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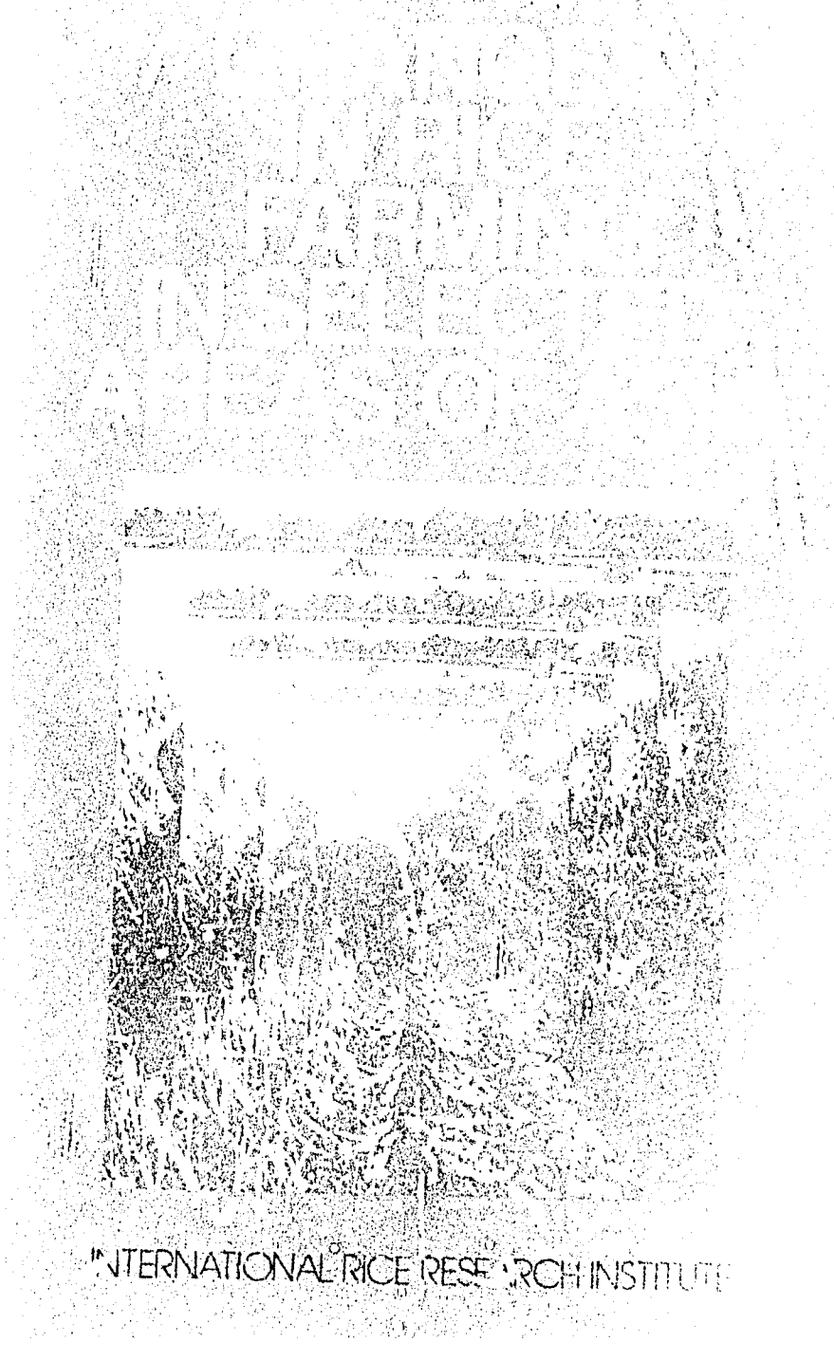

INTERNATIONAL RICE RESEARCH INSTITUTE

INTERPRETIVE ANALYSIS OF SELECTED PAPERS FROM

INTERNATIONAL RICE RESEARCH INSTITUTE

INTERPRETIVE ANALYSIS
OF SELECTED PAPERS FROM

CHANGES IN RICE FARMING IN SELECTED AREAS OF ASIA

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

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Foreword

IN 1971–73, DEVELOPMENT SPECIALISTS in agricultural economics, rural sociology, and related fields conducted surveys in 36 villages in 14 locations in six countries in South and Southeast Asia — India, Indonesia, Malaysia, Pakistan, the Philippines, and Thailand — to study the effects of the adoption of the new semidwarf rices and the associated technology on such factors as income, employment, and others. The data were collected by 34 scholars from 18 Asian universities and research institutes, with the cooperation of the International Rice Research Institute located in the Philippines and the Agricultural Development Council in Singapore.

The initial findings and preliminary analyses of the data were reported in the IRRI publication CHANGES IN RICE FARMING IN SELECTED AREAS OF ASIA (1975). The present report provides further and more in-depth analyses and assessment of these data.

These two companion volumes on "Changes in Rice Farming in Selected Areas of Asia" represent one of the first collaborative research undertakings of this type. Major benefits have been derived through the joint development of the methodology, the subsequent training of research workers, and the preparation of the final reports. This study, while valuable in its own right, has served as a model for organizing subsequent research investigations on similar topics.

The Institute extends appreciation to the cooperating researchers and others who participated in the study and made contributions to the report and to Dr. Randolph Barker who served as technical editor for the published report.

N. C. BRADY
Director General, IRRI

Preface

THE FIRST HALF (PART I) of this report analyzes data collected from the 36 study villages and farm interviews in six Asian nations. The analyses were conducted at IRRI, at the Department of Agricultural Economics of Cornell University (New York, USA), and at the Stanford Food Research Institute (California, USA).

The second half (Part II) deals with problems related to some of the study areas; the problems were considered of critical importance in local rice production by the research workers who carried out the original surveys.

A substantial appendix provides a detailed record of relevant information for each village and may be useful to those conducting further research in these selected areas of South and Southeast Asia.

The work summarized and assessed in this report represents the combined efforts of the 34 participants (see the following); the author identified for each section served as the section coordinator.

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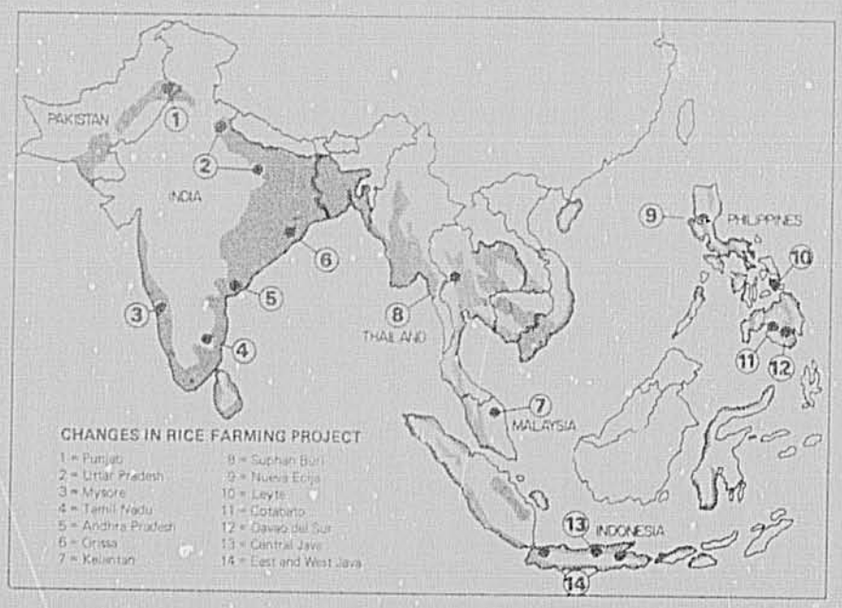
Introduction

THE STUDY OF CHANGES in rice farming in selected areas of Asia was so designed that the information from the individual case studies could be pooled for a comparative analysis of the 14 study areas. The same core set of questions was included in the interview schedules for each area. The data from 2,344 separate farms in 36 villages, assembled on a single computer tape, form the basis for the analysis in the first half of this report (Part I).

The varying rates in the adoption of modern rice technology, the use of modern inputs, the yield of rice obtained over the wide geographic areas represented by the 14 study sites (Fig. 1) are compared and explained in Part I. The analyses are based on those sets of data for which reasonably reliable quantitative estimates were obtained. Factors that caused variation among



1. Location of study areas included in the Asian farm survey (shading indicates approximate areas of intensive rice production).

villages were identified. The potential biases that may have resulted from the non-random selection of sites and villages were taken into account.

Village studies permit in-depth analysis and minimize the influence of such factors as environment which cause major variation in results among the study sites. Issues that can best be studied in a well-defined village setting are presented in both the IRRI report *Changes in Rice Farming in Selected Areas of Asia* (1975) hereafter referred to as *Changes* (1975) and in Part II of the present document.

PROCEDURES

The project leader in each of the study areas selected one to three villages to ensure that in at least one village, conditions were reasonably suitable for the adoption of new rice technology. Suitable localities had

- control over a water supply that would permit farmers to produce two or more crops each year,
- access to the inputs required in the new technology, and
- access to markets where produce could be sold.

A random sample of 150 to 250 farmers was drawn from one to three villages in each study area. The interviews were conducted in 1972 and 1973. The original farm survey questionnaire is Appendix A of *Changes* (1975).

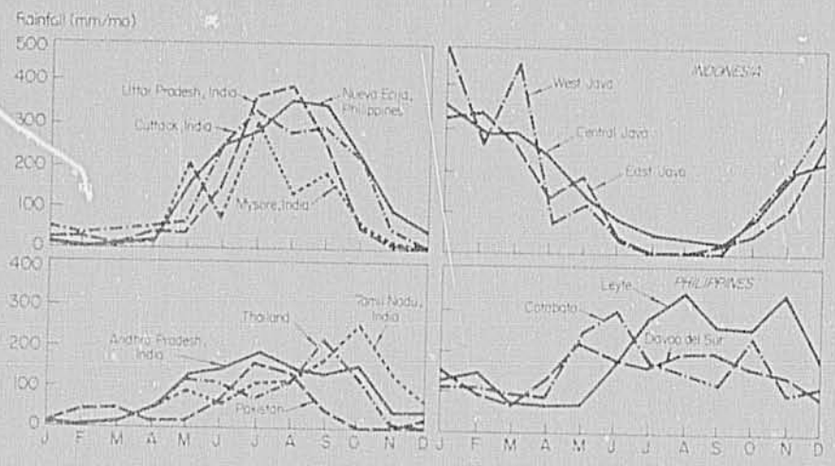
STUDY AREAS[1]

The 14 farm surveys were conducted over a broad geographic area (Fig. 1) and included a wide range of conditions under which rice is grown. Such variables as climate, farm structure, and irrigation in the study areas that influence farming conditions are discussed. Average rainfall data for selected sites are shown in Figure 2. Some of the basic characteristics of the sample villages are shown in Tables 1 and 2.

Climate. Nine of the study sites, including those in India, Pakistan, Thailand, and the northern Philippines, are located between 10° and 30° North latitude. In this area, the heaviest rains occur between June and November, and the main crop is normally harvested in November and December. Five of the nine sites situated between 15° and 25° North latitude (West Godavari and Cuttack, India; Suphan Buri, Thailand; Nueva Ecija and Leyte, Philippines) are subject to typhoons and heavy rains which occasionally severely damage the main rice crop.

Three study areas in Malaysia and southern Philippines are located between 0° and 10° North latitude where both the rainfall and solar energy are relatively evenly distributed throughout the year. The wet and dry seasons are less distinct than in the five sites situated between 15° and 25° North latitude. The

[1]This description of the study areas has been abstracted from *Changes* (1975).



2. Average monthly rainfall, 1967/71, at the different study sites.

study sites in Indonesia are situated between 5° and 10° South latitude. In this area, the heaviest rainfall occurs from December through May, and the main crop is harvested in April and May.

The cold weather during winter in the two study areas located in northern India and Pakistan favors the production of wheat as the dry-season crop. In all other areas where crops are grown under irrigation, rice is the principal second crop.

Farm structure. The variation in the size of the farm operating unit was greater than the variation in family size among the survey villages (Table 1). The size of the average village farm was 2.9 ha; it ranged from 0.5 ha in Java, Indonesia, to 7.8 ha in Thailand and Pakistan. Most of the 2,344 rice farms surveyed were small; 35% was less than 1 ha each, the size of 46% ranged from 1 to 4 ha each, and 19% exceeded 4 ha.

High rates of tenancy were found principally in the study areas in the Philippines where the traditional tenure pattern is based on a 50/50% sharing of cost and rice output between landlord and tenant. In recent years, under a government land reform program, the arrangement has changed toward fixed cash rent or leasehold. The tenancy rate was also high in Pedapulleru, India, and in the Pakistan villages. However, the rights of tenure appeared to be less stable than those in the Philippines, both in terms of the sharing arrangement and in a claim to work a given piece of land.

In all areas, the principal crop was rice. In about 50% of the villages, rice was the only crop of any significant hectarage. Sugarcane, tobacco, corn, and wheat were the major crops in the remaining percentage of the villages studied.

Water resources. Although all the study areas had irrigation water, the quality of water delivery systems varied widely among the villages. The quality

Table 1. Size and tenure characteristics in sample villages in selected areas of Asia, 1971/72.

