction of a new technology on one parcel of a farm may, through its use of particular resources, and its consequent influences on their relative scarcity and marginal value products, have significant effects on the deployment of other technologies in other quite different parcels.

Our analyses also demonstrate how relative changes in the levels of available resources, of expected outputs and inputs, and of other background conditions such as ownership status, can make important differences to a farmer's optimum choice of cropping patterns. At the same time they indicate the wide scope within most farm situations for compensating resource level adjustments by farmers, such that total cash surplus is little affected.

Our assessments clearly show that the economic impact of new technologies depend greatly on the resource levels of the farmers concerned. While IR36 is widely substituted for other varieties in all our models, the intensity of its projected cultivation varies greatly with the degree of irrigation and the availability of cash for purchasing material inputs. Where no irrigation is available and cash is scarce, only low input levels will generally be employed.

Some reasonably clear projected trends in adoption of new technologies emerge from our modeling processes. Thus wet seeding commonly appears as superior for the first rice crop at Iloilo, especially when relatively higher wage levels are assumed. Transplanting is still generally best for the second crop at Iloilo, however, owing both to its expected higher yield and to its shorter period of maturity in the field. At Pangasinan, on the other hand, transplanting seems economically superior for both first and second crops owing to its greater anticipated output.

Straw stacked for dry season feed at Pangasinan. The stack is by the house compound where the buffalo is kept.

Dry seeding is not projected as profitable at either site, due basically to its low expected yield linked to uncertainty, and to its clash in demand for labor with upland crops. It seems to be indicated only where a good expected performance is combined with an excellent prospect of growing a second rice crop. The latter is not often specified, however, owing largely to a lack of sufficient water over its feasible period of cultivation. In addition upland crops, and especially mungbean, appear as more profitable means of enhancing cash surpluses once the basic rice subsistence needs of the household have been met through a first rice harvest.

CHAPTER 4

The dynamics of technology adoption

We have studied the projected economic impact of new technologies in a series of individual farm-household situations, and have checked some wider implications through our systematic variation of elements away from the basic models. We have accordingly been able to make normative predictions on the acceptance and role of important new technologies on the two research sites. We now report on and analyze the actual process of technology adoption, as it took place at the district level among the two communities of farmers from 1975 to 1980.

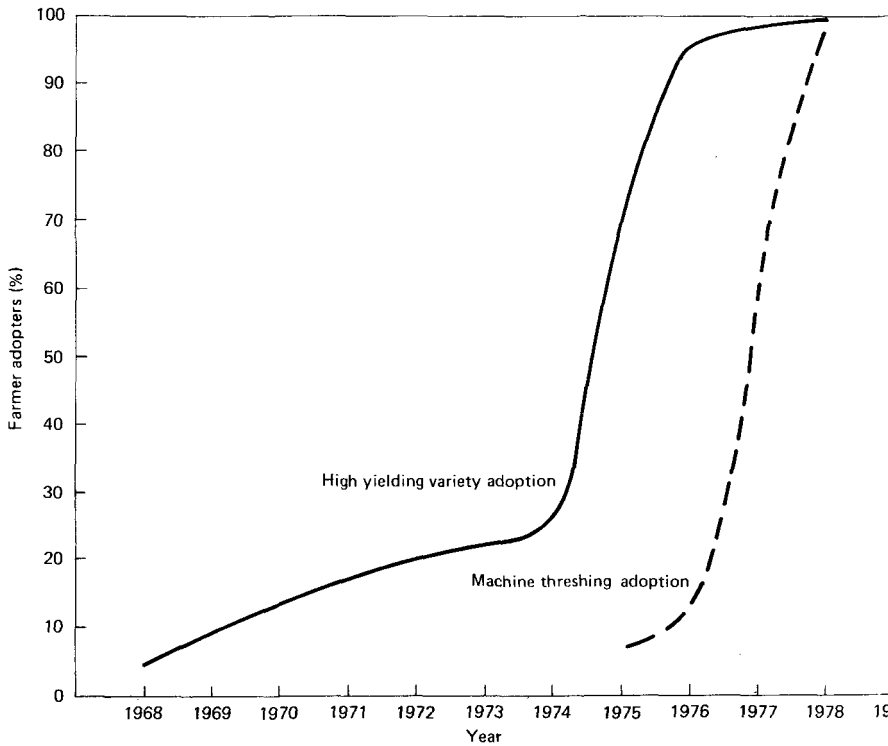
In practice, new technologies are not immediately adopted when they are introduced to farmers. Even where they are very profitable, lags are involved as they diffuse outwards over time and space from the original source. Studying this diffusion process, and the main features influencing and characterizing it, provides further insights into the relative benefits conferred by particular technologies. The broader social and economic effects of technologies, and the roles of research and extension personnel in facilitating their adoption, are usefully analyzed at these community and dynamic levels. First, however, some characteristics of technology diffusion and adoption should be reviewed.

Assume that a new technology is introduced in a given area. Its diffusion over time is the aggregated outcome of many separate decisions by individual farmers. Attempts to explain this process must show how major factors influence farmers' decisions. They must also indicate how farmers who make early decisions interact socially, and become an important factor influencing those farmers who have not yet decided to adopt.

Many researchers have studied the diffusion of technologies, and an excellent review of earlier research was made by Jones (1967). More recent work has been reviewed by Peterson and Hayami (1977), and selected references are given below. Researchers generally have been economists and sociologists, a fact which reflects the close interrelationship of economic and sociological phenomena in the diffusion process.

One commonly observed aspect of diffusion is the characteristic 'S' shape of the cumulative level of adoption over time. This is illustrated in Figure 4.1, which describes the diffusion of high yielding varieties and machine threshing in three villages in Iloilo Province. An early observation of this

pattern was in the classical work of Griliches (1957), who fitted logistic growth functions to data on the adoption of hybrid seed maize in the United States. Particular curves are characterized by three parameters — the *origin, slope,* and *ceiling.* Here the origin indicates when the technology was introduced, the slope the rate of adoption, and the ceiling the equilibrium level of use. The S-shape of the curve is determined by a learning process, whose nature is discussed below.

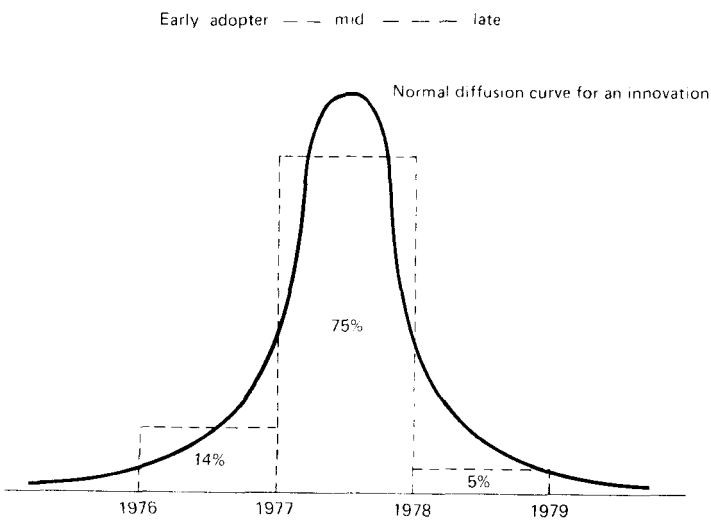


4.1. Adoption of high yielding varieties and machine threshing in three irrigated villages of Iloilo Province, Philippines (after Juarez and Duff 1980).

A main feature of Griliches' hybrid maize work was the considerable difference between separate 'S' curves for each location. These differences have also been true of other agricultural innovations, and economists have sought to explain them by economic factors. Thus the origin of the 'S' curve has been shown to depend on the size of the market for the innovation and its expected profitability; both these factors determine the expected reward (to a private firm or to a government agency) from introducing the technology into an area. The slope and ceiling of the curve are related to farmers'

expectations of profitability, as modified by resource limitations such as the availability of credit and suitable land. Recently the risk factor, springing from both yield and price variability, has also been recognized as a major element influencing both the rate of acceptance and the equilibrium level. While profitability, resource constraints, and risk are obviously important economic variables, and have statistically explained some of the differences in our three parameters, much unexplained variability remains. Similar conclusions apply to differences in the rates of adoption of high yielding varieties in the Philippines.

The learning process in diffusion has also been investigated. In one branch of sociological work, the focus has been on explaining why some individuals adopt innovations earlier than others. Using arbitrary cutoff points, Rogers and Shoemaker (1971) divided populations of adopters into 'innovator', 'early adopter', 'majority', 'laggard' and 'non-adopter' groupings by their timing of participation or innovativeness. In most instances the distribution of adopters categorized in this way has approached normal, in the manner of Figure 4.2 which includes figures describing the adopters of IR36 at the Pangasinan site.



4.2. Postulated distribution of adopter categories, and actual distribution of adopters of IR36, 36 economic cooperators at the Pangasinan, Philippines, Cropping Systems site.

Studies of people in these categories show that innovators form a small class of risk-takers characterized by a long time horizon, independence, personal initiative, practical ability, and entrepreneurship; they are actively

searching for new ideas, are prepared to adapt these ideas for their own purposes, and are willing to experiment with partial information. Iloilo farmer 2 provides a good example of such behavior. Early adopters, on the other hand, will take some risks but need more information and are partly dependent on the lead of others. A good example is Iloilo farmer 1.

The majority are those who want more complete information before acting. They are conformists and subject to the lead of others. They are often split further into 'early' and 'late' categories. Here, Iloilo farmers 3 and 4 exemplify the early, and Iloilo farmer 5 the late, majority. Laggards are those who require almost complete certainty before they adopt a new technique; they have a short time horizon, and are somewhat independent of social and conformist pressures. Non-adopters generally are the complete conservatives, with extremely high aversion to risk and high independence from community fashions. None of our case study farmers fell into these last two categories. Some generalized attributes of adopter categories are presented in Table 4.1.

Table 4.4. Generalized attributes of adopter categories (after Bollard 1979).

Category of adopter	Attitudes toward			Inter-dependence
	Risk	Time	Ignorance-	
Early	Risk-taker	High regard for future	Ignorance-accepter	Low
Mid				
Late				High
Laggard				
Non-adopter	Risk-averter	Low regard for future	Ignorance-averter	Low

Attempts have also been made to explain the positioning of individuals in these categories (Jones 1967, Rogers and Shoemaker 1971). While the attitudinal characteristics in Table 4.1 have importance here, size and specialization of business, expected profitability, level of education and skills, level of achievement motivation, and social status are major factors with direct relevance. After all these factors have been taken into account, however, there are large residuals in any statistical explanation.

Another branch of research work in the learning process comprises efforts to elucidate how individual farmers come to adopt or reject a new technology. The individual is posited as following an adoptive process of three to five stages:

1. *The awareness stage.* He learns about the technology, but lacks relevant information.
2. *The interest stage.* He becomes interested in the technology and seeks more information.
3. *The evaluation stage.* He assesses the technology in relation to his present and future interests, and decides whether or not to try it.
4. *The trial stage.* He tries the technology on a small scale, to determine its utility in his own situation.
5. *Adoption/rejection stage.* He either uses the technology on a full scale, or rejects it.