Location	Farms in sample (no.)	Size: Household (members)	Size: Farm (ha)	Pure owners (%)	Pure tenants (%)
		India			
Uttar Pradesh					
Dhanpur-Vijaypur	51	6	6.0	100	0
Tarna	43	8	1.2	100	0
Barain	57	7	1.2	100	0
Orissa					
Kandarpur	57	6	0.6	49	9
Korpada	112	6	0.6	62	5
Andhra Pradesh					
Pedapulleru	185	5	4.7	41	32
Mysore					
Gajanur	48	7	2.4	n.a.[a]	n.a.
Hosahally	43	8	4.8	n.a.	n.a.
Ashoknagar	51	7	2.8	n.a.	n.a.
Tamil Nadu					
Kariyamangalam	52	6	4.1	86	10
Palvarthuvenran	33	6	2.0	100	0
Manmalai	66	6	1.8	96	2
		Indonesia			
Central Java					
Nganjat	60	5	0.5	80	4
Kahuman	60	6	0.6	67	2
Pluneng	66	6	0.5	71	2
East-West Java					
Sidomulyo	75	6	0.5	86	7
Cidahu	80	4	0.5	90	1
		West Malaysia			
Kelantan					
Salor	157	6	0.9	58	11
Meranti	133	5	1.0	43	17
		West Pakistan			
Punjab					
Aroop	80	9	6.7	65	4
Maraliwala	80	11	7.8	23	41
		Philippines			
Nueva Ecija					
San Nicolas	55	7	2.5	16	56
Malimba	66	6	3.1	9	59
Mahipon	72	6	3.8	25	26
Leyte					
Canipa	49	7	1.7	17	77
Marcos	66	6	1.5	14	86
Tab-ang	56	5	1.2	33	57
Davao					
Beynte Nuwebe	39	6	1.7	8	92
Sinayawan	93	7	2.2	14	86
Cotabato					
Bulucaon	40	6	2.0	6	91
Maluao	36	6	2.9	44	53
Capayuran:					
Christians	36	6	1.9	14	86
Muslims (Cabpangi)	48	7	3.9	100	0
		Thailand			
Suphan Buri					
Rai Rot	47	6	7.0	75	6
Nong Sarai	59	6	7.8	66	5
Sa Krachom	44	6	7.8	64	13

[a] Tenure information was not available (n.a.) because sample farmers in the area were reluctant to disclose their tenure status.

Table 2. Cropping and irrigation characteristics in sample villages in selected areas of Asia, 1971/72.

Location	Av. rice area (ha)		Rice area irrigated (%)		Quality of irrigation[a]	Double-cropped rice area (%)
	Wet	Dry	Wet	Dry		
			India			
Uttar Pradesh						
Dhanpur-Vijaypur[b]	3.2	—	65	—	3	—
Tarna[b]	0.5	—	92	—	3	—
Barain[b]	0.7	—	31	—	4	—
Orissa						
Kandarpur	0.6	0.5	100	97	3	83
Korpada	0.6	0.5	98	100	3	83
Andhra Pradesh						
Pedapulleru	4.4	3.8	100	100	3	66
Mysore						
Gajanur	1.7	1.1	100	100	2	60
Hosahally	1.9	1.5	100	100	2	61
Ashoknagar	2.2	1.9	100	100	2	84
Tamil Nadu						
Kariyamangalam	1.4	0.8	100	100	2	61
Palvarthuvenran	1.3	1.2	100	100	3	91
Manmalai	0.7	0.6	100	100	2	89
			Indonesia			
Central Java						
Nganjat	0.5	0.5	100	100	1	100
Kahuman	0.6	0.6	100	100	1	100
Pluneng	0.5	0.5	100	100	1	100
East-West Java						
Sidomulyo	0.4	0.3	100	100	2	98
Cidahu	0.5	0.5	100	100	2	100
			West Malaysia			
Kelantan						
Salor	0.8	0.8	100	100	3	100
Meranti	0.9	0.9	94	94	3	100
			West Pakistan			
Punjab						
Aroop[b]	3.7	—	100	—	2	—
Maraliwala[b]	6.0	—	100	—	2	—
			Philippines			
Nueva Ecija						
San Nicolas	2.5	2.5	100	100	2	93
Malimba	3.1	3.1	100	100	3	92
Mahipon	3.8	0	0	0	5	0
Leyte						
Canipa	0.8	0.8	90	90	3	100
Marcos	0.4	0.4	99	99	3	100
Tab-ang	0.7	0.7	99	99	3	100
Davao						
Beynte Nuwebe	1.7	1.7	100	100	4	100
Sinayawan	1.9	1.9	100	100	4	100
Cotabato						
Bulucaon	1.8	2.0	100	100	3	100
Maluao	1.6	1.6	90	84	5	100
Capayuran:						
Christian	1.3	1.2	100	100	3	100
Muslims (Cabpangi)	1.4	1.3	100	100	5	95
			Thailand			
Suphan Buri						
Rai Rot	5.3	1.4	98	100	3	19
Nong Sarai	6.1	1.1	73	100	4	13
Sa Krachom	5.4	0	0	0	5	0

[a] 1 = very good; 5 = poorly irrigated or wholly rainfed. [b] Second crop is wheat.

of irrigation in each village was rated subjectively with the use of field observations and descriptions of the sites furnished by the project leader in each area. The best irrigated areas were rated as 1, while the poorly irrigated and rainfed villages were rated as 5 (Table 2).

Canal or gravity irrigation systems served most areas studied. Because these systems have a limited command area during the dry season, some of the irrigated farms in the survey areas received too much or too little water, depending on the season.

In Pakistan and in Uttar Pradesh in northern India, the canal command areas were overextended, and pump irrigation was widely used in the survey area to supplement or replace the canal water supply. In India, two of the three Tamil Nadu villages studied were served entirely by pumps, and the third village had a combination of pump and tank irrigation.

Large government operated pumps supplied water directly from the Kelantan River to a gravity irrigation network in northern Malaysia. Small privately operated pumps were used for the same purpose in one of the villages in Leyte, Philippines.

The most reliable irrigation and drainage systems were found in Java, Indonesia (particularly Klaten, Central Java), and in Mysore, India, where a storage reservoir constructed along the Tunga River in 1952 supplied water to the study area.

THIS REPORT

Part I is made up of four chapters based on the analysis of the combined survey data. The first chapter deals with factors that were found to affect the adoption of modern rice varieties. The second and third chapters deal with the association between yield, fertilizer input, and factors which influence the level of fertilizer used. Two important equity issues are discussed in the fourth chapter — the effect of adoption of new technology on employment, and the relationship between adoption of new technology and farm size. More detailed data related to the analysis in each chapter are in the appendix.

Part II of this report contains five special reports describing problems associated with the introduction of modern rice technology. The reader can refer to the corresponding chapter by the same authors in *Changes* (1975) for background on the study area and the introduction of modern varieties of rice in the respective study areas.

PART 1:
ANALYSIS OF COMBINED DATA FROM SURVEYS

The adoption of modern varieties

TERESA ANDEN-LACSINA and RANDOLPH BARKER

The area sown to modern varieties varied widely (from 9 to 100%) among villages, with Philippine villages showing by far the highest adoption. Seasonal suitability, water control, and profitability were important factors explaining this variation. Varieties with greater insect and disease resistance but with lower yield potential have become popular, particularly in the wet season. But modern varieties suited to the poorly drained conditions, which characterized many of the survey villages during the monsoon season, have yet to be developed.

THE PLANT TYPE of the new varieties of rice that were developed in the mid-1960s was characterized by short stature and stiff straw, and differed markedly from the tall weak stem plant type of the traditional indica varieties. Under favorable environmental conditions the new rice varieties respond to increased applications of chemical fertilizer with high yields. Thus, the modern technology associated with the high yielding varieties (HYV) is often called "seed-fertilizer" technology.

The original rice varieties were environment specific and performed best with an adequate supply of water and high solar energy. The rate of adoption in South and Southeast Asia varied considerably, exceeding 50% in some countries and covering only 10% of the area in others (Table 1). A major portion of this variation may be attributed to environmental factors.

The subsequent development of rice varieties with more resistance to insects and diseases and with improved quality (taste and appearance) has helped to extend the area where the HYV are grown. New varieties more suited to local conditions have been released through national programs, and this has enhanced the spread of the improved plant type. Despite these advances, however, the new rice varieties had spread to only about a quarter of the rice-growing area in Asia by the early 1970s.

Teresa Anden-Lacsina and *Randolph Barker* are Senior Research Assistant and Agricultural Economist, respectively, in the Department of Agricultural Economics, International Rice Research Institute, Los Baños, Laguna, Philippines.

The authors are indebted to Eugene Bennagen, Adelita Palacpac, and Celia Capule, who assisted with the tabulations and computations in this chapter and the three following.

Table 1. Proportion of total rice area planted to modern varieties, Asian countries, 1967/73. Source: D. Dalrymple, Development and Spread of High Yielding Varieties of Wheat and Rice in the Less Developed Nations, Aug. 1976.

Country	Proportion of total area in modern varieties (%)						
	1967/68	1968/69	1969/70	1970/71	1971/72	1972/73	1973/74
South Asia	3.8	6.4	9.9	12.9	17.2	20.6	24.3
India	4.9	7.3	11.3	14.5	19.3	22.1	25.6
Bangladesh	0.7	1.6	2.6	4.6	6.7	11.1	15.7
Nepal	—	3.7	4.2	5.7	4.5	14.8	15.8
Pakistan	0.3	19.8	30.9	36.6	50.0	43.7	43.2
Sri Lanka	—	1.2	4.9	5.0	12.0	42.7	54.8
Southeast Asia	3.2	7.2	10.0	12.6	15.7	20.0	25.3
Burma	0.1	3.5	3.1	4.0	3.9	4.4	5.1
Indonesia	—	2.5	10.4	11.1	16.0	24.4	36.9
Laos	0.1	0.3	0.3	8.1	4.5	7.5	7.5
Malaysia (West)	23.1	20.9	26.5	31.4	37.1	38.1	37.4
Philippines	21.2	40.6	43.5	50.3	56.3	54.0	63.3
Thailand	—	—	0.04	0.4	1.3	4.6	5.6
Vietnam (South)	0.02	1.7	8.4	20.0	25.7	[illegible].9	31.4
Total Asia	3.6	6.7	10.0	12.8	16.7	20.4	24.7

Rice researchers are now selecting and breeding varieties for tolerance of such unfavorable environmental conditions as drought, deep water, poor soils, and cold temperature. Fertilizer responsiveness is only one of many traits being considered in the development of rice varieties suited for different environmental conditions.

The term "high yielding varieties" may give the misleading impression that such rices give high yields under all conditions. No single term or phrase can adequately describe the increasingly diverse characteristics of the new rice varieties. Because this study is concerned with changes that have been associated with varieties developed and released to farmers since 1965, the terms *modern* (MV) or *new*, rather than high yielding, are used to distinguish recently released varieties from earlier ones.

Varieties in use prior to 1965 are referred to as *local* varieties (LV) and include those developed through breeding programs (improved local varieties) and other (traditional) varieties existing before 1965. The terms do not imply a complete lack of progress in varietal improvement prior to 1965. Actually, improved local varieties were found important in many study areas. Furthermore, the plant type characteristics of the more recently released MV are relatively similar to those of the improved LV. The favorable features of many LV are being bred into the MV.

EXTENT OF ADOPTION OF MODERN VARIETIES

The extent of adoption of MV in the study villages and the preference for specific varieties are analyzed in this chapter. An attempt is made to identify

those factors which may have contributed to the variation in extent of adoption of MV among villages.

The villages were classified into two types: 1) monoculture rice villages, where 90% or more of the cropped area that is suitable for rice production (excluding upland and tree crop areas) is planted to rice in both the wet and dry season; and 2) mixed-farming villages where, in addition to rice, another crop, such as sugarcane, tobacco, corn, or wheat, is of major economic importance. These other crops are grown either in rotation, e.g., rice followed by wheat or corn, or on different portions of the farm area during the same season, e.g., rice in combination with sugarcane or tobacco.

The difference in cropping patterns between these two types of villages reflects differences in environmental conditions. A rice-growing village that can grow a crop in addition to or in combination with rice is likely to have a more favorable environment for rice production because of better irrigation and drainage facilities. Monoculture villages tend to have no alternate or supplementary crop to rice and, generally, are centered in rice-growing areas.

The first of the MV — Taichung Native 1 (TN1), a short stiff-straw variety developed in Taiwan — was introduced into India in 1965. In 1966 and 1967, it was tested by farmers in the study areas located in India, but it did not spread because of its low resistance to major rice insects and diseases.

IR8, the first of the rice varieties named by the International Rice Research Institute (IRRI), was released in 1966. It was tried in many locations and gained popularity principally in the Philippines and in India. At the time of this survey, IR8 had been replaced in the Philippines largely by subsequent IRRI-released varieties, but it was still grown extensively in many parts of India during the dry season because of its high yield performance under favorable growing conditions.

IR5, which was released in 1967, and its sister lines Bahagia in Malaysia and Pankaj in India gained popularity in those areas where IR8 was found unsuitable. For example, at the time of the survey, IR5 — known as PB5 (Peta Baru or New Peta) in Indonesia — was the most popular of the new varieties in the study areas in Java, Indonesia.

National programs soon afterwards began to release rice varieties, many of which were based on crosses using IRRI plant material. These included C4-63 (Philippines) in 1967, Jaya (India) in 1968, RD1 (Thailand) in 1969, Ratna (India) in 1970, and Pelita (Indonesia) in 1971.

National programs in India, Indonesia, and the Philippines strongly supported the introduction of MV, and the adoption rate in most of the study villages was rapid (Table 2). Adoption of the new varieties was slower in villages in Thailand and in Pakistan.

Acceptance of the new rice varieties was slow in Thailand for two reasons. First, the low grain quality of the original IRRI rices was not suited to Thailand's dependence on the export of high quality rice for foreign exchange earning. Second, and more important, the short stature of the new varieties was

Table 2. Trend in the proportion of farmers who had used modern varieties (MV) by country and by type of farm in 32 villages in selected areas in Asia, 1966/72.[a]

Item	Villages (no.)	Farmers who had used MV (%)					
		1967	1968	1969	1970	1971	1972
By country							
India	12	27	43	77	93	96	96
Indonesia	5	28	64	83	88	90	90
Malaysia[a]	2	—	—	—	—	100	100
Pakistan	2	0	11	21	38	100	100
Philippines	9	36	71	91	99	100	100
Thailand	2	0	0	0	41	82	82
By type of farm							
Monoculture	17	32	60	73	85	92	92
Mixed farms	15	23	42	77	90	99	100
All villages[b]	32	26	50	73	87	96	95

[a]Data not available prior to 1971. [b]Excludes four rainfed and poorly irrigated villages: Mahipon, Maluao, and Cabpangi in Philippines and Sa Krachom, Thailand.

not suited to the poor water control conditions characteristic of the Thai rice-growing environment, where flooding, deep-water, and rainfed conditions are common. The grain quality of the new rice RD1 that was released in 1969 was superior, but this variety also was not suited to the prevailing conditions of poor water control.