Our understanding of these stages is helped by concepts of adaptive expectations (Nerlove 1958) and adaptive economic behavior (Petit 1975). In adaptive expectations additional available information, first from outside sources and then through practical trials by the individual, progressively improves the latter's forecast of the most likely range of outcomes from applying a given technology. Thus, uncertainty gradually gives way to a measurable risk.

In adaptive economic behavior, not only expected outcomes, but the means used to achieve them, are revised with increasing information and experience. Thus the farmer will progressively alter his usage of the technology, in terms of inputs and other management strategies, as he grows more familiar with it. In addition, a widening familiarity over time acquaints the farmer with the kinds of ongoing technical decisions characteristically linked with the technology and its expected range of outcomes. In the case of early dry-seeded rice, these outcomes could include early rain followed by prolonged drought and poor germination and growth; it would then be necessary to decide whether to abandon the crop, and reseed again as soon as it becomes sufficiently wet. The outcome might also involve climatic conditions which reinforced the predisposition of dry-seeded fields to become weedy; a decision on whether or not to employ more labor on weeding than originally expected would then be required. Such knowledge of technical implications will, in itself, contribute to the farmer's eventual decision on whether to adopt the technology on a full scale.

Studies of the learning process also must recognize social influences, where individual decisions are affected by other people in the wider society in which they live. Here influences may be characterized as those of people belonging to the individual's immediate society, and those of external agents. In our case the latter are primarily agricultural extension workers.

During the early stages of adoption, the primary social influence is from

local extension or advisory workers. They normally focus on leading farmers who are innovators. These early stages represent the first part of the diffusion curve (Fig. 4.1). Yet later, with the participation of early adopters and then the early majority, we enter a phase of communal interdependence where farmers tend to follow their neighbors. There may often be what sociologists term a 'bandwagon' participation effect. This sometimes has greater influence on individuals than the more rational set of factors discussed earlier. Indeed, if we assume that the percentage rate of adoption of a technology at any time is proportional to that part of the community which has already adopted it, diffusion will follow the logistic curve already indicated as characterizing the speed of agricultural innovations.

Measured time spans in the learning and diffusion process for agricultural innovations have varied greatly, depending on the host of factors described. Thus, Griliches (1957) gave a span of 16 years from origin to ceiling for hybrid corn in the United States. Against this, Lockwood and Moulik (1972) indicated a total period of only five years for high-yielding wheats in India.

ACTUAL CHANGES ON THE SITES

In the crop year 1974-75 when research was beginning at Iloilo, rice fallow was the predominant cropping pattern on the largely rainfed land area (Table 2.3). The main rice variety was transplanted BE3, although in irrigated portions some high yielding rices were also grown. Since the early seventies, there had been a gradual spread of modem rice varieties including IR5, IR1561, IR20, IR28 and IR30, but except on fully irrigated lands these did not form a significant portion of crops grown.

In the 4 years 1975 to 1979, considerable changes occurred. In 1975-76, farmers were familiarized with the first early-maturing rice varieties IR28 and IR30 through IRRI experiments, and these were widely adopted after their official release in 1976-77. In the latter year, experiments were started using the superior early-maturing variety IR36. Farmers began to switch to this after its official release in 1977-78, and it was still the dominant planted variety as late as 1980-81. This trend, which paralleled our budgeted expectations in Chapter 3, was illustrated by the behavior of economic cooperators (Table 4.2). By 1978-79, IR36 was grown on a major section of the site. With the advent of high-yielding early-maturing varieties, wet seeding became a useful, complementary technique of establishment under most conditions. By 1979, it had become predominant.

The spread of early-maturing, high-yielding varieties enabled the double-cropped rice area to extend. This is shown by the data on cropping pattern by water management category in Table 4.3. There were some increases in double-cropping on rainfed lowland, especially between 1975-76

Table 4.2 Percentage of lowland rice area under IR36 among economic cooperators at Iloilo and Pangasinan, Philippines, 1976-77 to 1978-79.

Site	Lowland rice area[a] (%)		
	1976-77	1977-78	1978-79
Iloilo	0 (39)	24 (39)	74 (45)
Pangasinan	5 (46)	28 (36)	60 (20)

[a]Figures in parentheses are numbers of farmers monitored for lowland rice varieties each year.

and 1976-77, although the proportion dropped again in 1977-78 with the reduced growing season brought about by the late start and early termination of rains. The most notable change, however, was on partially irrigated lands, where the proportions with two or more rice crops increased to a peak of 90% in 1977-78.

While the figures of Tables 4.2 and 4.3 apply only to the economic cooperators on the Iloilo test site, the trends described were generally true of the site as a whole. All in all, over the period 1975-79, the advent of the new varieties and the use of wet seeding increased the number of cropping patterns followed by farmers.

The basic resource endowments of land, labor and capital did not alter very much at Iloilo over our period of review. The major change was the land-complementing introduction of more irrigation, which was detailed in Chapter 2. There are indications that labor grew relatively scarce, and this is reflected both in rising wages for land preparation (Table 4.4) and in the widespread substitution of machine for hand threshing. Wages for transplanting do not seem to have altered greatly, perhaps because this practice was replaced by wet seeding.

Where capital was concerned, the early availability of credit for crop inputs at reasonable terms under the government-sponsored Masagana 99 was partially withdrawn by 1978, owing to the nonrepayment problems outlined earlier. Under Masagana 99, farmers were encouraged to grow modern varieties requiring high inputs of fertilizers and insecticides. They were assisted in doing this by more active extension activities. The Masagana provision nonetheless appears to have been replaced by credit from non-institutional sources on similar terms. Probably the major change in capital endowments was the almost wholesale switch to machine threshing

Buffalo grazing loose at Pangasinan after the harvest. This can be a problem for farmers whose cropping patterns depart from the norm.

(Fig. 4.1), which characterized rainfed as well as irrigated areas in all rice growing districts of Iloilo. Increases in machine-assisted cultivations were only minor, however. The complex issues of what actually happened in the labor and capital markets are dicussed further in detail below. Prices of rice and of the major material inputs, fertilizers and insecticides, did not show any clear upward trend in the late seventies (Table 4.4).

On the Pangasinan site over the same period, change was not nearly so extensive. In 1974-75, the predominant cropping pattern was transplanted rice followed by a relayed traditional variety of mungbeans. This was substantially the situation 5 years later. Already in 1974-75, over 50% of total rice lands were under high-yielding varieties, because this part of Central Luzon (Fig. 2. I) had been subject to modernizing influences longer than Iloilo. There was a large switch to IR36 between 1976-77 and 1978-79,

Table 4.3. Percentage of cropland in various cropping patterns, by water management category, 45 economic cooperators at Iloilo, Philippines, 1975-79.

Cropping pattern[a]	Cropland[b] (%)			
	1975-76	1976-77	1977-78	1978-79
		Rainfed lowland		
	(82.8)	(62.6)	(56.1)	(52.0)
2 or more rice	20	30	19	28
1 rice + 1 or more upland	20	43	30	46
2 or more upland	–	4	2	–
1 rice + fallow	35	21	48	25
1 upland + fallow	–	2	–	1
		Rainfed upland		
	(9.2)	(9.2)	(9.2)	(9.0)
2 or more rice	–	–	–	–
1 rice + 1 or more upland	8	66	8	6
2 or more upland	5	21	73	74
1 rice + fallow	12	–	6	–
1 upland + fallow	–	13	13	20
		Partially irrigated		
	(0)	(6.4)	(4.6)	(9.7)
2 or more rice	–	39	90	71
1 rice + 1 or more upland	–	–	3	22
2 or more upland	–	–	–	–
1 rice + fallow	–	61	7	6
1 upland + fallow	–	–	–	1
		Irrigated		
	(0)	(13.8)	(22.1)	(21.3)
2 or more rice	–	96	100	96
1 rice + 1 or more upland	–	–	–	3
2 or more upland	–	–	–	–
1 rice + fallow	–	4	–	–
1 upland + fallow	–	–	–	1

[a]"Upland" implies all crops other than rice. [b]Figures in parentheses are total hectarages of parcels enumerated in the particular year.
Sources: Roxas, et al (1978); Genesila, et al (1979).

however (Table 4.2), and at the same time a substantial increase in material input levels (Maranan 1980). Wet seeding, on the other hand, was never adopted on any scale, and experiences with dry seeding were disappointing.

These occurrences again match the predictions of our earlier modeling. The shorter span of growing season at the Pangasinan site meant that, except where there was full irrigation, double-cropping of rice was not feasible.

There was even less change in basic resource endowments at Pangasinan than at Iloilo, although here too irrigation facilities were expanded. While there were some increases in usage of both hand tractors and machine threshers, these were only minor. Price trends were similar to those at Iloilo (Table 4.4).

Table 4.4. Consumer price index and deflated average[a] average prices of rice and material inputs, 1975-79.

	1975	1976	1977	1978	1979
Consumer price index	100	109	120	138	156
Milled rice[b] ($/kg)	0.27	0.20	0.28	0.28	0.28
Fertilizer[c] (no./kg urea)	0.26	0.22	0.21	0.19	0.23
Malathion ($/cc)	0.01	0.01	0.01	0.01	0.01
Labor[d,e] ($/day)	0.67	0.67	0.67	0.67	0.67
Weeding	0.67	0.67	0.67	0.67	0.67
Transplanting	1.30	1.30	1.60	1.73	2.40
Land preparation	1.30	1.30	1.60	1.73	2.40

[a]By the consumer price index, 1975 = 100. [b]In Manila. [c]In Iloilo City. [d]On the Oton-Tigbauan site. [e]Without meals.
Sources: Consumer price index: National Census and Statistics office 1975-79. Milled rice price: Central Bank of the Philippines 1979. Fertilizer and malathion prices: IRRI 1979b.

Experiences with selected technologies

The speedy diffusion of IR36 at both sites could in part be attributed to previous familiarization with other early-maturing and high-yielding varieties in the early seventies, especially at Pangasinan. Had IR36 been the first of the new varieties, change would almost certainly have occurred more slowly. Now the step was merely to an even higher yielding and more profitable rice (Table 3.3) which was suitable over a wide range of conditions, palatable, and possessed greater tolerance for drought stress. This step was both attractive and easy to make.

Adoption proceeded further at Iloilo than at Pangasinan (Table 4.2), because there were few other high-yielding varieties to displace, and because IR36 was especially suited to the area. At both sites, material inputs

to IR36 were higher in irrigated than in rainfed areas. This was due to the greater yields and lesser uncertainties attached to irrigated cultivators. A similar distinction in input levels had applied to high-yielding varieties previously grown.