The spread of MV in the Punjab of Pakistan was affected by government policies designed to maintain adequate supplies of local high quality Basmati rice for export.

There was no pronounced difference in the trend of adoption of the new rices between monoculture and mixed-farming villages. By 1972, however, all farmers in the mixed-farming villages had tried the new varieties, while, on the average, 8% of the farmers in the monoculture villages had never planted the new rices (Table 2).

Cidahu in West Java, Indonesia, and Sa Krachom in Thailand were the only two villages surveyed where over half of the farmers had not tried the MV (Table 3). Crop loss caused by gall midge discouraged farmers in Cidahu, while in the rainfed village of Sa Krachom, lack of water control reduced the incentive to try the new varieties.

Although most farmers surveyed had grown MV at the time of the survey, the area actually planted to those varieties varied widely. An average of 65% of the rice area in all villages was planted to MV in the wet season (Table 3), the coverage ranging from 27 to 100% of the total rice area. In all villages but five, where two crops of rice were grown a larger percentage of the area was planted to MV in the dry season than in the wet season.

The largest difference in area planted to MV between the dry and the wet season occurred in the two villages in Orissa, India, both located within a few kilometers of the Central Rice Research Institute, Cuttack, and in the two

Table 3. Rate and extent of adoption of modern varieties (MV) by type of farm in 36 selected areas in Asia, 1971/72.[a]

Location	Year of greatest MV adoption	Farms where MV were tried[b] (%)	MV adopters at time of survey (%)		Percent of rice area in MV	
			Wet	Dry	Wet	Dry
	India					
Monoculture villages						
Kandarpur, Orissa	1967	97	68	97	15	97
Korpada, Orissa	1967	95	62	95	15	89
Pedapulleru, A. Pradesh	1970	64	12	45	9	44
Mixed-farm villages						
D. Vijaypur, U. Pradesh	1968	100	82	n.a.[c]	75	n.a.
Tarna, U. Pradesh	1969	100	100	n.a.	95	n.a.
Baram, U. Pradesh	1970	100	81	n.a.	50	n.a.
Gajanur, Mysore	1968	100	92	100	88	98
Hosahally, Mysore	1967	100	88	100	88	100
Ashoknagar, Mysore	1968	100	72	100	62	100
Kariyamangalam, Tamil Nadu	1969	100	100	100	50	100
Palvarthuvenran, Tamil Nadu	1969	100	100	100	49	42
Manmalai, Tamil Nadu	1969	100	100	100	70	85
	Indonesia					
Monoculture villages						
Nganjat, Central Java	1968	100	57	90	39	63
Cidahu, West Java	1971	45	45	46	26	45
Mixed-farm villages						
Pluneng, Central Java	1969	100	98	100	91	86
Kahuman, Central Java	1968	100	87	20	66	12
Sidomulyo, East Java	1968	99	99	95	95	95
	Malaysia					
Monoculture villages						
Salor, Kelantan	1969	100	32	96	22	89
Meranti, Kelantan	1969	100	50	91	32	67
	Pakistan					
Mixed-farm villages						
Aroop, Punjab	1971	100	74	n.a.	40	n.a.
Maraliwala, Punjab	1971	100	58	n.a.	49	n.a.
	Philippines					
Monoculture villages						
San Nicolas, Nueva Ecija	1967	100	100	100	100	100
Malimba, Nueva Ecija	1967	100	99	100	96	98
Mahipon, Nueva Ecija[d]	1967	99	99	n.a.	75	n.a.
Marcos, Leyte	1967	100	100	100	100	100
Canipa, Leyte	1967	100	100	100	100	100
Tabang, Leyte	1968	100	100	100	100	100
Beynte Nuwebe, Davao	1968	100	100	100	100	100
Sinayawan, Davao	1967	100	100	100	100	100
Bulucaon, Cotabato	1968	100	100	100	100	100
Mixed-farm villages						
Canayuran, Cotabato	1969	100	100	100	100	100
Cabpangi, Cotabato[d]	1969	100	100	100	82	100
Maluao, Cotabato[d]	1969	100	83	78	90	88
	Thailand					
Monoculture villages						
Rai Rot, Don Chedi	1970	87	87	92	41	98
Nong Sarai, Don Chedi	1971	77	75	96	21	96
Sa Krachom, Don Chedi[d]	1971	30	30	n.a.	4	n.a.

[a]Varieties planted in less than 5% of total rice area are not considered. [b]As of wet season of the survey year. [c]n.a. No dry season rice crop. [d]Rainfed or poorly irrigated.

irrigated villages in Thailand (Table 3). In these locations, as well as a number of others, MV suitable for the wet season conditions are not yet available. In Eastern India and in Thailand, it is not uncommon for fields to be flooded to a depth of half a meter for a considerable period of time. Flooding reduces tillering of the rice plant. MV that are suitable for the poor drainage or waterlogged conditions that characterize many of these sites have yet to be developed.

In contrast almost 100% of the rice-growing area in the villages surveyed in the Philippines had been planted to MV. The percentage is much higher than that for all other countries, particularly in the wet season (Table 3). This high degree of acceptability (over 50% of the entire growing area in the Philippine by 1973) might be related, in large part, to the location of the International Rice Research Institute in this Asian nation. In the initial stages of its varietal improvement work, IRRI released varieties that were apparently better suited to conditions in the Philippines than to those elsewhere in South and Southeast Asia.

VARIETAL PREFERENCE

While many varieties of rice are grown throughout tropical Asia, two or three dominate the planting pattern of any one lowland rice village. Some LV and MV have spread to more than one country (Table 4, 5, and Appendix A). The specific characteristics of many varieties are summarized in Appendix B. In reply to a survey question regarding preference for rice varieties for the wet and dry seasons, farmers most frequently gave "high yield" as their reason. Thus they prefer a rice variety that performs best under their specific rice-growing conditions.

To determine the degree to which varietal preference was related to specific plant and environmental characteristics, rice varieties were categorized according to date of release — local (before 1966), early modern (1966–1968), and late modern (1969–1971). The late MV generally had greater disease and insect resistance and better grain quality than the early MV.

In 1972, the early MV were preferred in the mixed-farming villages in both the wet and dry season (Table 6); LV were still strongly preferred, particularly in the wet season, in the monoculture villages. In the monoculture villages, farmer preference for the more recent releases was similar (28% for the wet season and 33% for the dry season) to that for the early MV (25%, wet season, and 33%, dry season).

The contrast in the adoption patterns between the monoculture and mixed-farming villages seems to be related to climate and the incidence of rice insects and diseases. For example, in the generally drier climates prevalent in the mixed-farming villages of India, IR8 continued to be popular although it was rarely grown in recent years in most of monsoon Asia because of its susceptibility to such diseases as the tungro virus.

Table 4. Preference of farmers for local and modern varieties in 36 Asian villages, 1971/72 wet season.

Country/village	Local varieties (%)			Modern varieties (%)				
	Mahsuri	Intan	Others[a]	IR8/Jaya[b]	IR5	IR20	C4-63	Others[c]
			India					
Monoculture villages								
Kandarpur, Orissa	—	—	6	—	—	—	—	94
Korpada, Orissa	—	—	25	3	—	—	—	72
Pedapulleru, A. Pradesh	50	—	—	50	—	—	—	—
Mixed-farm villages								
D. Vijaypur, U. Pradesh	—	—	25	67	—	—	—	8
Tarna, U. Pradesh	—	—	—	100	—	—	—	—
Barain, U. Pradesh	—	—	—	100	—	—	—	—
Gajanur, Mysore	—	—	—	100	—	—	—	—
Hosahally, Mysore	—	—	—	100	—	—	—	—
Ashoknagar, Mysore	—	—	—	41	—	57	—	2
Kariyamangalam, Tamil Nadu	—	—	64	19	—	17	—	—
Palvarthuvenran, Tamil Nadu	—	—	—	—	—	100	—	36
Manmalai, Tamil Nadu	—	—	—	—	—	64	—	36
			Indonesia					
Monoculture villages								
Nganjat, Central Java	—	—	78	—	3	—	—	19
Cidahu, West Java	1	—	93	—	4	—	—	2
Mixed-farm villages								
Pluneng, Central Java	—	—	98	—	—	—	—	2
Kahuman, Central Java	—	—	100	—	—	—	—	—
Sidomulyo, East Java	—	—	—	—	100	—	—	—
			Malaysia					
Monoculture villages								
Salor, Kelantan	14	85	1	—	—	—	—	—
Merante, Kelantan	15	2	83	—	—	—	—	—
			Pakistan					
Mixed-farm villages								
Aroop, Punjab	1	—	64	3	—	—	—	32
Maraliwala, Punjab	—	—	68	—	—	—	—	32
			Philippines					
Monoculture villages								
San Nicolas, Nueva Ecija	—	—	10	—	63	19	4	4
Malimba, Nueva Ecija	—	2	11	3	26	48	5	5
Mahipon, Nueva Ecija	—	31	20	1	36	10	1	1
Marcos, Leyte	—	—	42	20	14	—	24	—
Canipa, Leyte	—	—	20	30	20	5	16	9
Tabang, Leyte	—	—	38	46	7	2	7	—
Beynte Nuwebe, Davao	—	2	2	8	3	77	8	—
Sinayawan, Davao	—	—	5	—	3	84	5	3
Bulucaon, Cotabato	—	—	—	5	20	68	5	2
Mixed-farm villages								
Capayuran, Cotabato	—	—	—	—	28	28	34	10
Cabpangi, Cotabato	—	—	—	—	—	—	100	—
Maluao, Cotabato	—	—	10	—	4	76	3	7
			Thailand					
Monoculture villages								
Rai Rot, Suphan Buri	—	—	56	—	—	—	—	44
Nong Sarai, Suphan Buri	—	—	71	—	—	—	—	29
Sa Krachom, Suphan Buri	—	—	100	—	—	—	—	—

[a] Wide range of local varieties. [b] IR8 and Jaya are almost identical in plant type. Jaya was grown widely in India and IR8 in India and elsewhere. [c] Principally Ratna, CRRI series in India, and RD1 in Thailand.

Table 5. Farmers' preference for local and modern varieties in 36 Asian villages, dry season, 1971/72.

Country/ village	Local varieties (%)			Modern varieties (%)				
	Mahsuri	Intan	Others[a]	IR8/Jaya[b]	IR5	IR20	CR-63	Others[c]
India								
Monoculture villages								
Kandarpur, Orissa	—	—	2	46	—	—	—	52
Korpada, Orissa	—	—	5	60	—	—	—	35
Pedapulleru, A. Pradesh	6	—	—	82	—	—	—	12
Mixed-farm villages								
Gajanur, Mysore	—	—	—	95	—	5	—	—
Hosahally, Mysore	—	—	—	100	—	—	—	—
Ashoknagar, Mysore	—	—	—	96	—	4	—	—
Kariyamangalam, Tamil Nadu	—	—	—	96	—	4	—	—
Palvarthuvenran, Tamil Nadu	—	—	—	97	—	—	—	3
Manmalai, Tamil Nadu	—	—	—	83	—	17	—	—
Indonesia								
Monoculture villages								
Nganjat, Central Java	—	—	94	—	3	—	—	3
Cidahu, West Java	1	—	95	—	1	—	1	2
Mixed-farm villages								
Pluneng, Central Java	—	—	98	—	—	—	2	—
Kahuman, Central Java	—	—	100	—	—	—	—	—
Sidomulyo, East Java	1	—	19	2	78	—	—	—
Malaysia								
Monoculture villages								
Salor, Kelantan	91	9	—	—	—	—	—	—
Meranti, Kelantan	88	—	12	—	—	—	—	—
Philippines								
Monoculture								
San Nicolas, Nueva Ecija	—	15	2	—	21	48	—	14
Malimba, Nueva Ecija	—	55	10	—	—	30	—	5
Marcos, Leyte	—	—	39	29	20	3	9	—
Canipa, Leyte	—	—	7	37	28	4	20	4
Tab-ang, Leyte	—	—	45	41	8	—	6	—
Beynte Nuwebe, Davao	—	—	—	8	—	84	5	3
Sinayawan, Davao	—	3	28	13	3	48	—	5
Bulucaon, Cotabato	—	—	3	—	42	42	10	3
Mixed-farm villages								
Capayuran, Cotabato	—	—	—	—	9	23	54	14
Cabpangi, Cotabato	—	—	—	—	20	—	80	—
Maluao, Cotabato	—	—	11	3	17	44	22	3
Monoculture villages								
Rai Rot, Suphan Buri	—	—	—	—	—	—	8	92
Nong Sarai, Suphan Buri	—	—	27	—	—	—	4	69

[a]Wide range of local varieties. [b]IR8 and Jaya are identical in plant type; Jaya was grown widely in India and IR8 in India and elsewhere. [c]Principally Ratna, CRRI series in India and RD1 in Thailand.

In all probability, new releases, more resistant to pests and diseases, will continue to replace the currently popular MV, particularly in the more humid areas. However, LV will remain popular in many areas until MV that are suitable to local environmental conditions are developed.

Water control is a critical factor in the decision of a farmer to plant LV or MV because MV tend to require greater water control than to LV. Lack of water control often results in flooding, poor drainage, or drought conditions.

Table 6. Preference of farmers for specific varietal groups of rice, selected villages in Asia, 1971/72.