With wet seeding, the picture was not so clear, and as reported in Chapter 2 differed between the two sites. At Oton-Tigbauan a crude form of broadcasting followed by harrowing had been used extensively by farmers prior to the advent of BE3 in the mid-fifties. Its use had continued on the limited areas planted to fixed-maturity local varieties like Camaros and Arabhon. Wet seeding was now found especially applicable with the first crop of IR36. In addition, it had the advantage of saving transplanting labor in a situation of apparently growing labor shortage. Although more labor was often required for weeding, this was in the period after the peak demand for labor in initial cultivations, when its marginal value product was low (Figs. 3.1 and 3.2). Cash saved from hiring transplanting labor could also be used very productively in applying fertilizers to IR36, which was particularly responsive. The yields from wet seeding and transplanting at Iloilo were similar.

Wet seeding thus accompanied the spread of IR36 in a combination that was generally very profitable. By 1978-79, it was used for a large portion of the first crop. These developments were also encouraged by the special provision of package credit under the Masagana 99 program.

Transplanting was retained at Iloilo, however, for certain high parcels where water accumulated late. Transplanting was also used by farmers in some cases because its yield was either expected to be greater (as with Iloilo farmers 1 and 3, or less variable and therefore less risky. Again, transplanting remained common for the more limited areas where a second rice crop was possible. As indicated previously, yields from transplanting the second crop were generally expected to be higher. Thus in 1977-78 for IRRI cooperators growing second crops on rainfed land, an average recorded yield of 2.2 t/ha from transplanting compared with only 1.5 t/ha from wet seeding (IRRI 1979a). The planting of seedlings aged 2-3 weeks or more also reduced the period to maturity from 105 to 85-90 days, and lessened the probable loss of yields from drought stress late in the season (Bolton and Zandstra 1980). At this later stage of the crop year, after one harvest already had been gathered, cash to pay transplanters was not so scarce and was often available at a low shadow price (Fig. 3.4).

At Pangasinan, the rejection of wet seeding followed the indications of our case study models. Generally, it appeared to produce yields inferior to those from transplanting. It was harder to implement than at Iloilo owing to the relatively slower onset of rain (see Figs. 2.3 and 2.5), to greater difficulties in working the heavy clay loams of the test site, and to heavier weed growth. In addition, there did not seem to be the clear possibility of labor shortages that existed in Iloilo. All these factors acted to offset the actual or

perceived benefits of savings in transplanting, making the technique appear unprofitable to most farmers. Despite the efforts of IRRI personnel to develop wet seeding, it proved unpopular even with farmers cooperating in the IRRI tests and experiments. It was tried by other farmers on the site, but was found unsuitable, then generally rejected.

Machine threshing was adopted readily at Iloilo (Fig. 4.1), but was not especially popular at Pangasinan. Its major attractions for Iloilo farmers were undoubtedly the saving of labor inputs in an expected situation of labor scarcity, along with improved timeliness. Juarez and Duff (1980) estimated that these small threshers reduce labor inputs in threshing modern varieties from 26.0 to 1.4 man-days/ha. In addition, they allow a quick clearing of sheaves, which then leaves the ground free. The consequent ability to proceed quickly with more cultivations is very important where a second crop is encouraged, and labor and time are expensive. Machine threshers are generally more technically efficient than purely manual approaches, because handling losses are less. Their smallness and ease of operation, together with their availability under the usual contractual arrangements, make them highly desirable pieces of machinery which can be employed easily even in harvest areas of a few hundred square meters. It is thus common for machines to be used by several farmers in one day. The cost to the farmer of harvesting and threshing still remains at one-sixth of the harvested crop, with one-third of this share being passed to the owner of the thresher instead of to threshing laborers. The total cost in kind of threshing to the farmers is slightly less, because the shorter period of harvesting and threshing means that fewer meals have to be supplied to participating workers.

From the viewpoint of the laborers, machine threshing eliminates the slow and very hard work of foot threshing, which provides a lower return per unit of time spent than harvesting. The current balance of labor supply and demand in the Iloilo study area is such that, at least during harvesting and land preparation, there is plenty of alternative employment available at a higher wage rate than hand threshing.

At Pangasinan, second rice cropping did not increase much with improved varieties owing to the shorter growing season (Fig. 2.5). There was also more labor available for harvesting and threshing. In this situation, there was no great stimulus for introducing small machine threshers, which in 1981 were still not important.

The technology of dry seeding was investigated and promoted by researchers at both test sites. It seemed an excellent possible approach to better use of the limited growing seasons, through increasing the possibility of a second rice crop. In practice, however, this expectation was not fulfilled, and the use of the technique remained minor on both sites. The chief reasons for its rejection by farmers have been outlined in Chapter 2, but the circumstances may now be explained more fully.

In the situation originally envisaged by researchers, dry seeding would take place shortly before a time of light, sporadic rainfall. This rain would provide adequate moisture for germination, and would be succeeded by intermittent showers to sustain the germinated crop and allow good establishment. The actual outcome was rarely like this, however, since farmers generally seeded later than anticipated because of delayed initial land preparation. At Pangasinan with its heavier soils, cultivation did not begin until after early rains had softened the soils and reduced power requirements for cultivation to a level within the limited capacity of the buffalo used as work animals. Again, once dry seeding had been completed, rainfall was often not sufficient, so germination was very poor. Establishment of a new wet-seeded or transplanted crop then had to be effected. In other cases, uneven germination caused subsequent difficulties with uneven ripening. This had not mattered with traditional, photoperiod-sensitive varieties, but with fixed-maturity rices was a crucial disadvantage.

Other problems arose from a characteristically vigorous weed growth, which either needed expensive, pre-emergence chemical control with butachlor, or an exceptionally high input of hand weeding. Where weeds were not properly controlled, they both reduced yields and caused problems for subsequent crops. Such weed control was expensive at a time of year when shadow prices of both cash (for buying herbicides or hiring labor) and family labor (for weeding) were generally high, owing to the need to cultivate other crops. Again, if the dry-seeded crop failed, more expenditure on seeds and cultivation for a new crop would have to be incurred.

On top of all these difficulties, there was no certainty that a second crop of rice would be possible. Except in very limited locations, the last feasible date for planting of a second crop might not be achievable because of resource constraints within the whole farm business at turnaround time. In addition, there were sometimes problems stemming from lack of access to the dry-seeded parcels by draft animals, owing to the continuous presence of immature rice in intervening parcels belonging to other less innovative farmers. So far as growing a second *upland* crop was concerned, dry seeding gave no real advantage. There was no urgency in this case, since it was normally necessary to wait after an early harvested rice crop until fields were sufficiently dry, to avoid rotting of seeds under excessively wet conditions (Fig. 4.3). At the Pangasinan site with its high-pH soils, dry seeding had an additional problem of iron deficiency, especially near the irrigation canals.

All these difficulties meant that for most farmers the substitution of dry seeding for wet seeding or transplanting was a considerable risk. This risk might well not be rendered acceptable through the perceived advantage of a possible second rice crop. Indeed, the various factors just described accounted for the low expected yields from dry seeding in the modeling in

Tractor cultivation to speed turnaround for a second rice crop at Iloilo. Contract work like this is expensive.

Chapter 3. They also explained the rejection of dry seeding in most of the cases treated (Tables 3.4 and 3.5).

Finally, for mungbean, the introduction of higher yielding, shorter maturing varieties, combined with simple but effective methods of pest control, seemed likely to be more profitable than traditional practices at each site. EG2 at Iloilo, and CES ID-21 at Pangasinan, gave yields of over 1 t/ha when grown experimentally with recommended preflowering and postflowering applications of monocrotophos. Actual experiences in the practical farm context were disappointing, however, and in 1978-79 the original upland crop technologies were still predominantly used by farmers.

The basic difficulty once more was climate. While successful early planting of mungbean was shown to be strongly linked to higher yields, it frequently failed due to excess moisture. On the other hand, later plantings (after early October in Iloilo and early November in Pangasinan) ran into increasingly dry conditions which drastically reduced both stand at establishment and yield. The incidence of attack by beanfly also rose progressively. In addition to these physical factors, higher yielding variety seeds were expensive, and would remain so until they were adopted quite widely. The costs of recommended pest control inputs were also considerable. In

practice farmers were hesitant to incur extra costs where risks of low yields, or even crop failure, were substantial. They continued to follow traditional practices which, despite their low average yields of around 250 kg/ha, at least involved no substantial input costs, and accordingly imposed no great loss when they failed.

The proportion of rainfed lowland under upland crops following rice at Iloilo showed no clear trend (Table 4.3). The variations of 20-46% were attributed more to climatic conditions within a particular year than to any other factor.

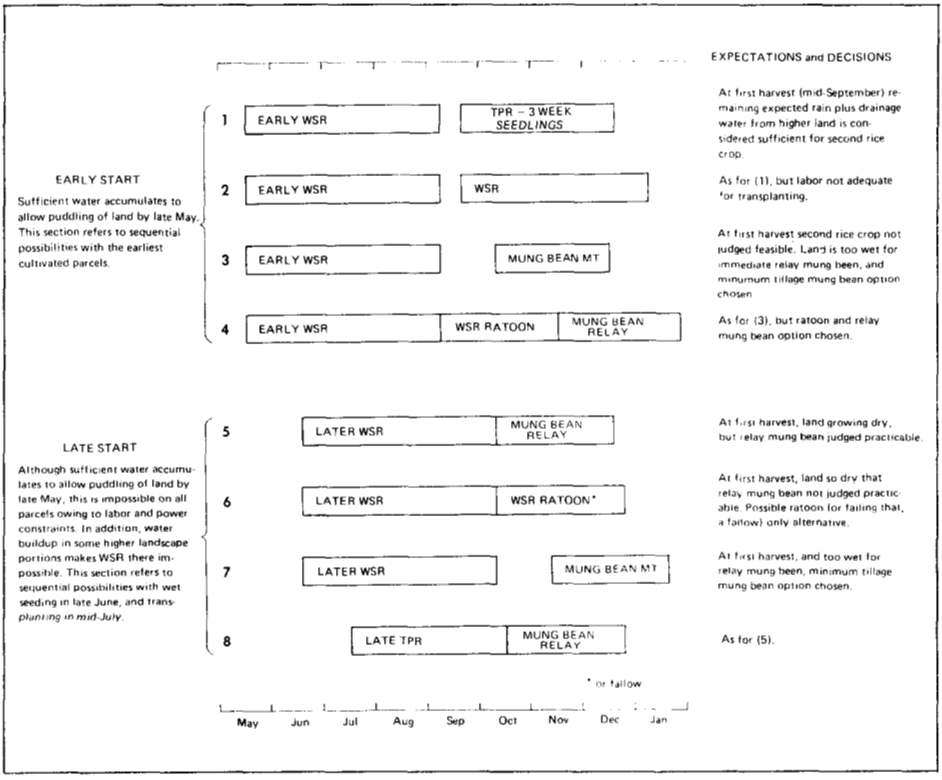
Sequential aspects

It is important to note that while some technologies have been discussed here as competing alternatives, this is not the full picture. For these technologies are also successive options in a sequential decision-making process, where a farmer's choices alter with his perception of climatic factors and resource availability. In this process, the technologies may complement one another, as demonstrated in the modeling in Chapter 3. Although a particular technology may not be adopted under normal conditions, it may become suitable under climatic circumstances which occur only once or twice every few years.