Type of farming	Villages (no.)	Farmers (%) preferring		
		Local	Early modern[a]	Late modern[b]
		Wet season		
Monoculture	17	47	25	28
Mixed farming	15	28	49	23
		Dry season		
Monoculture	17	34	33	33
Mixed farming	10	22	71	7

[a]Includes the following varieties first released from 1966–68; IR8 and IR5 (known officially in Indonesia as PB8 and PB5), C4-63, Jaya, and IR6 (known officially in Pakistan as Mehran 6).[b] Includes the following varieties first released from 1969 to 1971; IR20, IR22, IR24, Ratna, Pankaj, RD1, and RD5. Although Jaya and IR20 were released in 1969, Jaya, which has characteristics very similar to IR8, was classified with the early modern group; IR20, bred specifically for resistance to insects, was classified with the late modern group.

Table 7. Farmers' preference for rice varieties classified according to plant height and level of water control, 36 villages in selected areas in Asia, 1971/72.

Type of rice preferred	Farmers preferring (%)				
	Wet season			Dry season	
	Good irrigation	Average irrigation	Rainfed	Good irrigation	Average irrigation
Semidwarf[a]	35	51	32	51	54
Intermediate[b]	40	19	32	27	27
Tall	25	30	36	22	19

[a]Includes IR8, IR20, IR22, IR24, Jaya, Ratna, CR-series and lines not officially released, such as IR6. [b]Includes IR5, C4-63, Mahsuri, Pankaj and BPI-76.

To determine to what degree farmer preference for a specific rice variety was associated with water control, varieties were categorized as tall, intermediate, or semidwarf. Also, farms were cross-classified according to varietal type and irrigation at one of the three levels of water control — good irrigation, average irrigation, and rainfed (Table 7). The preference for semidwarf rices was lowest in the rainfed areas.

Although only three varieties of intermediate stature had been widely disseminated (IR5, C4-63, and Mahsuri), they were relatively popular in the rainfed areas. Rice breeders are devoting more attention to this plant type which may be better suited to unfavorable growing conditions and low management practices than are semidwarf rices.

AREA SOWN TO MODERN VARIETIES AS RELATED TO YIELD AND INCOME GAINS

Farmer preference for MV because of their high yield suggested that the level of adoption could be related to the income advantage achieved from improved

yields of the MV over the LV. In this analysis, income refers to the gross returns from rice less fertilizer cost. In 9 of the 14 locations, there were enough observations for MV and LV to permit a comparison of the yield and income advantage. Very few LV were being grown at the four Philippine sites, and data were not available from one of the two sites in Malaysia for these to be included. In some villages, the quality of land, water control, and management practices used for MV and LV differed markedly even within the same farm.

No clear relationship between the yield or income gap and the percentage of area sown to MV could be discerned (Table 8). For example, in Varanasi, India, LV are grown in the low-lying areas that are not served by the tube well irrigation, because flooding makes such areas unsuitable for MV. Also, in Don Chedi, Thailand, the deep water in some areas precludes the use of MV. Thus, the big gap in yield and income between MV and LV at a given site reflects and environment where some of the poorest rice-growing areas are planted to LV. Generally, the better rice-growing areas are used for planting the MV.

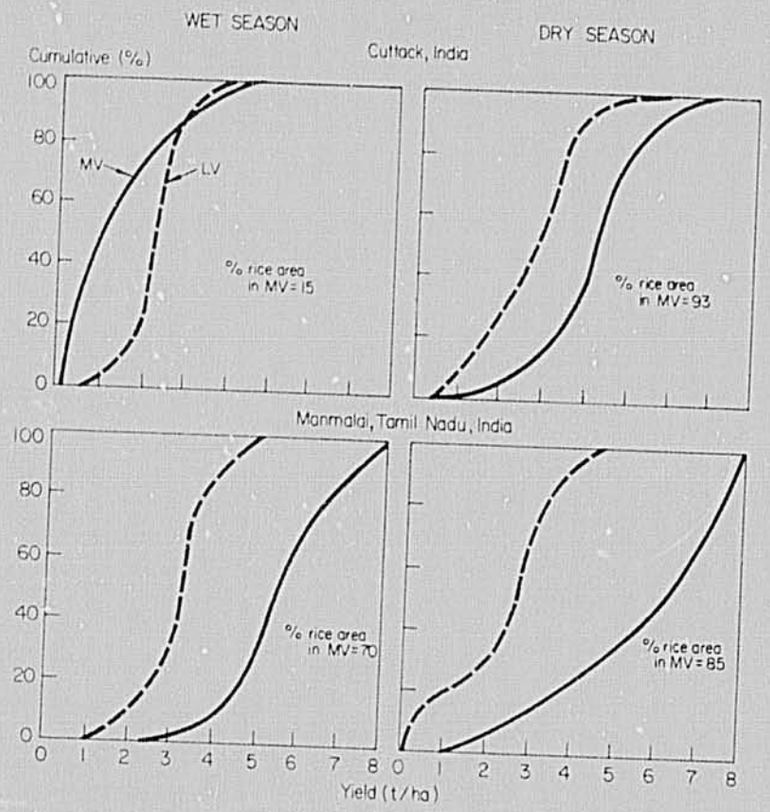
The relationship between income, yield, and area in MV was examined for selected sites by comparing cumulative frequency curves for MV and LV(Fig. 1 and 2). These curves are generated by ranking farm yields and farm income from high to low for LV and MV separately.

In the neighboring villages of Kandarpur and Korpada in Cuttack, India, LV

Table 8. Average yield and income from modern rice varieties (MV) and local varieties (LV) compared, in villages in 9 areas in Asia, 1971/72.

Village location	Yield (t/ha)			Income (US$/ha)[a]			Rice area in MV (%)
	MV	LV	MV/LV	MV	LV	MV/LV	
	Wet season						
India							
Varanasi, U. Pradesh	3.5	1.2	2.9	211	94	2.2	46
Cuttack, Orissa	3.0	2.3	1.3	274	215	1.3	15
West Godavari, A. Pradesh	4.1	3.1	1.3	320	259	1.2	9
Shimoga, Mysore	5.2	2.8	1.9	464	287	1.6	77
N. Arcot, Tamil Nadu	4.9	3.0	1.6	425	288	1.5	58
Indonesia							
Klaten, Central Java	5.4	4.9	1.1	304	334	0.9	66
Subang, West Java	3.2	3.0	1.1	126	128	1.0	50
Pakistan							
Gujranwala, Punjab	2.8	1.8	1.6	69	72	0.9	44
Thailand							
Don Chedi, Suphan Buri	2.5	1.7	1.5	96	63	2.9	22
	Dry season						
India							
Cuttack, Orissa	4.0	2.9	1.4	345	266	1.3	92
Pedapulleru, A. Pradesh	5.4	2.4	2.3	406	178	2.3	44
N. Arcot, Tamil Nadu	5.2	3.5	1.5	458	393	1.2	82
Indonesia							
Klaten, Central Java	6.2	5.2	1.2	352	352	1.0	58
Subang, West Java	3.9	3.0	1.3	157	130	1.2	45

[a]Gross returns less fertilizer cost.

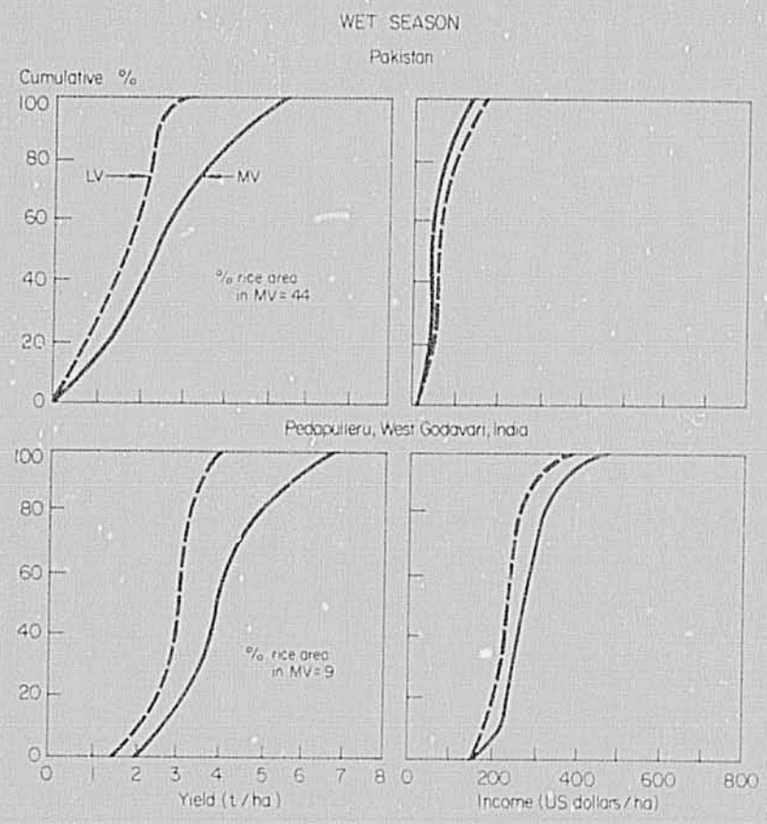


1. Cumulative frequency distribution of farm yields for local (LV) vs modern (MV) varieties and associated levels of MV adoption in villages in two areas of India, 1971/72 wet and dry seasons.

appeared to show a yield advantage during the wet season (Fig. 1). This contrast between seasons in yield performance and area in MV is typical of many rice-growing areas.

In Manmalai, Tamil Nadu, India, by contrast, higher yields of MV were associated with a high percentage of the rice-growing area being sown to MV in both seasons. In this part of India, solar radiation is high during both the wet and dry seasons. The climate in Western Tamil Nadu differs considerably from that of the coastal areas of India such as West Godavari and Cuttack.

In the two study villages in Pakistan and Pedapulleru in Andhra Pradesh, India (Fig. 2), where the level of adoption of MV was low, no income advantage for the MV was found. The support prices for rice are set carefully by the Pakistan government to ensure that farmers will produce an adequate amount of Basmati rice for export. This price support policy is discussed in the last chapter of this report.



2. Cumulative frequency distribution of farm yields and income (net of fertilizer cost) for villages in Gujaranwala, Pakistan and West Godavari, India, 1971/72 wet season.

ESTIMATING THE PERCENT OF THE RICE-GROWING AREA SOWN TO MODERN VARIETIES[1]

While the number of farmers adopting MV has generally been quite high, the percentage of the rice-growing area (RGA) sown to MV varies markedly among the study villages. To explain the variation in the RGA planted to MV in each village, the factors thought to contribute a major part to this variation were incorporated into a regression model.

In this model the percent of the RGA planted to MV is expressed as a function of four explanatory variables as follows:

[1] For a more detailed statistical analysis see T. L. Anden, "An Interregional Analysis of the Factors Related to the Adoption and Yield Levels of Modern Varieties and Fertilizer Use," M.S. thesis submitted to the University of the Philippines at Los Baños, February 1975.

$$MV = a + \beta_1 PR + \beta_2 S + \beta_3 T + \beta_4 P + u$$

where

MV = percent of the RGA planted to MV in each village;

PR = the ratio of the price of MV to the price of LV, the highest value being 1.3 in the three villages in Leyte, Philippines, and the lowest, 0.6 in the two study villages in Pakistan;

S = dummy variable for season, where wet season = 1, and dry season = 0;

T = dummy variable for the type of farming area where all monoculture rice villages (excluding those in the Philippines) are given the value 1 in the wet season and all other villages zero;

P = dummy variable for Philippine villages = 1, and for all other villages = 0;

a = a constant showing the percent RGA in MV when all variables have a zero value; and

u = a random error term.

The results of the analysis must be interpreted cautiously because the number of *dummy variables* in the regression can introduce bias into the estimated coefficients. Predominantly rainfed villages and the village of Kahuman in Central Java, Indonesia, which had an inexplicably low percentage of the RGA planted to MV in the dry season, were not included in the analysis.

The results of the regression are

$$MV = 48.9 + 34.5^{*}\, PR - 7.5\, S - 52.5^{**}\, T + 18.3^{**}\, P \qquad R^2 = 0.739$$

* = statistically significant at the 5% level

** = statistically significant at the 1% level

The observations of all variables are shown in Appendix C, together with the actual and estimated values of the percent area in MV. The regression explains approximately 75% of the variance among villages in the proportion of the RGA that is planted to MV.

A 0.1 variation (higher or lower) in the price ratio of MV to LV(PR) can change the RGA planted to MV by about 3.5%. For example, the unfavorable price ratio of MV to LV in Pakistan (0.6) reduces the RGA planted to MV by 13.8% as compared with those villages where there is no differential in the price of MV to LV. Generally, the negative impact of price and higher production (fertilizer) cost is offset to some extent by the yield advantage of the MV over the LV.

The difference in adoption between wet and dry seasons (S) is estimated as only 7.5%. In the monoculture areas in the wet season, however, the area sown to MV in the nine villages outside the Philippines (T) is extremely low (Table 3). In fact, the poor rice-growing conditions for MV appears to reduce the RGA in MV by 52.5% in these villages.

The impact of a location in the Philippines where many new rice varieties were developed and tested by IRRI is shown by the last variable (*P*). An 18.3% greater area in MV in the RGA may be a consequence of being located in the Philippines.

CONCLUSIONS

Wide variability exists in the level of adoption of modern rice varieties (MV) across the rice-growing areas of Asia, even in the irrigated areas represented by this study. In some villages, over 90% of the area was planted to MV, while in others less than 20% of the RGA was sown to those varieties. Factors contributing to this variability are seasonal suitability of the rice variety, the degree of water control, and profitability.

The first MV were short statured and, under ideal rice-growing conditions, responded well (high grain yields) to fertilizer. They were well suited to areas characterized by good irrigation combined with high solar radiation. Although medium-statured varieties appear to have a lower yield potential than the short-statured rices, the rices of medium stature had greater tolerance to unfavorable soil-water environments and were thus becoming popular in many of the study villages, particularly in the wet season. In other villages local varieties remained more popular than the MV, probably because these areas have poor drainage and are unsuitable for the modern rices.

The wide acceptance of the new rice varieties in the Philippines suggests that proximity to research centers such as IRRI is an important contributing factor in the transfer of technology.

Research for rice production in the national systems must be concentrated in the development of high yielding rices that are suited to agroclimatic conditions. Varieties are needed that perform well under different growing conditions, such as salinity, drought, flooding, and deep water. It is also possible to raise rice yields by improving the irrigation systems so that existing varieties and technology can be adopted. To increase production in unfavorable agroclimatic environments both strategies should be pursued with equal determination.

APPENDIX A. **Farmers' preference for local and modern varieties by season and by type of farm in 36 villages in selected areas in Asia, 1971/72.**

Country/village	Wet season				Dry season			
	Local varieties	Farmers preferring (%)	Modern varieties	Farmers preferring (%)	Local varieties	Farmers preferring (%)	Modern varieties	Farmers preferring (%)
			India					
Monoculture villages								
Kandarpur, Orissa	Others[a]	6	CR series[b]	72	Others	2	Ratna	52
			Ratna	20			Jaya	46
			Pankaj	2				
Korpada, Orissa	Others	25	CR series	67	Others	5	Ratna	35
			Ratna	5			Jaya	60
			Jaya	3				
Pedapulleru, A. Pradesh	Mahsuri	50	IR8	13	Mahsuri	6	IR8	21
			Jaya	37			Jaya	61
Mixed-farm villages								
D. Vijaypur, U. Pradesh	Others	25	IR8	67				
			Ratna	8				
Tarna, U. Pradesh			IR8	88				
			Jaya	12				
Baram, U. Pradesh			IR8	77				
			Jaya	23				
Gajanur, Mysore			IR8	57				
			Jaya	43				
							IR8	54
							IR20	5
Hosahally, Mysore							Jaya	41
			IR8	11			IR8	11
Ashoknagar, Mysore			Jaya	89			Jaya	89
			IR20	57			IR20	4
			IR22	2			Jaya	96
			Jaya	41				
Kariyamangalam, Tamil Nadu GEB24		64	IR8	19			IR8	96
			IR20	17			IR20	4
Palvarthuvetiran, Tamil Nadu			IR20	100			IR8	97
							IR22	3
Manmalai, Tamil Nadu			IR20	64			IR8	83
			IR22	36			IR20	17

(continued on opposite page)

APPENDIX A continued

Country/village	Wet season				Dry season			
	Local varieties	Farmers preferring (%)	Modern varieties	Farmers preferring (%)	Local varieties	Farmers preferring (%)	Modern varieties	Farmers preferring (%)
Indonesia								
Monoculture villages								
Nganjat, Central Java	Sigadis	78	IR5	3	Sigadis	60	IR5	3
			Other IR series[f]	19	Rojelele	4	Other IR series	3
					Gembiro	28		
					Gondomono	2		
Cidahu, West Java	Mahsuri	1	IR5	4	Shynta	4	IR5	1
					Rojolele	1	CR-1014	1
					Mahsuri	1	C4-63	1
					Sigadis	1	Other IR series	1
					Gembiro	1		
					Others	88		
Mixed-farm villages								
Plumeng, Central Java	Gembiro	9	IR Series	2	Gondomono	9	C4-63	2
	Gondomono	8			Others	1		
	Others	3						
Kahuman, Central Java	Gondomono	100			Gembiro	88		
					Gondomono	10		
					Others	2		
Sidomulyo, East Java			IR5	100	Mahsuri	1	IR5	78
					Others	19	IR8	2
Malaysia								
Monoculture villages								
Salor, Kelantan	Intan	85			Mahsuri	91		
	Mahsuri	14			Intan	9		
	Others	1						
Meranti, Kelantan	Mahsuri	15			Mahsuri	88		
	Intan	2			Others	12		
	Others	83						
Pakistan								
Mixed farm villages								
Aroop, Punjab	Basmati	63	IR6	32				

	Mahsuri	1	IR8	3				
	Others	1						
Maraliwala, Punjab	Basmati	58	IR6	32				
	Others	10						
			Philippines					
Monoculture villages								
San Nicolas, Nueva Ecija	Others	10	IR series	86	Intan	15	IR series	83
			C4-63	4	Others	2		
Malimba, Nueva Ecija	Intan	2	IR series	82	Intan	55	IR series	35
	Others	11	C4-63	5	Others	10		
Mahipon, Nueva Ecija	Intan	31	IR series	48				
	Tjeremas	10	C4-63	1				
	Peta	3						
	Others	7						
Marcos, Leyte	Peta	14	IR series	34	Peta	14	IR series	52
	Tjeremas	28	C4-63	24	Tjeremas	25	C4-63	9
Canipa, Leyte	Peta	2	IR series	64	Others	7	IR series	73
	Others	18	C4-63	16			C4-63	20
Tab-ang, Leyte	Peta	15	IR series	55	Peta	26	IR series	49
	Tjeremas	4	C4-63	7	Others	19	C4-63	6
	Others	19						
Beynte Nuwebe, Davao	Intan	2	IR series	88			IR series	95
	Others	2	C4-63	8			C4-63	5
Sinayawan, Davao	Others	5	IR series	90	Peta	23	IR series	69
			C4-63	5	Intan	3		
					Others	5		
Bulucacn, Cotabato			IR series	95	Others	3	IR series	87
			C4-63	5			C4-63	10
Mixed-farm villages								
Capayuran, Cotabato			IR series	66			IR series	46
			C4-63	34			C4-63	54
Cabpangi, Cotabato			C4-63	100			IR5	20
							C4-63	80
Maluao, Cotabato	Others	10	IR series	87	Others	11	IR series	67
			C4-63	3			C4-63	22
			Thailand					
Monoculture villages								
Rai Rot, Suphan Buri	Kau-ta-lang	44	RD1	44			RD1	92
	Others	12					C4-63	8
Nong Sarai, Suphan Buri	Others	71	RD1	29	Others	27	RD1	69
							C4-63	4
Sa Krachom, Suphan Buri	Kau-ta-lang	32						
	Others	68						

[a] "Others" refers to local varieties other than those mentioned above. [b] Releases of the Central Rice Research Institute in Cuttack, India. [c] Releases of the International Rice Research Institute — IR5, IR24, IR22.

APPENDIX B: **List of varieties and their basic characteristics**

ADT-27. 1965. An indica × japonica hybrid of early maturity and intermediate height released by Madras State of India. Moderately responsive to nitrogen. Small, round grains; good cooking quality.

Apostol. A tall traditional variety. Strongly sensitive to photoperiod.

Bahagia. 1968. A sister selection of IR5 released by West Malaysia. Intermediate in plant type and maturity.

BAM 3. A selection from a tall traditional variety suited to low-lying areas. Released by the Orissa State of India. Good cooking quality.

Basmati 370. 1933. A selection from the Basmati variety of old India. Known for its aroma and kernel elongation character. Late in maturity and low yielding. Commands a high market price in South Asia and East Africa.

Bengawan. 1941. Released by the Central Research Institute of Agriculture, Indonesia. A tall variety weakly sensitive to photoperiod. Noted for its good eating quality. Medium responsive to fertilizer.

BPI-76. 1960. An intermediate variety developed by the Philippine Bureau of Plant Industry. Strongly sensitive to photoperiod. Slender grains.

C4-63. 1967. An intermediately tall variety developed by the University of the Philippines, College of Agriculture about 1967. Weakly sensitive to photoperiod. Noted for its good eating quality.

C4-63G. c. 1968. A pure line selected from C4-63. With green basal leaf sheath. (green base).

C4-137. 1969. An intermediately tall variety released by the University of the Philippines College of Agriculture. Weakly sensitive to photoperiod.

C0-29. c.1960. A hybrid variety of Madras State (India) having early maturity and blast resistance. Moderately tall. Medium grain quality.

C0-33. c.1970. A semidwarf variety of Madras State (India) originating from IR8 × ADT-27. Also known as Karuna. Early maturing and responsive to nitrogen. Small, round grains. Good cooking quality.

Darn. 1960. A tall variety released by the Central Research Institute of Agriculture, Indonesia. Relatively insensitive to photoperiod. Medium grain quality.

Dee-geo-woo-gen. A semidwarf variety of Taiwan. Insensitive to photoperiod. Taichung Native 1. IR8 and many semidwarf lines were derived from Dee-geo-woo-gen.

GEB-24. c.1930. A spontaneous mutant selected from a traditional variety of Madras State. Good grain quality. Parent of many Indian varieties. 150-day maturity. Although low yielding, it commands a higher price than do modern rice varieties.

Intan. 1940. A tall variety released by the Central Research Institute of Agriculture, Indonesia. Also grown in the Philippines. Weakly sensitive to photoperiod.

IR8. 1966. A semidwarf variety. First variety named by The International Rice Research Institute (IRRI). Relatively insensitive to photoperiod. Outstanding in nitrogen response. Poor grain type. Lacks resistance to bacterial blight, tungro virus, brown planthopper, and grassy stunt virus.

IR5. 1967. Developed at IRRI. Intermediate in height and weakly sensitive to photoperiod. Poor grain type. More resistant to adverse weather conditions than other IRRI semidwarf varieties, but lacks resistance to tungro, brown planthopper, grassy stunt, and the stem borers.

IR6. 1970. A name given to the breeding line IR6-156-2 before it was named as Mehran 69 in Pakistan.

IR20. 1969. A semidwarf named by IRRI. Weakly sensitive to photoperiod. Moderately resistant to tungro and leafhoppers. Medium long and slender grains.

IR22. 1969. A semidwarf named by IRRI. Weakly sensitive to photoperiod. Slender grains. Susceptible to tungro and the leafhoppers.

IR24. 1971. A semidwarf named by IRRI. Relatively insensitive to photoperiod. Soft and moist cooking quality. Moderately resistant to tungro and leafhoppers.

Jaya. 1968. A semidwarf variety released by the All-India Coordinated Rice Improvement Project. Relatively insensitive to photoperiod. Poor grain type.

Jhona 349. 1933. A selection from Jhona, a traditional variety of the Punjab area (India and Pakistan). More high-yielding than other local varieties. Poor grain quality.

Kullakar. A 130-day traditional variety from which ADT-23 was isolated. Native to Madras State of India. Short and red grains.

Malinja. 1964. A moderately tall and relatively early maturing (though sensitive to photoperiod) hybrid developed in Malaysia. Highly susceptible to diseases.

Mahsuri. 1966. An intermediate variety released by the Rice Department of Malaysia. Relatively insensitive to photoperiod. Priced for its fine grains.

Mayang Ebos. A tall and late traditional variety of Malaysia which has very strong grain dormancy. Sensitive to photoperiod.

Mehran 69. 1970. A semidwarf, long-grain selection from IR6-156-2 released in Pakistan. Slender grains.

Palman 246. 1939. A selection from Palman, a traditional variety of the Punjab area (India and Pakistan). Grain appearance good, but poor cooking quality.

Pankaj. 1969. A sister line of IR5 selected in India.

PB5 (Peta Baru 5). Indonesian name for IR5.

PB8 (Peta Baru 8). Indonesian name for IR8.

Pebifun. A relatively early, moderately tall, indica variety of Taiwan. A major variety grown in the double-cropping area of West Malaysia during 1942–1964.

Pelita. 1971. Released by the Central Research Institute of Agriculture, Indonesia. Weakly sensitive to photoperiod. Grains relatively more attractive than those of PB5 or PB8.

Peta. 1941. A tall variety released by the Central Research Institute of Agriculture, Indonesia. Also grown in the Philippines. Weakly sensitive to photoperiod.

Ratna. 1970. A semidwarf variety released by the Central Rice Research Institute, India. Weakly sensitive to photoperiod. High grain quality.

RD1. 1969. A Thai semidwarf variety. First hybrid variety named by the Thailand Rice Department (now Rice Division). Long and slender grains. More high-yielding than traditional varieties.

RD3. 1969. A Thai semidwarf variety. Similar to RD1, it is also non-glutinous. Long and slender grains. More high-yielding than traditional varieties.

RD5. 1973. A moderately tall Thai hybrid variety having a plant type intermediate between the tall traditional type and the semidwarf. Weakly sensitive to photoperiod. Long and slender grains.

Ramadja. 1954. A tall variety released by the Central Research Institute of Agriculture, Indonesia. Weakly sensitive to photoperiod.

Ria. 1966. IR8 under a Malaysian name.

Rojolele. A tall traditional variety of the bulu type; purified from a farmer's variety.

Relatively insensitive to photoperiod. Its bold grains command a higher price than those of PB5.

Siam 29. A tall traditional variety sensitive to photoperiod. Both Malaysian and Thai strains have the same name. Slender grains.

Sigadis. 1954. A tall variety developed by the Central Research Institute of Agriculture, Indonesia. Relatively insensitive to photoperiod. Medium responsive to fertilizer. Good eating quality.

SL0-13. c.1950. An intermediately tall strain selected from a traditional variety. Developed in Andhra Pradesh, India.

SL0-19. c.1959. A tall and early maturing strain selected from a traditional variety. Developed in Andhra Pradesh, India.

Syntha. 1963. A tall variety developed by the Central Research Institute of Agriculture, Indonesia. Weakly sensitive to photoperiod. Medium responsive to fertilizer. Good eating quality. Slender grains.

Taichung 65. 1927. A ponlai (japonica) variety of Taiwan. Well adapted to double cropping in the subtropics and tropics.

Taichung Native 1. 1960. The first semidwarf variety released by the Taiwan Provincial Department of Agriculture. Relatively insensitive to photoperiod. Poor grain type. Susceptible to many diseases and insects.