Some links between technologies in the sequential process are described in Figure 4.3. This applies to conditions in those restricted lowland rainfed areas of Iloilo where second rice crops may sometimes be grown. The figure refers to operations over time, and includes an appropriate time scale. Several of the technologies just discussed are considered, and indeed may be adopted together on separate parcels.

In this illustration we do not include the probability of dry seeding. It may have been rejected, or never considered. We assume that wet seeding is the chosen method of establishing the first rice crop, whenever it is feasible. As time passes, however, and wet seeding is completed in lower landscape positions subject to power and labor constraints, the buildup of water in higher positions may make wet seeding impossible. This is recognized in time to establish a seedbed, which then allows higher parcels to be subsequently transplanted (alternative 8, Fig. 4.3).

If the earliest wet seeding of IR36 is in the last week of May, the initially sown parcel will fall due for harvesting in the first week of September. Given adequate power and labor resources, and the farmer's perception of sufficient water for a second rice crop, a seedbed might be established in the same week, and the parcel transplanted in the third week of September (alternative 1, Fig. 4.3). Assuming that 3-week-old IR36 seedlings were used, they would be ready for harvesting 12 weeks later, in mid-December. Alternatively, if labor was short or expensive in September, wet seeding might be employed in late September to give a harvest in early January



4.3. Some cropping sequences on rainfed land under various conditions, Iloilo, Philippines (WSR = wet seeded rice, TPR = transplanted rice, MT = minimum tillage).

(alternative 2, Fig. 4.3). This could be expected to give a substantially lower yield than transplanting (Bolton and Zandstra 1980). As already indicated, these options of second rice crops, whether by transplanting or wet seeding, will only become available in some years, and then only in restricted parts of the rainfed complex. In other years, even on these early wet planted areas, an upland crop or ratoon may be the only feasible options (alternatives 3 and 4, Fig. 4.3).

For those parcels whose first crop is either wet seeded or transplanted in June or July (late start, Fig. 4.3), it may be October or later before the first harvest. By then, under normal weather conditions, a second rice crop on rainfed lowland will almost certainly be impossible. The farmer's choice in these parcels will lie between an upland crop, a rice ratoon, or a fallow. If in early October he perceives the land to be growing dry, he may decide to underseed the rice crop in its final week, according to the traditional relay cropping method (alternative 5), or to omit the upland crop entirely and to

fallow the land with a chance of some ratoon (alternative 6). If the soil is still wet, he may decide to harvest the rice, wait a little, and then broadcast his upland crop following some minimal tillage (alternative 7). This last option may be taken only in some years under climatic conditions at Iloilo. Similar possibilities apply with lands transplanted in mid-July (alternative 8).

In cropping seasons when rainfall continues late (Fig. 2.3), it may be possible to contemplate following the second rice crop in alternatives 1 and 2 by either an upland crop or ratoon in early January. Usually by this stage, however, the only possibility is a fallow. Indeed, as already indicated (Table 4.3), a single rice crop followed by a fallow is still very common on rainfed lowland. In the dry year of 1977-78, it covered 48% of the area farmed by economic cooperators.

Figure 4.3 only presents a basic frame of sequential decisions which might be made by a farmer in the circumstances defined. Other facets of technological choice, such as the variety of seed (affecting yield and maturity data), the inputs of fertilizers and pesticides, and the hours spent on different activities by men and animals, will also be varied to a degree with changing climatic and environmental events and resource availabilities. Any study of how technologies and associated inputs are adopted must take these sequential dimensions into account.

Similar ranges of sequential choices are likely to face the cultivators of most rainfed areas. In irrigated lands, however, the ranges (and their accompanying uncertainties) will generally be reduced.

FARMERS' BEHAVIOR IN ADOPTION

The behavior of economic cooperators in adopting IR36 is detailed in Tables 4.5 and 4.6. The sample of 45 Iloilo farmers has been divided into 'early', 'mid', 'late' and 'laggard' groupings, according to their adoption behavior over the 2 years 1977-78 and 1978-79 (Table 4.5). Since adoption of IR36 was rapid (Table 4.2), the 'mid' and 'late' groupings are divided according to the degree of adoption within the one year, 1978-79.

Subject to basic limitations of the small sample, the Iloilo figures contain interesting trends. Again confirming the prognostications of our earlier modeling, adoption was quite positively linked to degree of irrigation. As already indicated, this is likely to have been due to higher expected yields and to the lower risk of changing to a new variety under irrigated conditions. Adoption was also (except in respect of the two laggard farmers) correlated with degree of owner operation, and assessed emphasis on the goal of setting aside money to buy material inputs. As discussed in Chapter 3, owner-operators can be expected to favor new income-producing opportunities more than share-tenants, since they gain the full benefit of any

improvement. There was little relationship between adoption and total farm area, however.

More detailed checking on the reasoning of the four early adopters and the two laggards showed that the early adopters were particularly encouraged to use IR36 by the introduction in 1977 of irrigation on parts of their previously rainfed land, and by the possibility this early-maturing variety then offered (in comparison with the photoperiod-sensitive BE3) of getting two rice crops. The early adopters were also stimulated by the reported high yields and resistance to pests and diseases of this new variety. These farmers were not particularly rich, and were classed in the middle-income group for the Iloilo site.

In respect of the two laggards, both had lands primarily in higher landscape positions where water availability was a problem. They continued to use BE3, since they believed it to be more resistant to drought than IR36, and to give higher yields under these circumstances where two crops were never possible. They were also encouraged in using BE3 by its good eating quality and lower requirements of purchased inputs. One of these laggards was moderately wealthy, and derived income from hiring out a hand tractor and portable thresher. The other was poor.

Adoption of IR36 at Pangasinan also occurred rapidly, and there were three very early adopters in 1976-77 (Table 4.6). Here again adoption was positively related to degree of irrigation, but seemed to have no particular

Table 4.5. Average features of IR36 adopters, 45 economic operators at Iloilo, Philippines, 1977-79

Feature	Early[a] (>90% 1977-78)	Mid[b] (80-100% 1978-79)	Late[b] (1-80% 1978-79)	Laggard (0% 1978-79)
Farm area[c] (ha)	1.57 (4)	1.90 (23)	1.76 (16)	2.17 (2)
Lowland rice area (ha)	1.45	1.63	1.58	2.00
Rice area irrigated (%)	65	30	10	(4)
Farmer's schooling (yr)	7	5	4	6
Farmer's age (yr)	48	53	46	43
Owner-operator[d] (%)	50	40	19	50
Weight to input-purchasing goal[e]	84	80	45	88
Adoption[f] (%)	96.5	98.4	51.1	0

[a]Percentages in the headings are proportions of total area planted to IR36 first crop. [b]Excluding "early" adopters. [c]Figures in parentheses along this row are number of farmers in each class. [d]This classification refers to tenancy mode of largest parcel. [e]Farmers are scored 0-100 according to the importance they place on setting aside money to buy modern inputs at recommended levels. [f]In the years of classification.

Table 4.6. Average features of IR36 adopters, 34 economic cooperators at Pangasinan, Philippines, 1976-79.

Feature	Early[a] (adopted 1976-77)	Mid[a] (adopted 1977-78)	Late[a] (adopted 1978-79)	Laggard (not adopting)
Farm area[b] (ha)	1.92 (3)	2.28 (28)	1.99 (2)	1.44 (1)
Lowland rice area (ha)	1.12	1.85	1.61	1.12
Adoption[b,c] (%)	46 (1)	33 (16)	2 (2)	0 (1)
Proportion rice area irrigated 1978-79 (%)	100	74	28	94
Fertilizer input 1978-79 (kg/ha)	294	209	289	258

[a]Excluding farmers in other classes. [b]Figures in parentheses along this row are numbers of farmers to which existing data refer. [c]Average percent of total area planted to IR36 first crop in the year of classification.

connection with farm area. The early adopters also had markedly higher fertilizer inputs than other farmers.

The behavior of the Iloilo cooperators in adopting wet seeding was also examined. None of the above variables seemed to have significant connections with earliness of adoption, which again occurred rapidly over the period 1976-77 to 1977-78.

The adoption data at Iloilo and Pangasinan match quite well the findings of Barker and Herdt (1978), who in examining differences in adoption of modem varieties, fertilizers, and insecticides in the Philippines, Malaysia, and Thailand found that these did not vary significantly with hectarage farmed. These workers did not classify the samples by degree of irrigation, however.

Personal behavior

The adoptive process posited earlier characterized the early innovators of our study, who normally passed through all five stages outlined. There is also no doubt that both adaptive expectations and adaptive economic behavior have significance in the reality of these stages. A major feature observed at Iloilo and Pangasinan is the merit attached to technologies which can perform flexibly in the adaptive behavior context. A technology is favored if it can provide attractive economic rewards at a range of input levels, and is also resilient in face of the common sets of circumstances calling for tactical decisions.

An excellent second crop of mung bean at Pangasinan. This was broadcast as a relay after rice.

Thus, IR36 not only gave exceptionally high yield at high fertilizer and insecticide levels, but remained economically dominant when these inputs were maintained at low rates similar to those employed with traditional varieties. Again, IR36 was resilient to drought stress late in the growing season, and adapted well to transplanting from the seedbed at ages ranging from 3-7 weeks. In similar fashion, the popularity of wet seeding for the first crop at Iloilo sprang from the fact that it could be implemented at a reasonable standard even where only low tillage inputs were available, and that its schedule of weeding could be adjusted according to labor availability (and the shadow price of labor). It could also be expected to give similar yields to transplanting where similar material inputs were used. In contrast, the improved mungbean EG2 would give greater yields than local varieties at Iloilo with high applications of insecticides and fertilizers and in an adequate moisture regime. At lower traditional material input levels or where very dry conditions developed, however, its yields were less than those from ordinary local seed. These were important reasons for its rejection.

Such experiences indicate that the personal utilities attached by farmers to technologies depend on their profitable performance under the range of

input levels and climatic conditions characterizing their particular situations. Farmers also favor technologies which they can tailor to their own circumstances, and are then further adaptable as these circumstances change. Average expected profitability and risk are accordingly inadequate by themselves as criteria, and these wider aspects must also be taken into account. We use the term 'robust' to describe a technology which stays profitable at changing input levels and in changing climatic circumstances. It was also observed at both Iloilo and Pangasinan that once farmers had found lR36 profitable at relatively low input levels, they moved in subsequent seasons to progressively increase their material inputs, especially of fertilizer. Because this too was profitable, it had the effects described later on local markets for credit.