Tangkai Rota. A traditional variety of Malaysia having relatively erect leaves, intermediate height and maturity. A parent of IR5.

Tjeremas. c.1940. A tall variety developed in Indonesia. Has the same parents as Peta. Also grown in the Philippines. Weakly sensitive to photoperiod.

TKM-6. c.1950. A relatively early and tall hybrid derived from GEB-24 × C0-18. Slender grains. Moderate resistance to stem borers. Developed in Madras State, India.

APPENDIX C. **Input data used in regression analysis of factors affecting the adoption of modern varieties (MV) in 32 selected villages of Asia, 1971/72.**

Season/village	Area planted to MV(%)		Price ratio MV/local (PR)	Dummy for season (S)	Dummy for type of (T)	Dummy for Philippine villages (P)
	Actual	Estimated				
		Wet season				
B. Nuwebe, Davao	100	94	1.0	1	0	1
Bulucaon, Cotabato	100	87	0.8	1	0	1
Capayuran, Cotabato	100	90	0.9	1	0	1
Marcos, Leyte	100	104	1.3	1	0	1
Sinayawan, Davao	100	94	1.0	1	0	1
San Nicolas, Nueva Ecija	100	90	0.9	1	0	1
Tab-ang, Leyte	100	104	1.3	1	0	1
Canipa, Leyte	97	104	1.3	1	0	1
Sidomulyo, East Java	97	72	0.9	1	0	0
Malimba, Nueva Ecija	95	90	0.9	1	0	1
Tarna, U. Pradesh	95	69	0.8	1	0	0
Gajanur, Mysore	88	76	1.0	1	0	0
Hosahally, Mysore	88	72	0.9	1	0	0
Cabpangi, Cotabato	82	90	0.9	1	0	1

(continued on opposite page)

APPENDIX C continued

Season/village	Area planted to MV(%)		Price ratio MV/local (PR)	Dummy for season (S)	Dummy for type of (T)	Dummy for Philippine villages (P)
	Actual	Estimated				
Pluneng, Central Java	81	72	0.9	1	0	0
Dhanpur-Vijaypur, U. Pradesh	73	65	0.7	1	0	0
Manmalai, Tamil Nadu	70	69	0.8	1	0	0
Kahuman, Central Java	66	69	0.8	1	0	0
Ashoknagar, Mysore	62	76	1.0	1	0	0
Kariyamangalain, Tamil Nadu	50	69	0.8	1	0	0
Maraliwala, Punjab	49	62	0.6	1	0	0
Palvarthuvenran, Tamil Nadu	49	69	0.8	1	0	0
Rai Rot, Don Chedi	41	23	1.0	1	1	0
Aroop, Punjab	40	62	0.6	1	0	0
Nganjat, Central Java	39	69	0.8	1	0	0
Cidahu, West Java	26	20	0.9	1	1	0
Meranti, Malaysia	32	23	1.0	1	1	0
Salor, Malaysia	22	23	1.0	1	1	0
Nong Sarai, Don Chedi	21	26	1.1	1	1	0
Kandarpur, Orissa	15	23	1.0	1	1	0
Korpada, Orissa	15	23	1.0	1	1	0
Pedapulleru, A. Pradesh	9	20	0.9	1	1	0
		Dry season				
Ashoknagar, Mysore	100	83	1.0	0	0	0
B. Nuwebe, Davao	100	101	1.0	0	0	1
Bulucaon, Cotabato	100	94	0.8	0	0	1
Cabpangi, Cotabato	100	98	0.9	0	0	1
Canipa, Leyte	100	112	1.3	0	0	1
Capayuran, Cotabato	100	98	0.9	0	0	1
Hosahally, Mysore	100	80	0.9	0	0	0
Kariyamangalam, Tamil Nadu	100	76	0.8	0	0	0
Marcos, Leyte	100	112	1.3	0	0	1
San Nicolas, Nueva Ecija	100	98	0.9	0	0	1
Sinayawan, Davao	100	101	1.0	0	0	1
Tab-ang, Leyte	100	112	1.3	0	0	1
Malimba, Nueva Ecija	98	98	0.9	0	0	1
Gajanur, Mysore	97	83	1.0	0	0	0
Kandarpur, Orissa	97	83	1.0	0	0	0
Rai Rot, Don Chedi	96	83	1.0	0	0	0
Nong Sarai, Don Chedi	96	86	1.1	0	0	0
Sidomulyo, East Java	94	80	0.9	0	0	0
Korpada, Orissa	89	83	1.0	0	0	0
Pluneng, Central Java	89	80	0.9	0	0	0
Salor, Malaysia	89	83	1.0	0	0	0
Manmalai, Tamil Nadu	86	76	0.8	0	0	0
Meranti, Malaysia	67	83	1.0	0	0	0
Nganjat, Central Java	63	76	0.8	0	0	0
Cidahu, West Java	45	80	0.9	0	0	0
Palvarthuvenran, Tamil Nadu	44	76	0.8	0	0	0
Pedapulleru, A. Pradesh	44	80	0.9	0	0	0

Yield and fertilizer input

RANDOLPH BARKER

There is a high positive correlation between village average rice yields and the average level of applied nitrogen. However, yield response to nitrogen differs considerably from one village to another. Yield response to nitrogen is also highly variable from year to year in most locations when judged from data for nearby experiment stations. The yield potential of modern varieties at nearby experiment stations is much higher than the average yield obtained in neighboring villages. While this suggests that yields can be increased substantially, the factors explaining this yield gap are not identified in this study.

FERTILIZER IS THE PRINCIPAL INPUT associated with the modern rice varieties. To meet the growing demand for food from limited land resources, chemical fertilizers are used increasingly to improve the productivity of the available crop land.

Data from the village surveys were examined to determine the variation in yield and fertilizer use among study areas, and the possible causes of this variability. Then, the fertilizer response data obtained from experiment stations near the study areas were examined to identify the potential yield response to fertilizer. Finally, comparisons were made between the yields at the experiment station and the average yields achieved in the villages.

VILLAGE SURVEYS

The average village yield correlates positively with the amount of fertilizer input. A correlation coefficient of 0.86 was realized when those villages where severe insect and disease damage occurred during the survey year were excluded from the analysis (Fig. 1). Data on yield and nitrogen input of modern varieties (MV) and traditional varieties (TV) by village are summarized in Appendix A. The correlation between the use of MV and nitrogen input was low (Fig. 2). In a number of villages where 100% of the area was planted to

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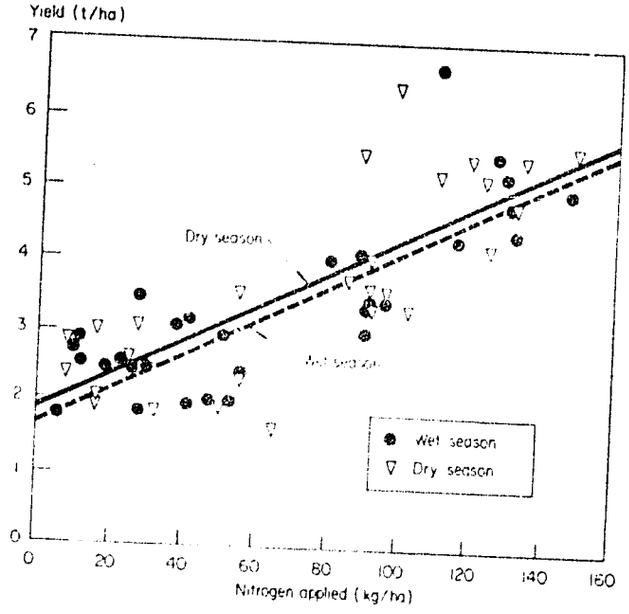
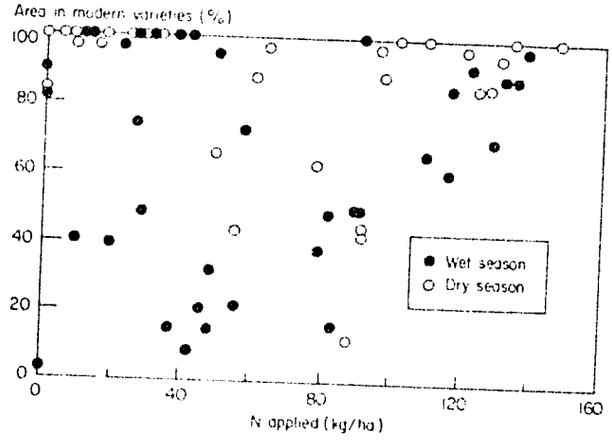
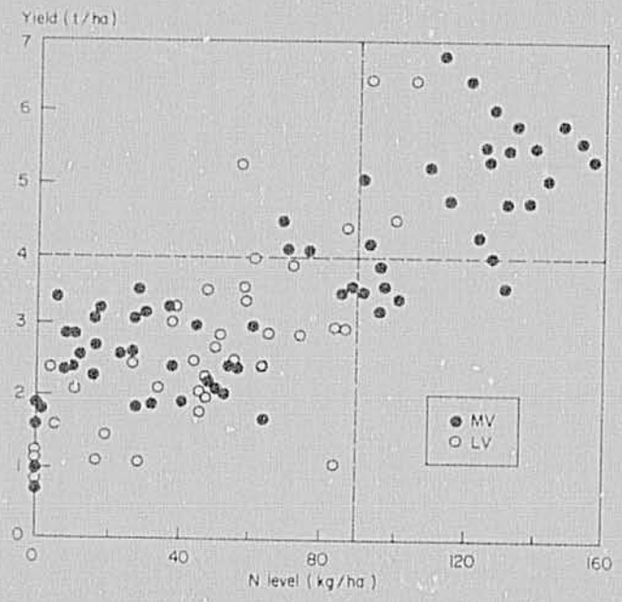


1. Relationship between average farm yield and nitrogen level per hectare by village, wet and dry seasons, selected villages in Asia, 1971/72.



2. Relationship between percent area planted to modern varieties and nitrogen applied per hectare by village, selected areas of Asia, 1971/72 wet and dry seasons.



3. Relationship between average farm yield of rice and nitrogen applied per hectare, 36 villages in Asia, 1971/72 wet and dry seasons. MV = modern varieties; LV = local varieties.

MV, the fertilizer input was very low. However, a high level of nitrogen input (above 80 kg/ha) was associated with a high proportion of the land in MV. This suggests that in the areas planted to MV, the constraint on nitrogen input and yield has been lifted in some, but not in all, cases. Village average yields were calculated separately for MV and local varieties (LV). Most of the average yields exceeding 4 t/ha were achieved with MV, using 90 kg nitrogen/ha (Fig. 3). In many cases, however, the level of applied nitrogen and the yield were low for both MV and LV. Identification of the factors that restrict the level of nitrogen input can help improve the yields of MV.

The range in yield and fertilizer input was greater for MV than for LV of rice. The lowest yield and amount of applied fertilizer for MV occurred with the poorly irrigated and rainfed villages (Sa Krachom in Thailand; and Mahipon, Maluao, and Cabpangi in the Philippines). The average yield of MV was 1.3 t/ha, and no fertilizer was used in three of the four villages.

Among the remaining 32 villages (Table 1), the yield of the MV was lowest for monoculture villages (those growing only rice in paddy fields) during the wet season and highest for the mixed-farming villages (where crops other than rice are included in the rotation) during the dry season.[1]

[1] For a more complete definition of monoculture and mixed-farming villages, see the previous chapter.

Table 1. Average yield and nitrogen input for modern rice varieties in monoculture and mixed-farming villages in selected areas of Asia, 1971/72.

	Villages (no.)	Yield (t/ha)	Applied N (kg/ha)
		Monoculture	
Wet season	17	2.4(2.9)[a]	45
Dry season	17	3.2	54
		Mixed farming	
Wet season	15	4.5	104
Dry season	10	5.1	112

[a]Value in parentheses was based on "normal" yields in 7 villages. Tungro and gall midge caused serious crop damage during the survey year.

Table 2. Yield and nitrogen input for modern varieties (MV) by nitrogen level and percentage of area in MV, 32 villages in Asia, 1971/72.

Village category[a]	Villages (no.)	Area in MV (%)	Yield (t/ha)	Nitrogen (kg/ha)
		Wet season		
Low nitrogen				
Low MV	4	38	2.8	23
High MV	7	100	2.6[b]	25
High nitrogen				
Low MV	8	25	3.0[b]	71
High MV	13	78	4.3[b]	118
		Dry season		
Low nitrogen				
Low MV	0	—		—
High MV	9	99	2.7	17
High nitrogen				
Low MV	4	36	5.0	105
High MV	14	90	4.4	105

[a]Low nitrogen = less than 45 kg N/ha; high nitrogen = 45 kg N/ha and over; low MV = less than 50% of area planted, high MV = 50% or more of area planted. [b]Severe yield loss due to tungro or gall midge in two or three villages.

The low yields in the monoculture villages were caused by a severe crop loss in 7 of the 17 villages due to tungro virus and to gall midge infestation during the survey year. Despite the apparently greater insect and disease hazard during the wet season, the level of nitrogen applied and the yield achieved for the MV in the wet season were similar to those in the dry season.

Villages were grouped by season (wet and dry) into four categories according to the level of nitrogen input and the amount of area in MV (Table 2). Experiments at IRRI have shown that 60 kg nitrogen/ha can be profitably applied to MV even under wet-season conditions.[2] The application of less than 45 kg nitrogen/ha was considered *low nitrogen*. Planting less than 50% of the rice are of MV was classified as *low MV*.

[2] International Rice Research Institute, Annual Report for 1972 (1973), pp. 48–50.

Among the 11 villages classified as *low nitrogen*, two in Thailand and two in Pakistan were classified as *low MV*. Poor water control in the wet season causes flooding and deep-water conditions, which are not appropriate for the cultivation of MV in Thailand. In Pakistan, the low price for the MV of rice as compared with that for the local Basmati rice (an export commodity) limits the growing of MV. Fertilizer application in both of these Asian nations is low because of the high cost of the input.