In moving from early to late adopter classes at our two sites, we find that personal decisions over the five stages are overtaken by social influences. While lRRI research workers had some effect through their scattered trials and experiments, their major role was in influencing early innovators. For later adopters, the first three stages of learning also included social interaction, and the fourth stage was eliminated. For them, the cultivation practices of others provided increasing practical evidence of the success of IR36 and other technologies. Again, the very success and increasingly widespread adoption of these technologies generated fashionable pressures to conform on those who had not yet taken up the new innovations. Most later adopters accepted technologies within the limits of their own resource and environmental constraints, and without any preliminary trial.

Wider patterns

It is relevant here to check the behavior of farmers with new technologies in the environmentally similar areas surrounding our two research sites. It could be postulated that adoption behavior on the sites resulted directly from the continuing influence of IRRI research workers with their experiments and trials. As such, it was quite untypical of what happened under more normal circumstances.

In fact, adoption behavior in these peripheral areas was close to that on the sites. In localities adjacent to the Iloilo research area, farmers when questioned appeared to have little knowledge of IRRI, and the direct influence of research per se on the site was obviously very small. Yet, these farmers had over the years of the IRRI project adopted and rejected the same technologies: IR36, wet seeding, and machine threshers had become widespread, but little dry seeding had been used. The reasons for these actions seemed similar to those analyzed earlier.

The main differentiating element was the absence of IRRI and the sporadic presence of officers from the Bureau of Agricultural Extension. The demonstrations by these officers of how new technologies and associated

inputs should be used had been a limited but still highly useful contribution, which helped early innovators. The basic suitability and robust profitability of the three accepted new technologies meant that farmers would readily adopt them without major programs on the part of extension workers. A similar diffusion of technologies had also taken place in the three irrigated villages quoted earlier (Fig. 4.1), although these were all much further away.

TOWARDS APPROPRIATE TECHNOLOGIES

We have tried to appraise in a dynamic context the relative economic merits of new technologies at our two research sites. We have shown how these appraisals relate closely to those made through the modeling in Chapter 3. We now define as an 'appropriate' technology one which is profitable in the situations of resource and environmental constraints pertinent to our target farmers. It is also robust in the sense of remaining profitable over the ranges of conditions commonly encountered in these situations.

Our six major new technologies are matched with important attributes in Table 4.7. It is clear from earlier discussions of these attributes why IR36, wet seeding at Iloilo, and machine threshing are appropriate, while the other technologies are not. All the profitable and thus widely adopted technologies are well tailored to the resource situation of the farmers. IR36 yields more with existing resources, and will profitably absorb greater material inputs and labor if desired. Wet-seeding the first crop at Iloilo does not affect yield, but reduces to one-quarter the high-priced labor inputs at peak cultivation time. Although it doubles weeding inputs, it allows them to be staggered to match times of more plentiful available labor at a low shadow price. Machine threshing reduces the physical labor input to less than one-quarter of foot threshing levels. While its cost in kind remains at one-sixth of the crop, the improved timeliness means that cleared ground can be used immediately for further cultivations. With the exception of labor inputs in threshing, these three technologies are also robust to input and environmental changes. In addition, IR36 and wet seeding complement each other.

In contrast, the three other technologies are not nearly as suitable. Wet seeding at Pangasinan disqualifies itself by its low yield. Dry seeding is rejected by its low yield, very high weeding inputs, and inflexibility to environmental changes. EG2 mungbean is expensive in both material and labor inputs, and while it can give a much higher yield, it is not robust to either input or environmental changes.

Table 4.7. Attributes of new technologies.

	Rice IR36	WSR 1st crop Iloilo	WSR 1st crop Pangasinan	DSR	Mungbean EG2	Machine threshing
Basis of comparison[a]	other common HYV[b]	TPR	TPR	TPR	Local varieties	foot threshing
Output	higher	same	lower	lower	higher	slightly higher
Labor inputs						
Peak cultivation	same	quarter	quarter	half	higher	same
Harvesting-threshing	according to yield	same	lower	lower	higher	quarter[c]
Weeding inputs	same	double	double	treble	same	same
Fertilizer inputs	according to yield	same	same	same	higher	same
Insecticide inputs	according to yield	same	same	same	higher	same
Robustness[d]						
Input changes	good	good	poor	poor	poor	poor
Environment changes	good	good	poor	poor	poor	poor

[a]For all items except robustness. [b]HYV = high-yielding variety. [c]But cost is only slightly less (still 1/6 share of crop, but minus meals). [d]The attributes of robustness involve a broader comparison with other available technologies.

FACTOR AND PRODUCT MARKET CHANGES

Adoption of new technologies by significant groups of farmers can lead to major changes in the levels and patterns of resource use. On the other hand, resource availability, both at the individual farm-household level and at the aggregate community level, determines the tempo and manner of technology adoption. Our exercises at the two sites yielded valuable insights into the dynamic interaction between the resource base and technology adoption in rice-based cropping systems.

In general, the effect of new technologies is to raise the level of input usage (Table 3.3). Depending on the nature of the demand and supply schedules, this tends to increase input prices. Because this change, and a parallel decline in the price of outputs, occurs progressively over time, the maximum benefits from new technologies may be expected to accrue to early adopters. Yet, the actual or anticipated input price rises will, *in themselves,* encourage adoption of further technologies which help to counter this trend. This process is illustrated by the spread of wet seeding and machine threshing at Iloilo. The anticipation of price rises may also call forth previously unexploited resources which have similar countering effects. An example here is the development at Iloilo of informal credit.

Where attempts to grow two rice crops were made, the period of land cultivation for the first crop was compressed into a relatively early peak time. The period of first crop harvesting was also followed quickly by cultivations for the second crop. These two measures helped to maximize the chance of growing a good second crop by avoiding the expected drought stress (which also occurred under partially irrigated conditions) later in the year. If land preparation, harvesting and threshing technologies had remained unchanged from traditional approaches, a second crop would have caused high demands for labor at both peak periods. It still might not be unduly expensive if ample hired workers were available at reasonable wages. This would imply that the supply of labor was highly elastic, however, and that big increases in its price did not occur with raised demands for it. Even in our models of Chapter 3, the enhanced use of fixed-price hired and share workers accompanying the use of new technologies caused increases in the marginal value products of labor (Figs. 3.1 and 3.2). These small rises in shadow price are nonetheless economic propositions for farmers who have adequate cash resources.

In actuality at Iloilo, the supply of hired labor in the short run was rather limited. While hired labor use had always been common, particularly for transplanting and harvesting, this came from the smaller farm households. The supply of labor within the community was in equilibrium with the demand for labor arising from the single rice cropping system. In the absence of migratory labor, seasonal fluctuations in labor demands were reflected in seasonal but relatively minor changes in wage rates. Thus, the projected increase in demand for labor was bound to raise its price substantially. Indeed, there were grave doubts as to whether labor would be obtained at all in some circumstances in the short run, because the supply of migratory labor from surrounding areas was very limited. This applied especially to the transplanting of the second crop, which under traditional conditions was lower paid than harvesting. At the same time, there was also evidence that total labor supply was declining with outmigration, and that even under the maintenance of traditional technologies an increase in wages could be expected.

It accordingly seems that if no innovations were available to reduce the labor demand, only those farmers who could secure the necessary workers and afford to pay substantially higher wages for all operations could have adopted a rice-rice pattern. This could not be adopted widely throughout the community unless the higher wages attracted labor from other areas.

Fortunately for our Iloilo farmers, wet seeding and machine threshing both became available. Wet seeding drastically reduced the need for hired labor in crop establishment. Machine threshers did the same at harvest time. The latter also increased technical efficiency and timeliness, and their owners' one-third share of the traditional one-sixth payment to the workers

did not seem to cause resentment. Indeed, not only were the workers' returns for time spent with the machine threshers higher than they had been under foot threshing arrangements, but as previously indicated ample further employment opportunities were generally available elsewhere. Given the drudgery associated with manual threshing, workers even in relatively labor surplus villages might have felt that the foregone earnings were below their opportunity cost.

As a result of these developments, prospective bottlenecks in labor supply were eliminated, and the adoption of the double rice cropping patterns proceeded within the constraint of climatic and soil factors.

The house compound. A range of tree crops and vegetables are characteristically grown for home consumption

Scrutiny by Jager (1980) of total labor inputs per hectare at Iloilo from 1975 to 1979 shows that, after rising greatly in 1976-77 when transplanting and foot threshing were retained but double cropping was introduced, they subsequently fell again to earlier levels with the introduction of wet seeding and machine threshing technologies. This aspect is considered further in the discussion of factor shares below.

While the wages for weeding and transplanting remained constant over our period of development, the real price of labor for land preparation still rose considerably (Table 4.4). The fact that the share of yield retained by

labor in harvesting and threshing remained at one-sixth denoted an actual increase in rate per hour, because the new varieties gave higher yields. It is interesting to record that, despite these changes, there was little increase in use of another important new machine technology, mechanical cultivators. These were almost certainly held back by rapidly escalating gasoline prices, which made them far more expensive than man and animal cultivation even at their substantially enhanced real prices.

An increase in availability of reasonably priced informal sector credit was a further interesting response to the introduction of new technologies at Iloilo. As previously indicated (Table 4.7), the widely adopted high-yielding rice variety IR36 was robust to input changes, and this included its economic response to much higher inputs of fertilizer. An appreciation by farmers of this potential was aided in 1976-78 by the Masagana 99 program, whose package of credit-supported practices included IR36 and an application of about 250 kg of urea and 16-20-0 compound in equal portions. By 1978, however, the Masagana program was in serious difficulties owing to the failure of many participants to repay loans, and to the banning from participation of others because some members of their group were defaulters. By 1980, Masagana was virtually unused in Iloilo, and the only major formal sector alternative was the Rural Bank, whose subsidized lending policies at l%/month almost exclusively benefited larger farmers with collateral. The deficiencies of this latter type of rationing policy in raising the cost of loans to other borrowers have been well analyzed in a wider context by Gonzales Vega (1977). Under these circumstances it might have been predicted that the high cost of informal loans, which in the period of traditional technologies had an implicit interest rate of l0-12%/month, would make the continued use of high fertilizer inputs by the majority of farmers impossible.

In practice this did not occur, and a review in 1980 showed that most farmers continued to use quite large fertilizer applications. Further checking showed that the required credit had been provided by the informal sector. One arrangement for such credit involved the provision of fertilizer at planting time, and a repayment in terms of unmilled rice directly after the first harvest. Comparing the prices of fertilizer and of unmilled rice at the appropriate times denotes the reasonable interest rate of around 3%/month. The persons involved in providing this informal credit were relatives and close business contacts, such as landlords. Perhaps 80% of the current credit requirements of farmers in the Iloilo area were provided through the informal sector in 1980.

In this context, the Masagana 99 program appears as a useful stimulus, which enabled farmers to appreciate the benefits gained from applying relatively high applications of fertilizer to new rice varieties. Following this learning experience and the parallel reduction of uncertainty, those provid-

ing informal credit in the community felt assured of a reasonable return to lending, and were prepared to extend loans at fair rates.

Rice prices did not alter markedly on the sites over our period of study (Table 4.4), being more influenced by national rice price policies. However, introduction of new technologies may also have major effects on output prices, and in general will tend to depress them. Thus, a careful preliminary survey of product market conditions in the target area is a vital part of any initial review preceding the introduction of new technologies. It should be carried out in conjunction with more general reviews and predictions for the country or geographical region as a whole. There can be much harm from introducing a technically feasible technology which is economically attractive in the first year or so, if the long-run effect is to depress severely the price of the product in question. Such actions can severely disrupt a farm economy, and may be of little benefit to consumers who also suffer from the dislocations involved. Indeed, even for rice in the Philippines, continued further increases of total output may substantially depress prices below their current real levels. This is a development which must be fully reviewed when considering further modifications to rice-based cropping patterns.

Labor absorption and factor shares

Table 4.8 shows the changes in factor shares among economic cooperators at Iloilo, as a single transplanted rice crop with manual threshing shifts to a wet-seeded double rice crop using mechanical threshing.

It is striking that while overall physical labor use per rice crop is almost halved, and total labor use for the double-crop system is certainly no higher than that for the previous single-crop system, labor earnings are slightly increased. This is attributable to the greater harvesting and land preparation opportunities in the double rice system. These activities were much more remunerative than transplanting and threshing.

Much of the additional value of output is captured by land, and parallels developments noted by Hayami (1979).

These figures indicate that although income distribution in the community may have deteriorated with greater inequality developing, all groups appear to be better off in absolute terms in the short run. Continuing population increases and the shrinking of other employment opportunities may change this, however. At Iloilo the change from transplanting to wet-seeding, and from manual to mechanical threshing, accompanied an increase in cropping intensity. Similar changes in technology without increased cropping intensity are now reported in irrigated areas of the Philippines where double rice cropping has been practiced for many years. This has disturbing implications for labor absorption in both rice farming and the wider rural sector, and needs careful investigation.

Table 4.8. Changes[a] in factor and income shares, 45 economic cooperators at Iloilo, Philippines.

	Rice - fallow (TPR manual threshing)		Rice - rice (both WSR, machine threshing)					
			1st crop		2d crop		Total	
Total value of output ($)	451		473		378		851	
Factor payment ($)								
Current inputs	38	(12)	60	(19)	62	(22)	122	(21)
Capital: total	16		36		28		63	
hired	–		26	(8)	21	(8)	47	(8)
owned	16	(5)	9	(3)	7	(2)	16	(2)
Land	125	(40)	131	(42)	105	(38)	236	(40)
Labor: total	137		90		82		172	
hired	104	(33)	64	(20)	53	(19)	117	(20)
family	33	(10)	26	(8)	29	(11)	55	(9)
Total ($)	316	(100)	316	(100)	277	(100)	593	(100)
Residual ($)[b]	135		157		102		258	
Total income (value added) ($)[c]	413	(100)	413	(100)	316	(100)	729	(100)
Farmer's "net" income ($)[d]	184	(45)	192	(46)	138	(44)	329	(45)
Hired laborers' wage earning ($)	104	(25)	64	(16)	53	(17)	117	(16)

[a]Figures in parentheses in top half of table are percentages of total factor payments. Figures in parentheses in bottom half are percentages of total value added. [b]Total value of output minus total factor payments. [c]Total value of output minus total current inputs. [d]Residual plus payments to owned capital and family labor.

BROADER IMPLICATIONS

Although our analysis of technologies at the two sites is based on experiences over 4 years, this time was needed by researchers as a learning period during which methods of testing, and suitable criteria on which to judge performance, could be worked out. It now seems possible to identify appropriate technologies in other places without such exhaustive and time-consuming review. We believe that our experiences, and similar ones elsewhere, help us to define the role of crop development and extension officers working with farming systems like those on our two sites.

Thus we feel that crop development officers should establish the main sets of resource and environmental conditions characterizing their region, and that for each set of conditions, information should be collected according to the check list of Table 4.9. Basic biophysical data is required on rainfall, land, and cropping patterns, and socioeconomic data on farm-level inputs and outputs and their prices. Background knowledge is also needed on the structure of farms, families, and other major local institutions. These data will help officers to establish pertinent resource and environmental restraints. Technologies tailored appropriately to the sets of conditions

expected to provide cash for higher material inputs, so long as a cash-using technology is seen as profitable and not too risky.

Where technologies appropriate in the sense described here can be introduced to farmers, there should be no need for costly and elaborate extension services and rural development institutions to service their introduction. If such organizations are necessary to support and maintain the widespread adoption of certain new technologies, these are unlikely to be appropriate.

defined in this way may then be either developed, or chosen from other places. Such technologies can be released as parts of suggested cropping patterns, which are observed in trials and demonstration plots over the target area.

Table 4.9. Relevant bio-physical and socioeconomic parameters of target areas.

Parameter	Detail
Bio-physical	
Rainfall	Monthly, for at least 10 years if possible
Land	Extent of lowland rainfed, lowland irrigated, and upland areas, and extent of each landscape position within each land type. Predominant water table levels and cropping patterns within each landscape position. Timings of each cropping pattern.
Socioeconomic	
Households	Typical size and food subsistence requirements. Outside remittances.
Farms	Frequency distribution of land areas, types of tenure systems.
Other institutions	General characteristics of markets for labor, credit, and chief marketed products. Economic functions of landlord. Water use rights, etc; Activities of local extension services and other government agencies.
Inputs and outputs	Inputs and outputs per hectare for all major crops, by landscape positions and farm size groups. Associated cropping patterns.
Prices	Expected prices of labor, credit, animal and machine power, labor, fertilizer, insecticides, and other material inputs, and important seasonal variations in these parameters.

While actual adoption by farmers must remain a major test of suitability for any technology, a close monitoring of its ongoing practical performance, and of the immediate reactions to it of farmers participating in the trial process, should also be carried out. The feedback from such monitoring will be invaluable both to crop development officers themselves, and to their colleagues engaged in more fundamental research work at central institutes.

The role of extension officers is to give subsequent wider demonstrations of those technologies which seem appropriate on the basis of initial testing. This may be crucial in speeding adoption. Where technologies are unsuccessful in this wider context, a careful monitoring of underlying reasons is useful information for the crop development officers and research workers. At a still later stage extension officers will be concerned with providing further limited demonstrations of proven technologies, until they are well established at least amongst early adopters.

An ongoing review of changes in relative resource endowments engendered by the introduction of new technologies is also important. This review should be made so that newly emerging resource constraints, such as the labor scarcities described above, may be countered by further technology adaptations. As already indicated, the informal credit market can be

CHAPTER 5

Assessing the benefits of new technologies

We believe our work has demonstrated how realistic farm-level assessments of new technologies must take account of the whole household resource base and consumption needs of those concerned. Each case study farm included quite complex sets of circumstances, whose specific features heavily influenced the actual choice and combination of technologies. Because these circumstances differed across farms, the nature and effects of technology adoption varied considerably. Our work has also shown how wider district and community level analysis can complement that at the household level in understanding this economic impact of new technologies. Factors such as the overall supplies of labor and other resources are important, and significantly condition household-level changes. Thus both household and district levels must be carefully considered in developing technologies appropriate to a particular region. We have noted too that appropriate technologies should not only be profitable in the typical local resource situation, but robust to changes in climatic and other environmental conditions.

We feel that understanding these various aspects is very important for persons concerned in promoting rural development through better technologies. These persons include research workers, development and extension officers, and planners. We hope that our detailed study of two small sites in the Philippines will help them in better appreciating the requirements of appropriate new technologies in their own regions.

Our linear programming approach has important limitations, including the lack of explicitly incorporated variability and risk-uncertainty considerations. The farmers' goals were assumed to be a maximization of cash surplus after meeting subsistence food requirements. Certainly, this is a highly simplified view of the multiplicity of objectives that farmers actually had. Many other aspects of farm-household behavior were treated in relatively simple fashion. However, our detailed examination of case study farmers enabled the models to be suitably specified and constrained, such that they adequately simulated the farmers' actual historical behavior. The overall assessments of the likely impact of new technologies were thus generally validated over the period studied. Our avoidance of any rigorous modeling

at the district level reflects the great difficulty of adequately defining broad social factors in such an analysis.

The wider assessment problem

Despite their many differences, we believe that most farming systems of both South and South East Asia are sufficiently market oriented to allow use of monetary performance criteria. Most of the non-economic, sociocultural, and other variables which operate at farm level are themselves undergoing rapid changes in the process of modernization, with the result that exclusive economic criteria are unlikely to be overly restrictive in providing good technology assessments. Thus, in theory at least, and subject to the disadvantages just outlined, modeling techniques of the kind demonstrated in the study are quite applicable to the wider assessment of farming problems.

The difficulty facing those who work for cropping systems improvement in many poorer countries is that even a relatively simple technique such as linear programming cannot be used for routine analysis of new technologies. The required skills, time, and computer facilities put this and similar techniques beyond their reach. Resort to such methods may be useful and justified only where a technology or set of technologies are expected to drastically change the prevailing resource allocation patterns of farms, and are planned to be extended over a large area of population. Simpler techniques must accordingly remain the basis for routine, site-level evaluations. Banta (1980) has argued for the use of the non-computer based whole-farm technique, 'simplified programming', which is carefully directed towards gaining an understanding of farming systems through an in-depth analysis of farm case studies. This technique has been reviewed by Jayasuriya (1980). It is very doubtful, however, whether the degree of judgment and skill required to operationalize even this approach is available in many situations.

Yet in each situation it should be possible for the experienced agricultural specialist aware of the relevant technical and socioeconomic factors, and of the types of interaction dealt with in our study, to make a reasonably accurate assessment of what kind of technologies are most appropriate. In doing this he should set out to assemble the range of parameters listed in Table 4.9, using both secondary sources and personal observation of circumstances at the farm, village, and town level. The construction of schematic models of the farming systems involved, indicating resource flows and interactions, is also a useful step towards better understanding, and allows relevant data to be marshalled in an orderly manner. Some quantification of these relationships can help determine the relative importance of particular subsystems and linkages within the system. An example of such a model is given by Hart (1979).

Once such background understanding has been gained, performance criteria for proposed technologies may be computed using partial budgeting

tools. Costs and returns analysis which takes particular account of returns to scarce factors valued at their opportunity costs will be one useful approach here: what other evaluations are pertinent will depend on the nature of the systems operating at the location. For example, consider a location that has limited market access, and in which farmers produce primarily for their own consumption and cannot sell much of their produce. The objective of increasing food production per unit of land and labor invested may be of greater importance than that of increasing total returns over variable costs. Elsewhere, in a situation of power and labor scarcity, returns to these latter factors may be the most important.