The remaining seven *low nitrogen* villages are located in southern Philippines (Leyte, Cotabato, and Davao). The low level of fertilizer use contrasts sharply with the 100% adoption of MV and the wide use of insecticides in these villages. Whether the major constraint to nitrogen use is of a physical or a socioeconomic nature is not clear. The interest rates and input prices tended to be higher, rice prices lower, and irrigation less developed in the southern Philippines than in Central Luzon, Philippines, where fertilizer is more widely used.

Nitrogen input was as low in the dry season for the 11 *low nitrogen* villages as it was in the wet season excluding Pakistan, which has no dry-season rice crop. In Thailand and in southern Philippines, however, favorable growing conditions during the dry season allow almost 100% of the area in the study villages to be planted to MV. No village had a low level of applied fertilizer combined with small areas planted to MV (Table 2).

Among the high nitrogen users, less than 50% of the rice area was planted to MV in only 4 of 18 villages in the dry season and in 8 of 21 villages during the wet season. The lack of suitable MV in the wet season limited an increase in rice production in these 8 villages which were located in eastern India; Central Java, Indonesia; and Malaysia.

VILLAGE-LEVEL FERTILIZER RESPONSE

The yields over ranges of nitrogen input (overall range: 0–150 kg/ha) were compared in villages growing both MV and LV (Table 3). They varied markedly among the study areas. In Orissa, India, LV performed better than the MV at all levels of applied nitrogen because of an infestation of gall midge to which the MV were susceptible. In Central Java, Indonesia, the yields of MV and LV were similar.

In all other locations, the yields of the MV were superior. The MV may have had the advantage of being grown under better conditions and with higher inputs i.e., insecticides, fertilizers, etc., and better management than those of the LV, even on the same farm. For example, farmers frequently planted the MV in those farm areas with better soil and water conditions and tended to give the new varieties extra care.

The data do not suggest that the yields of rice in villages where low levels of fertilizer are used could be increased merely by applying more nitrogen. Each farm has a different response function, and no data are available to estimate

Table 3. Yields of modern varieties (MV) and local varieties (LV) for selected ranges of applied nitrogen in 36 villages in Asia, 1971/72 wet season.[a]

Country and village	Rice type	Yield (t/ha)					
		0	1–30 kg N/ha	31–60 kg N/ha	61–90 kg N/ha	91–120 kg N/ha	121–150 kg N/ha
		Wet season					
India							
Andhra Pradesh							
Pedapulleru.	MV	—	—	3.9	4.5	4.3	—
	LV	—	—	3.0	3.0	3.1	—
Orissa							
Kandarpur-Korpada	MV	1.0	1.1	1.3	1.7	—	—
	LV	2.1	2.3	2.4	2.6	—	—
Uttar Pradesh							
Dhanpur-Vijaypur	MV	—	—	—	4.9	—	—
	LV	—	—	—	5.1	—	—
Tarna-Barain	MV	—	—	3.6	—	—	—
	LV	—	—	1.7	—	—	—
Mysore							
Gajanur-Hosahally-Ashoknagar	MV	5.4	—	—	—	—	—
	LV	3.0	—	—	—	—	—
Tamil Nadu							
Kariyamangalam-Palvarthuvenran-Manmalai	MV	—	—	—	5.0	4.6	4.6
	LV	—	—	—	3.5	2.8	3.0
Indonesia							
Central Java							
Nganjat-Kahuman-Pluneng	MV	—	—	5.5	4.8	5.7	5.8
	LV	—	—	4.0	4.2	5.4	5.7
West Java							
Cidahu	MV	—	—	—	[illegible]	2.5	—
	LV	—	—	—	3.1	3.0	—
Malaysia							
Kelantan							
Salor-Meranti	MV	—	—	2.3	—	—	—
	LV	—	—	2.1	—	—	—

(continued on opposite page)

individual farm functions. However, a more realistic impression of the farm yield response to nitrogen input can be achieved by estimating the functions for the village, using the area in MV, since the village is a relatively homogeneous physical unit.

Nitrogen response curves were derived for 12 villages where there was an adequate range in level of fertilizer application (Appendix B, C). The villages were classified into three groups according to the range of nitrogen applied per hectare: low N, 0–60 kg/ha; moderate N, 30–100 kg/ha; and high N, 50–190 kg/ha (Table 4). In the wet season when 60 kg N/ha was applied, the average yield was 1.1 t/ha higher than when no fertilizer was used. When 100 kg N/ha

Table 3. continued

Country	Rice type	Yield (t/ha)					
		0	1–30 kg N/ha	31–60 kg N/ha	61–90 kg N/ha	91–120 kg N/ha	121–150 kg N/ha
			Wet season				
Thailand							
Suphan Buri							
Rai Rot-Nong Saria-Sa Krachom	MV	1.9	2.4	—	—	—	—
	LV	1.0	1.9	—	—	—	—
Pakistan							
Punjab							
Aroop-Maraliwala	MV	2.7	2.8	2.7	—	—	—
	LV	1.7	1.9	1.7	—	—	—
			Dry season				
India							
Andhra Pradesh							
Pedapulleru	MV	—	—	—	4.8	5.1	5.4
	LV	—	—	—	2.8	3.1	3.3
Tamil Nadu							
Kariyamangalam-Palvarthuvenran	MV	—	5.2	3.9	4.3	—	—
	LV		2.8	3.7	3.4	—	—
Indonesia							
Central Java							
Nganjat-Kahuman-Pluneng	MV	—	—	5.9	6.6	6.2	—
	LV	—	—	5.9	5.8	6.5	—
West Java							
Cidahu	MV	3.8	—	3.3	2.9	4.2	—
	LV	2.5	—	2.7	2.8	3.1	—
Malaysia							
Kelantan							
Salor-Meranti	MV	—	1.2	2.1	2.8	—	—
	LV	—	0.9	1.9	2.9	—	—

[a]Only villages where both MV and LV are found. A minimum of 5 observations/village for a given nitrogen range.

was applied, the average yield was only 0.7 t/ha higher than when 30 kg N/ha was used. The response function in the high nitrogen group was heterogeneous, and no consistent pattern was discerned.

For the dry season, the response curves of some of the villages — Rai Rot (Thailand) and Salor (Malaysia), in the low nitrogen group, and Kahuman (Indonesia) and Kariyamangalam (India) in the high nitrogen group — were comparatively steep. In Rai Rot and Salor, 60 kg N/ha increased the respective yields by 1.5 and 2.5 t/ha over those with no fertilizer. In Kahuman and Kariyamangalam, increasing the nitrogen from 50 to 150 kg N/ha increased the yield by 2.5 t/ha.

Generally, the nitrogen yield response curves for the individual villages

Table 4. Yield increase due to applied nitrogen, calculated from a response curve fitted to farm data from selected villages in Asia, 1971/72.

Response	Wet season			Dry season		
	Villages (no.)	Applied N (kg/ha)	Kg grain/ kg applied N	Villages (no.)	Applied N (kg/ha)	Kg grain/ kg applied N
			Low N (0–60 kg/ha)			
High	3	0–60	25	2	0–60	35
Low	2	0–60	10	1	0–40	12
			Moderate N (30–100 kg/ha)			
High	0	—	—	0	—	—
Low	3	30–70	14	2	30–80	10
			High N (50–190 kg/ha)			
High	1	50–130	16	2	50–150	25
Low	3	50–130	4	2	50–150	9

were highly variable, but were not as steep as the response curve based on village average yields shown earlier in Figure 1. The village average response curve represents more of a long-run response (discussed in the next chapter). Differences in environmental factors, physical resources, management, and use of inputs may be responsible for the variability in individual average response curves. Considerable variability in response among years was noted even under experimental conditions.

The incremental efficiency (kilograms of rough rice per kilogram of applied nitrogen) was computed over the range of N (0 to 130 kg N/ha) for each of the 12 study villages (Table 4). The unit gain in grain production per unit of nitrogen input was greater in the dry season than in the wet except for the moderate nitrogen group. The unit gain in the grain production per unit of applied nitrogen tended to be lower in the villages applying high nitrogen than in those with low nitrogen. The results for the low-response villages are consistent with the rule of thumb in Asia — 1 kg N/ha produces 10 kg rough rice.

EXPERIMENTAL DATA

While the results of experiments on yield response to fertilizer input conducted under the controlled environment of an experiment station are relatively accurate, their value for extension recommendations is limited because the conditions under which rice is grown in an experimental plot and a farmer's field can vary markedly. Nevertheless, such experimental results indicate the variation in yield response to fertilizer and the yield potential, both among locations and between seasons, and among varieties grown in the same season at the same location.

The results of nitrogen-response experiments were compiled from 12 exper-

Table 5. Soil characteristics at the experiment stations near the study areas in selected countries of Asia.

Location	Texture	pH	Organic matter (%)	Extractable P (ppm)	Exchangeable K (meq/100 g)
		India			
Andhra Pradesh					
Maruteru Agricultural Research Station	Clay	7.0–7.5	1.5	10.0	0.6
Uttar Pradesh (Nainital)					
Pantnagar Research Station	Sandy loam to silt clay loam	7.5–8.3	2–4	11–28	0.2–0.3
Uttar Pradesh (Varanasi)					
Uttar Pradesh Rice Research Exp. Station, Faizabad	n.a.[a]	7.0	0.85	12.5	0.15
Orissa					
Central Rice Research Institute	Sandy to clay loam	5.7–6.0	0.5–0.8	21–27	0.9–1.4
Tamil Nadu					
Paddy Breeding Station Coimbatore	Clay	7.7–8.2	1.5	2.2–6.7	0.8
Mysore					
Mandya Research Station	n.a.	6.0	0.88	11.4	0.21
		Indonesia			
West Java					
Pusakanegara Experiment Station	Clay	6.3	2.4	n.a.	n.a.
East Java					
Modjosori Experiment Station	Loam	6.6	1.2	n.a.	n.a.
		Thailand			
Suphan Buri					
Suphan Buri Experiment Station	Light clay	5.3	2.0	7	0.3
		Philippines			
Central Luzon					
Maligaya Rice Research and Training Center	Clay	6.9	1.5	8	0.5
Visayas					
Visayas Rice Experiment Station	Clay	7.0	3.3	10	0.9

[a]n.a. = not available.

iment stations which were selected because of their proximity to the study areas (Appendix D). The characteristics of the soil at each of these stations are summarized in Table 5.

Nitrogen response functions were estimated for selected varieties (Appendix E, F). Maximum yield and nitrogen at maximum yield were estimated for selected varieties in the wet season (Table 6) and the dry season (Table 7). Because information on the nitrogen response for LV was scarce in most locations, the performance of the new varieties could not be compared with that of popular LV.

The yield maximum for the majority of cases (23 of 31 observations for MV)

Table 6. Maximum yield and nitrogen input at maximum yield for selected varieties of rice at experiment stations in selected areas of Asia, 1967/75 wet season.

Location	Variety[a]	Period	Maximum yield[b] (t/ha)	Nitrogen at[b] maximum yield (kg/ha)
		India		
Maruteru Agricultural Research Station, A. Pradesh	IR8/Jaya	1967/68,1970/72	4.1	119
	Mahsuri[c]	1971/75	3.8	0
Pantnagar Research Station, Western U. Pradesh	IR8/Jaya	1967/68,1971/73	5.7	47
	IR20	1971/72	5.6	165
Uttar Pradesh Rice Research Experiment Station (Faizabad)	IR8/Jaya	1967/70	5.3	206
	Ratna	1971/73	1.1	83
Central Rice Research Institute, Orissa	IR8/Jaya	1967/69,1971/72	4.6	143
Tamil Nadu Paddy Breeding Station, Coimbatore	IR8/Jaya	1967/73	6.2	227
	IR20	1971/72	5.3	180
	CO-32[c]	1967/69	5.2	126
Mandya Experiment Station, Mysore	IR8/Jaya	1967/69,1971/73	5.7	202
		Indonesia		
Pusakanegara Experiment Station, West Java	PB5(IR5)	1969/71	6.0	140
Mojosari Experiment Station, East Java	PB5 (IR5)	1970	4.4	0
		Malaysia		
Muda Project Area, Kedah	Bahagia (IR5)	1968/71 (Class IV Soil)	3.1	114
		Thailand		
Suphan Buri Experiment Station, Don Chedi	RD1	1969/70,1974	4.0	98
		Philippines		
Maligaya Rice Research and Training Center, Central Luzon	IR8	1968/75	3.8	52
	IR20	1968/75	4.8	91
	Peta	1968/75	3.0	0
Visayas Rice Experiment Station, Visayas	IR8	1968/75	4.4	115
	IR20	1965/75	5.6	87
	Peta	1968/75	3.8	49
Average	Modern varieties		4.9	

[a]Because of the close similarity in their basic characteristics, IR8 and Jaya are considered as one variety. Data used for 1967/68 are for IR8; data for 1969/73 are for Jaya. [b]The maximum yield (Y) and nitrogen input (N) at maximum yield are calculated from the fertilizer response function of this form:

$$Y = a + b_1N + b_2N^2$$

Where Y denotes tons of rice per hectare and N denotes kilograms of nitrogen per hectare.

From the estimated coefficients of this functions, we can calculate the following:

$$\text{Maximum } N = \frac{b_1}{2b_2}$$

$$\text{Maximum } Y = a - \frac{b_1^2}{4b_2}$$

[c]A local improved variety developed before the introduction of modern varieties.

Table 7. Maximum yield and nitrogen input at maximum yield for selected varieties of rice at experiment stations in selected areas of Asia, 1967/75 dry season.