The analysis of technology adoption at Iloilo and Pangasinan has shown that a particularly useful and quite simple measure for preliminary assessment of the potential attractiveness of a technology is the ratio of returns to variable input costs. New technologies are most attractive, and likely to be adopted, when the ratio of returns to variable costs of the new technology is higher than that of the farmers' existing technology. The ratios for existing technologies reflect underlying resource availabilities and other system characteristics. For Iloilo and Pangasinan they were generally in the order of 1.5: 1 to 2.1 (Table 3.3). The highly successful wet seeding technique at Iloilo showed a higher ratio than this, while at Pangasinan most experimental patterns had lower ratios. Use of this criterion goes beyond assessment based solely on returns over variable costs, since it implicitly takes into account the actual opportunity costs of resources within a particular farming system.

Assessment of a new technology using such simple partial budgeting criteria should be treated as providing a quick initial result, some of whose limitations we have demonstrated in this book. Many factors impinge on the technology adoption and farm adjustment process, and their consequences go beyond a mere increase in output or farm incomes. They have implications for product markets, labor absorption and employment, income distribution and equity, and social relationships in the community. Some of these factors will become evident through the ongoing monitoring of how a newly introduced technology is adopted. This latter phase is another important part of technology assessment, and in our view the main continuing role of crop development and extension officers, once they have initially assessed a technology, and introduced and demonstrated it to farmers.

In the foreseeable future much ex-ante technology evaluation will probably continue to concentrate on the potential for farmer adoption via higher farm profitability. However, other effects of new technologies including their impact on the rural poor who do not own land also need to be taken into account, and criteria for assessment should reflect such wider social goals

and values. These goals must certainly be considered prior to a wide-scale dissemination of technologies through a rural community.

Appendix Tables

Appendix Table 3.1. Key to week numbers.[a]

	Week no.		Week no.		Week no.
14	Apr 2–8	32	Aug 6–12	50	Dec 10-16
15	Apr 9–15	33	Aug 13–19	51	Dec 17–23
16	Apr 16–22	34	Aug 20-26	52	Dec 24-31
17	Apr 23–29	35	Aug 27-Sep 2	1	Jan 1–7
18	Apr 30–May 6	36	Sep 3–9	2	Jan 8–14
19	May 7–13	37	Sep 10-16	3	Jan 15–21
20	May 14–20	38	Sep 17–23	4	Jan 22–28
21	May 21–27	39	Sep 24–30	5	Jan 29-Feb 4
22	May 28–June 3	40	Oct 1–7	6	Feb 5-11
23	June 4–10	41	Oct 8-14	7	Feb 12-18
24	June 11–17	42	Oct 15–21	8	Feb 19–25
25	June 18–24	43	Oct 22-28	9	Feb 26-Mar 4
26	June 25–July 1	44	Oct 29–Nov 4	10	Mar 5–11
27	July 2–8	45	Nov 5–11	11	Mar 12-18
28	July 9–15	46	Nov 12–18	12	Mar 19-25
29	July 16–22	47	Nov 19–25	13	Mar 26–Apr 1
30	July 23–29	48	Nov 26–Dec 2		
31	July 30–Aug 5	49	Dec 3–9		

[a] Our 'crop year' runs from April 2 - April 1; beginning approximately at the end of the dry season on both sites (Figs. 2.3 and 2.5).

Appendix Table 3.2. Key to resource levels, lloilo, Philippines, farmers.[a]

Resource and level	Farmer				
	1	2	3	4	5
Land		*Unweighted total land area (ha)*			
0.5	1.9	1.7	1.3	1.7	0.8
1.0	3.7	3.4	2.5	3.4	1.6
2.0	7.4	6.8	5.0	6.8	4.8
3.0	11.1	10.2	7.5	10.2	4.8
4.0	14.8	13.6	10.0	13.6	6.4
Family labor		*Av total available family labor (h/wk)*			
0.5	37	42	106	100	60
1.0	74	84	213	200	119
2.0	148	168	426	400	238
3.0	222	252	639	600	357
4.0	296	336	852	800	476
Credit		*Total credit available from all sources ($)*			
1.0	200	373	200	67	40
2.0	400	746	400	133	80
3.0	600	1120	600	200	120
4.0	800	1493	800	267	160
5.0	1000	1867	1000	333	200
6.0	1200	2240	1200	400	240

[a]Where 1.0 is the 'basic' resource level in the original situation.

References

ANDERSON, J.R. 1976. On formulating advice to farmers from agronomic experiments. Miscellaneous Publications No. 3, Department of Agricultural Economics and Business Management, University of New England, Armidale, Australia.

BANTA, G.R. 1980. Asian cropping systems research: micro-economic evaluation procedures. unpublished PhD thesis, University of Alberta, Canada.

BARKER, R. and R.W. HERDT 1975. Equity implications of technology changes. In International Rice Research Institute (1978b). Changes in rice farming in selected areas of Asia. Los Banos, Philippines.

BARLOW, C., S. JAYASURIYA, V. CORDOVA, N. ROXAS, O. YAMBAO, C. BANTILAN, and C. MARANAN 1979. Measuring the economic benefits of new technologies to small rice farmers. IRRI Research Paper Series No. 28, International Rice Research Institute, Los Banos, Philippines.

BENITO, C.A. 1976. Peasants' response to modernization projects in Minifundia economies. Am. J. Agric. Econ. 58: 143-151.

BOLLARD, A. 1979. Agricultural project design and evaluation in an island community. Monograph No. 15, Development Studies Centre, Australian National University, Canberra.

BOLTON F. 1980. Double-cropping rainfed rice in Iloilo Province, Central Philippines. Unpublished PhD thesis, University of Reading, England.

BOLTON, F.R. and H.G. ZANDSTRA. 1980. Double-cropping rainfed rice in Iloilo Province. Unpublished IRRI Saturday Seminar paper. International Rice Research Institute, Los Banos, Philippines.

CENTRAL BANK OF THE PHILIPPINES. 1979. Official price statistics. Manila, Philippines.

CLAYTON, E.S. 1965. Economic planning in peasant agriculture. Economics Department, Wye College, University of London, England.

FLINN, J. C., S. JAYASURIYA, and C. A. KNIGHT. 1980. Incorporating multiple objectives in planning models of low-resource farmers. Austr. J. Agric. Econ. 24, 1:35-45.

GENESILA, M.P., R.S. SERVANO, and E.C. PRICE. 1979. Socio-economic studies in Iloilo, 1976-78. Unpublished paper presented at the Annual Cropping Systems Seminar Workshop, March. International Rice Research Institute, Los Banos, Philippines.

GONZALES VEGA, C. 1977. Interest rate restrictions and income distribution. Amer. J. Agric. Econ., 59, 5, 973.

GRILICHES, Z. 1957. Hybrid corn: an exploration in the economics of technological change. Econometrica, 25, 4, 501-522.

HARDAKER, J.B. 1975. Agriculture and development in the Kingdom of

Tonga. Unpublished PhD thesis, University of New England, Armidale, Australia.

HART, R.D. 1979. One farm system in Honduras: a case study in farm systems research. Paper presented at the Farming Systems Research and Development Workshop, August. University of Colorado, U.S.A.

HAYAMI, Y. 1978. Anatomy of a peasant economy. International Rice Research Institute, Los Baños, Philippines.

HUYSMAN, A. 1981. Decision making and risk. Unpublished seminar paper presented at the Department of Agricultural Economics, International Rice Research Institute, Los Baños, Philippines.

HEYER, J. 1972. An analysis of peasant farm production under conditions of uncertainty. J. Agric. Econ. 13(2): 135-146.

IRRI 1978a. Annual report for 1977. International Rice Research Institute, Los Baños, Philippines.

IRRI 1979a. Annual report for 1978. International Rice Research Institute, Los Baños, Philippines.

IRRI 1979b. Unpublished data on prices. Department of Agricultural Economics, International Rice Research Institute, Los Baños, Philippines.

IRRI 1981. Unpublished benchmark information from Iloilo Cropping Systems Site. Department of Agricultural Economics, International Rice Research Institute, Los Baños, Philippines.

JAGER, F.J. 1980. Some effects of the introduction of an irrigation system on the decision making of small farmers. A case study in the Province of Iloilo, Panay Island, in the Philippines. Unpublished paper, University of Wageningen, Holland.

JAYASURIYA, S. 1980. Simplified programming. *In* B. T. Tan et al, eds. Improved farm management teaching in Asia. Agricultural Development Council, Inc.

JONES, G. 1967. The adoption and diffusion of agricultural practices. World Agricultural Economics and Rural Sociology Abstracts, 9, 3.

JUAREZ F. and B. DUFF 1980. The economic and institutional impact of mechanical threshing in Iloilo and Laguna. Unpublished paper prepared for the IRRUAES Village Studies Workshop, April. International Rice Research Institute, Los Baños, Philippines.

LOCKWOOD, B. and T.K. MOULIK. 1972. Seeds of development in a Delhi village. In Epstein T.S. and D.H. Penny. Opportunity and response: case studies in economic development. Hurst and Company, London, England.

Low, A.R.C. 1975. Small farm improvement strategies - the implications of a computer simulation study of indigenous farming in South East Ghana. Oxford Agrarian Studies, 14: 3-19.

MARANAN, C.G. 1980. A study of changes in cropping patterns, incomes and expenditures of selected farm families in Pangasinan. Unpublished paper 80-07, Department of Agricultural Economics, International Rice Research Institute, Los Baños, Philippines.

MOORMAN, F.R., H.G. ZANDSTRA, H. BRAMMER, and R.L. TINSLEY. 1976. A land classification for cropping systems research. Unpublished paper presented at the Workshop on Environmental Factors in Cropping Systems, April. International Rice Research Institute, Los Baños, Philippines.

MORRIS, R. 1978. Soil and climatic determinants in relation to cropping

patterns. Unpublished paper presented at the IRRI Conference, April. International Rice Research Institute, Los Banos, Philippines.

NATIONAL CENSUS and STATISTICAL OFFICE. 1975-79. Official price statistics. Manila, Philippines.

NICOLAS, J.S. 1977. Level and pattern of income distribution among households in 5 selected cropping systems pilot barrios of Manaoag, Pangasinan: an analysis of benchmark information. Unpublished paper 77-10, Department of Agricultural Economics, International Rice Research Institute, Los Banos, Philippines.

NERLOVE, M. 1958. Adaptive expectations and cobweb phenomena. Quart. J. Econ. 72, 227-240.

NORMAN, D.W. and R.W. PALMER-JONES. 1976. Economic methodology for assessing cropping systems. Unpublished paper delivered at the Symposium on Cropping Systems Research and Development for the Asian Rice Farmer. International Rice Research Institute, Los Banos, Philippines.

PALADA, M.C., R.L. TINSLEY, and R.R. HARWOOD. 1976. Cropping systems agronomy program for rainfed lowland rice areas in Iloilo. Unpublished Saturday Seminar Paper, April. International Rice Research Institute, Los Banos, Philippines.

PETERSON, W. and Y. HAYAMI. 1977. Technical changes in agriculture. In Martin L.R. (ed). A survey of agricultural economics literature, Vol. 1. University of Minnesota Press, Minneapolis, for the American Agricultural Economics Association.

PRICE, E.C. 1977. Impact of new rice technology on cropping patterns and land utilization. Unpublished paper, Department of Agricultural Economics, International Rice Research Institute, Los Banos, Philippines.

PERRIN, R.K, D.L. WINKELMAN, E.R. MOSCARDI, and J.R. ANDERSON. 1976. From agronomic data to farmer recommendations: an economics training manual. Information Bulletin 27, CIMMYT, Mexico.

PETIT, M. 1975. Farmers' adoption of technical innovations. Eur. Rev. Agric. Econ., 3(2/3), 293-322.

ROGERS, E.M. and F.F. SHOEMAKER. 1971. Communication of innovations: a cross-cultural approach. The Free Press, New York, U.S.A.

RAYMUNDO, M. 1978. Personal discussions. International Rice Research Institute, Los Banos, Philippines.

ROXAS, N, M.P. GENESILA, and E.C. PRICE. 1978. Socio-economic and agronomic aspects of IRRI cropping systems research in a rainfed lowland rice area in Iloilo. J. Agric. Econ. Dev. 8 (2): 205-220.

RUTHENBERG, H. 1976. Farming systems in the tropics. Clarendon Press, Oxford, England.

THAMBAPILLAI, D.J. 1978. Methods of multiple objective planning: a review. World Agric. Econ. Rural Sociol. Abstr. 20,(12): 803-813.

THODEY, A.R., and RAPEEPUN SEKTHEERA. 1974. Optimal multiple cropping cropping systems for the Chiang Mai valley. Report 1, Department of Agriculture, Chiang Mai University, Chiang Mai, Thailand.

WARDHANI, M.A. 1976. Rational farm plans for land settlement in Indonesia: a study using programming techniques. Thesis Reproduction Series, Development Studies Centre, Australian National University, Canberra, Australia.

ZANDSTRA, H. G., E. C. PRICE, J. A. LITSINGER, and R. A. MORRIS. 1981. A methodology for on-farm cropping systems research. International Rice Research Institute, Los Baños, Philippines.

Index

Adoption, see Diffusion and adoption of new technologies.
Agricultural districts, district level analysis, Preface, 4, 97.
Agronomic cooperators, monitoring, 5, 31
Appropriate technologies, 1, 88, 94-95, 97.

Banta, G.R., 98.
Barker, R., 85.
Baseline survey, 11.
Benito, C.A., 21.
BE3, 14, 44, 72, 77, 84.
Bolton, F.R., 29, 77, 82.
Bureau of Agricultural Extension, 14, 87.

Case study farmers, the 10 studied, 30-34; models of, 34.
Cash, affecting technology use, 54-57, 59-62; and land, 57; and weed control, 79; expenses, 18; incomes, 17-18; marginal value product, 45; shortages, 19; surplus, 59-61; usage in model, 45. (see also credit)
Clayton, E.S., 21.
Climate, and mung beans, 80; in crop development, 94.
Costs and returns analysis, 2-3, 99.
Credit, and fertilizers, 19, 92-3; institutional, 19; interest rates, 19; (see Masagana 99); non-institutional, 19. (see also cash)
Crop development and extension officer, 94-95; and assessment, 98-99.
Cropping intensity, 57, 93.
Cropping patterns, 56-59, 64, 81-2; and landscape positions, 81; history of, 12-14; Iloilo and Pangasinan, 13; selection and complementarities in the model, 46.
Cropping System Programs, 25; Asian Cropping Systems Network, 2; broader implications, 94; Iloilo site, 5, 6-7, 73; Pangasinan, 5, 7-10, 74; research methodology, 5.

Diffusion and adoption of new technologies, 24, 67-72, 83, 84-88; adopter groupings, 69, 83, 84; and irrigation, 84; and profitability, 99; and tenancy, 83; farmer's behaviour, 83-87; in non-site areas, 87-88; learning process, 69, 71-72; logistic form, 68; on the sites, 72-81; resource use effects, 89-93; sequential aspects 81-83; time span involved, 72.
Direct seeding, see seeding, direct.
Double cropping, 13, 27, 72, 93.
Dry seeding, see seeding dry.
Duff, B., 78.

Economic co-operators, 83; monitoring, 5, 11; purpose of, 30, records of, 31.
Extension officers, role of, 94-95.

Family labor, 16, 42f; availability, 59.
Farm households, adjustments within complex, 64; household level analysis, Preface; 4, 97; off farm activities, 17; models, 5, 20.
Farming systems, monitoring of, 5, 11, 13; and improvement, 98; (see economic cooperators, agronomic cooperators).
Fertilizers, 17, 54, 55; and credit, 92.
Flinn, J.C., 26.

Goals, 25-26; 98.
Griliches, Z., 68, 72.

Hand tractors, 76.
Hardaker, J.B., 21.
Hart, R.D., 98.
Hayami, Y., 67, 93.
Herdt, R.W., 85.
Heyer, J., 21.
Historical technologies, derivation of, 23; in model, 35-36, 54.
Huysman, A., 29.

Iloilo, and Masagana 99, 92; dynamics of technology adoption, 72f; farm level impacts of new technologies, 35f; farming systems, 9f; irrigation and labor supply, 90; physical characteristics of the site, 6-7: technology adoption, 99; research activities 5. (see also Cropping systems programs and Cropping patterns)
Income distribution, 93.
International Rice Research Institute (IRRI), Preface, 5, 14, 36, 77, 87.
Irrigation, 10-11, 13; and adoption, 83; and uncertainty, 83.
IR36, 38, 40, 44, 45, 47, 53, 54, 62, 69, 74, 76, 81; and adoption, 83-87.
IR1561, IR28, 72
IR5, IR20, IR28, IR30, 72.
IR42, 55.

Jager, F.J., 91.
Jayasuriya, S., 98.
Jones, G., 67, 70.
Juarez, F., 78.

Kapopoy, 44, 64.

Labor, and factor shares, 93; and weed control, 79; complementarities in use, 46-48; exchange, 15; family, 15, 42, 59; hired, 15, 90; marginal value product, 44, 59, 77; market, 17, 90; share, 16, 42; use at Iloilo, 15; use at Pangasinan, 16; usage in model, 42-45.
Land, at Iloilo, 6; at Pangasinan, 8; marginal value product, 45; preparation for use, 14-15; usage in model, 22, 45, 57-59, 63-64.
Linear programming (LP), format used, 34; limitations of 27, 97, 98; specifying the model, 21-27, 34.
Livestock raising, 10.
Lockwood, B., 72.
Low, A.R.C., 21.

Machine threshing, see Threshing.
Maize, 13; harvesting, 17; hybrid, 68; new varieties, 28.
Manaoag, Pangasinan province, 7; land system, 8.
Maranan, C.G., 31, 75.
Marginal opportunity costs, 49.
Marginal Value Product, of cash, 45; of labor, 44. 59, 77: of land, 45.
Masagana 99, 16, 19, 73-74, 77, 92.
Mechanical cultivator, 92.
Models, choice of farmers for, 31-34; development of, 20f; resource changes. 59-61; effects of changes on technology selection, 51f; effects of labor changes, 59; effects of land changes, 57; effects of weather changes. 55-56: farm household, 20-27; goals. 24-26; effects of material input requirements. 54; effects of output changes 51-53; effects of ownership status, 54: pattern selections and complementarities, 46; risk aversion incorporation, 27; sub-optimal choices. 48; wage changes, 53. (see also linear programming).
Monetary performance criteria, 98.
Morris, R., 5, 29.
Moulik, T.K., 72.
Mung bean, after rice, 13, 17; new variety performance and pest control, 80-81, 86.

National Grains Authority (NGA), 19.
Nerlove. M., 71.
New technologies, Preface, 1, 36, 54; adoption of, 67-72. 99; appropriateness, 5, 88; assessment, 97-99; and labor absorption, 93: and robustness, 87; derivation of, 23; design of, 5, 27; economic impact of, 35-65, effect of, on resource use, 89-93: example, 25; monitoring, 31; role of, in economic development, I, 2; tailoring, 94. (see also Diffusion and adoption of new technologies).
Nicolas, J.S.. 16.
Norman, D.W., 2.

Oton, lloilo Province, 6; land system, 7.

Palmer-Jones, R.W., 2.
Pangasinan, adoption of IR36, 84; adoption of mung bean, 88; and dry seeding, 79, *88;* dynamics of technology adoption, 72f; farm level impacts of, new technologies, 35f; farming systems, 9f; physical characteristics of the site, 7-9; technology adoption, 99. (see also Cropping systems programs: Seeding, dry).
Perrin. R.K.. 2.
Peterson, W., 67.
Petit, M., 71.
Philippine Bureau of Plant Industry (BPI), 5.
Philippine Cotton Corporation, 13.
Philippines, University of the, at Los Baños (UPLB). 14.
Pigs, as cash supplements. 18.
Price, E.C., 13.

Rainfall, influence on cropping patterns, 13; Iloilo, 7; Pangasinan, 10.
Rapeepun, Sektheera, 21.
Ratooning, 52, 53, 82.
Relay cropping. 74.
Rice, adoption of new varieties, 16, 87; and risk, 27; choice of varieties, 81, 82; double cropping (see Double cropping); dry seeding (see Seeding dry); for

household consumption, 17, 26, 38; improved varieties of, 14; land preparation, 14: prices, 93; threshing (see Threshing); transplanting, (see Transplanting); wet seeding (see Seeding wet); yields, 17, 51-53. (see also BE3: Kapopoy; IR36; IR42; IR1561, IR28; IR5, IR20, IR28, IR30).
Risk and uncertainty, 20, 27, 41.
Rogers, E.M., 69.
Roxas, N., 16.

Seeding, direct, 14, 28.
Seeding, dry (DSR) 28, 40, 53, 63, 64, 66, 71, 75, 78, 79, 81, 88.
Seeding, wet (WSR), 28, 40, 53, 55, 59, 64, 65, 73, 75, 79, 81-82, 88, 89, 93.
Shoemaker, F.F., 69.
Soils, Iloilo, 7; Pangasinan, 8-9, 79. (see also Land).
Subsistence goal, 26.
Systems approach, on farms, 3, 20.

Technologies, see Appropriate technologies, Diffusion and adoption of new technologies, Historical technologies, New technologies.
Tenancy, 9f; and adoption, 83.
Thodey, A.R., 21.
Threshing, manual 16; machine, 78, 88, 90; Tilyadora, 16.
Tigbauan, Iloilo Province, 6; land systems, 7.
Transplanting (TPR), 14f, 28, 62f, 65, 76f, 82.

Upland Crops, 11, 28, 29, 38, 66; at Pangasinan, 79.
Urea, see Fertilizers.

Wages, 53, 91.
Wag-wag-aga, 36.
Wardhani, M.A., 21.
Weed control, and dry seeding, 28, 79.
Wet seeding, see Seeding, wet.

Zandstra, H.G., 5, 77, 82.