Location	Variety[a]	Period	Maximum yield[b] (t/ha)	Nitrogen at maximum yield[b] (kg/ha)
		India		
Maruteru Agricultural Research Station, A. Pradesh	IR8/Jaya	1968/70,1972/73	5.8	163
	Ratna	1971/74	5.3	192
Central Rice Research Institute, Orissa	IR8/Jaya	1968/69,1971	8.5	208
	Ratna	1971/72	5.6	179
Tamil Nadu Paddy Breeding Station, Coimbatore	IR8/Jaya	1967/69,1972/73	6.8	285
	ADT-27[c]	1967/68	3.8	100
		Indonesia		
Pusakanegara Experiment Station, West Java	PB5 (IR5)	1971, 1973	4.7	0
Mojosari Experiment Station, East Java	PB5 (IR5)	1971, 1973	7.2	378
		Malaysia		
Muda Project Area, Kedah	Bahagia (IR5)	1969/70 (Class I-IV Soils)	3.9	105
		Thailand		
Suphan Buri Experiment Station, Don Chedi	RD1	1970/71,1974	5.6	119
		Philippines		
Maligaya Rice Research and Training Center, Central Luzon	IR8	1968/75	6.4	143
	IR20	1970/75	5.6	151
	Peta	1968/75	4.3	59
Visayas Rice Experiment Station, Visayas	IR8	1970/75	5.2	151
	IR20	1970/75	4.6	46
	Peta	1970/75	0.9	295
Average	Modern varieties		5.7	

[a] Because of the close similarity in their basic characteristics, IR8 and Jaya are considered as one variety. Data used for 1967/68 are for IR8; data for 1969/73 are for Jaya. [b] The maximum yield (Y) and nitrogen input (N) at maximum yield calculated from the fertilizer response function of this form:

$$Y = a + b_1 N + b_2 N^2$$

Where Y denotes tons of rice per hectare and N denotes kilograms of nitrogen per hectare. From the estimated coefficients of this function, we can calculate the following:

$$\text{Maximum } N = -\frac{b_1}{2b_2}$$

$$\text{Maximum } Y = a - \frac{b_1^2}{4b_2}$$

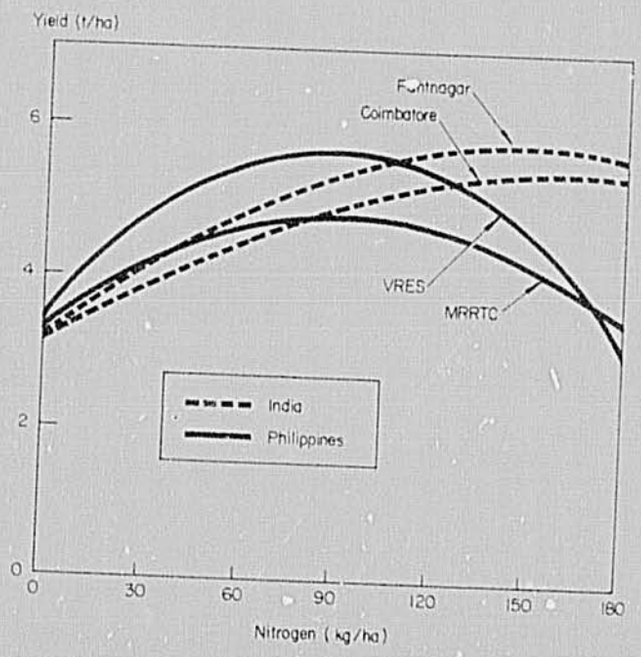
[c] A local improved variety developed before the introduction of modern varieties.

ranged from 4.5 to 6.5 t/ha; at this maximum, the applied nitrogen ranged between 90 and 180 kg/ha. Maximum yields, on the average, were only about 0.5 t/ha higher in the dry than in the wet season. The maximum yields for three LV (Peta, Mahsuri, and ADT 27) ranged from 3.2 to 4.7 t/ha. These maxima

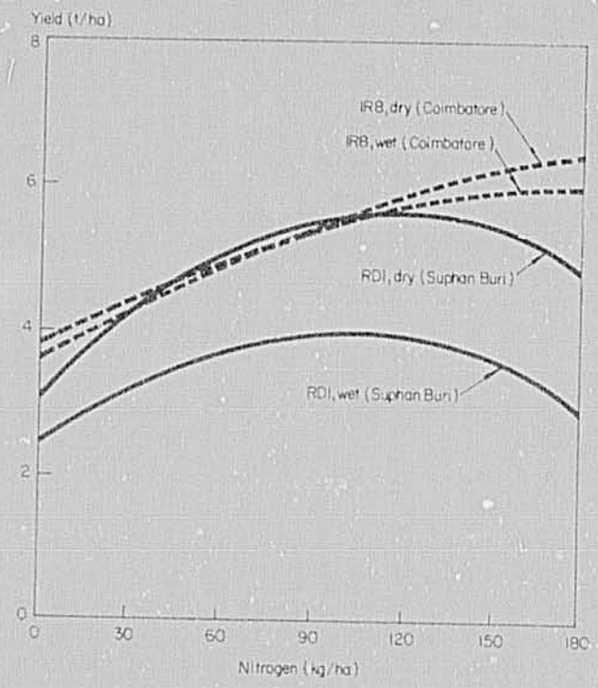
were achieved for Peta and Mahsuri with no or very low levels of applied nitrogen. However, the variety ADT 27 showed good response to applied nitrogen.

IR8 was the most widely grown variety at the various experimental sites. Data for IR8 and Jaya in India were combined since the responses of these two rice varieties were almost identical. The average of maximum yields for IR8 in four monoculture rice locations (Maruteru and Central Rice Research Institute in eastern India, Maligaya and Visayas in the Philippines) was 4.2 t/ha in the wet season and 6.6 t/ha in the dry season. In the wet season, the average of maximum yields for four mixed-farming sites (Pantnagar, Faizabad, Coimbatore, and Mandya, all in India) was 6.2 t/ha. At these four sites the level of solar energy and the yield potential during the wet season are about the same as for the dry.

The difference in nitrogen response by location is due in part to the differences in soils. Maximum yields were almost identical for rice variety IR20 grown in the wet season in two locations in India (Pantnagar and Coimbatore) and two in the Philippines (Visayas and Maligaya) (Fig. 4), but the nitrogen required to achieve maximum yield was about 90 kg/ha in the Philippines and 180 kg/ha in India. The soils in the Philippines are relatively young compared with those in India.



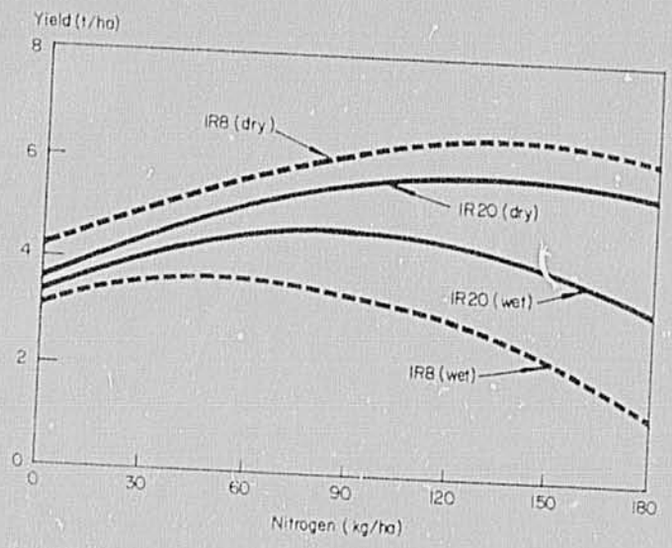
4. Yield response of IR20 to nitrogen in India, 1971/72, and in Visayas Rice Experiment Station (VRES) and Maligaya Rice Research and Training Center (MRRTC), Philippines, 1968/75 wet season.



5. Yield response to nitrogen by variety in Coimbatore, India, 1967/73 wet season and 1967/69, 1972/73 dry season; in Suphan Buri, Thailand, 1969/70 wet season and 1970/71, 1974 dry season.

Wet and dry season functions were compared for two locations (Suphan Buri, Thailand, and Coimbatore, India) using the same rice variety in each season at each location (Fig. 5). The dry season yields exceeded those of the wet season at Suphan Buri throughout the range of the functions. Such findings were fairly typical of the monoculture rice locations and are related to the higher incidence of solar energy and, generally, lower damage due to weather, disease, and insect attack. Under farm conditions, the contrast between dry and wet season response may not be as pronounced, particularly if the dry season irrigation is not adequate. At the experiment station at Coimbatore, India, the response functions for the wet and dry seasons were similar, reflecting the more favorable growing conditions during the wet season in this much drier mixed-farming location.

Two MV of rice which are grown at the same location may respond differently to applied nitrogen (Fig. 6). At Maligaya, Philippines, IR20 performed better than IR8 during the wet season, but IR8 was superior during the dry season. IR20 was more resistant to the major rice insects and diseases. However, IR8 showed a higher yield potential in the dry season when insects and



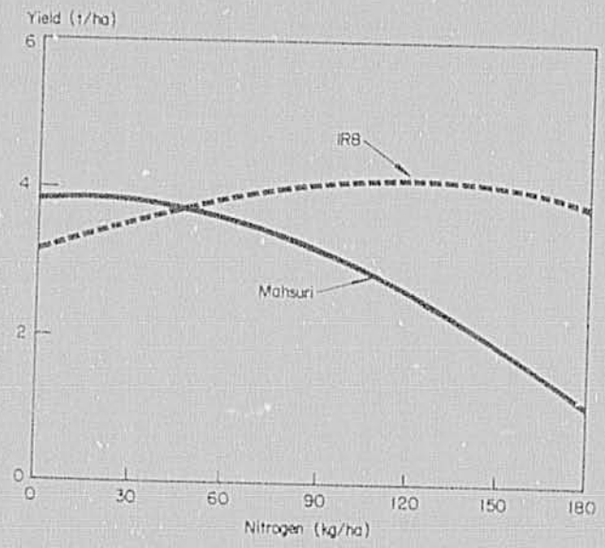
6. Yield response of IR8 to nitrogen, 1968/75 wet and dry seasons; and IR20, 1968/75 wet season and 1970/75 dry season, Maligaya Rice Research and Training Center, Philippines.

diseases are less of a problem. Thus, although IR8 is no longer grown extensively in Southeast Asia, it remains popular in the dry season in many parts of India.

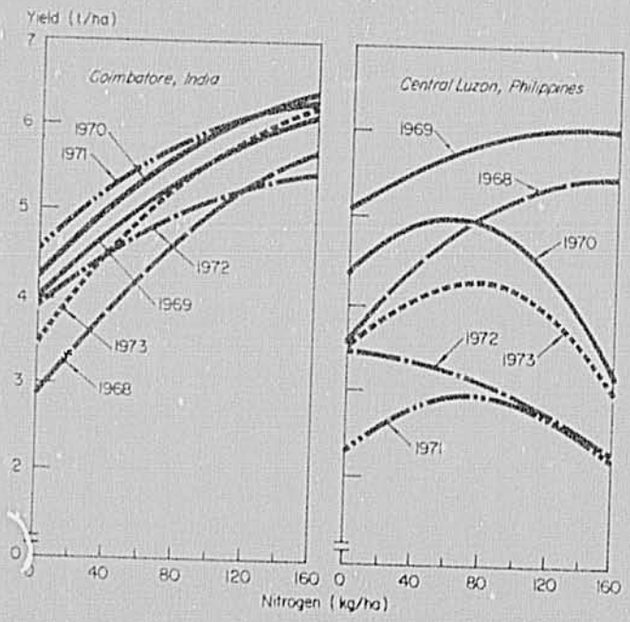
The question as to whether the performance of MV is inferior, equal, or superior to that of the local rices at low levels of nitrogen received special consideration during the 1973–74 worldwide fertilizer shortage. It was reported that farmers in some areas could not obtain fertilizer, or were unwilling to pay the high price, and were thus switching back to LV.

Experimental data at IRRI suggested that the yield performance of MV was equal to and sometimes superior to that of LV when no nitrogen was applied (Appendix G). Generally, however, fertilizer response experiments are conducted with all other factors maintained at high levels. A reduction in the level of inputs and other management practices might introduce factors that favor the use of certain local rices over the MV. Mahsuri, an improved LV originally released by the Rice Department of Malaysia, has become popular in Andhra Pradesh and other parts of India as well as in Malaysia, Bangladesh, and Burma. It performed better than IR8 at low levels of applied fertilizer at the Maruteru Agricultural Research Station (Fig. 7). Mahsuri has good seedling vigor and tillers well under the extremely poor drainage conditions found in much of eastern India. Rice breeders are working to develop rices that combine high productivity with characteristics that enable them to perform well under poor environment and low management.

Finally, the yields of the same variety (IR8/Jaya) vary among years (Fig. 8). The yield variation of IR8 is greater at Maligaya Station than at Coimbatore



7. Yield response of IR8 to nitrogen, 1967/68 and 1970/72; and of Mahsuri, Maruteru, Andhra Pradesh, India, 1971/75 wet season.



8. Yield response to nitrogen of IR8 (or Jaya) in two locations, Tamil Nadu Paddy Breeding Station, Coimbatore, India, and Maligaya Rice Research and Training Center, Central Luzon, Philippines, 1968/73 wet season.

Station during the wet season. The uncertainty of response reflected in the Maligaya data is typical of most of the rice-growing areas of Asia and undoubtedly affects a farmer's decision on the level of fertilizer input.

THE GAP BETWEEN EXPERIMENT STATION AND FARM YIELDS

To examine the gap between experiment station data and village surveys, the average yield and nitrogen input for MV obtained from the village surveys at each site were compared with the "optimum" yield and nitrogen input at the nearest experiment station (Table 8). Optimum yield refers to the yield achieved with a nitrogen input that gives a 2 to 1 return above cost at prevailing local paddy and nitrogen fertilizer prices.

A yield gap of 2 t/ha or higher at the experiment stations was associated with a large difference in the level of applied nitrogen. In a number of cases, however, the yield gap was less than 2 t/ha, and farmers used more fertilizer than was used at the experiment station. Apparently, the experiment station used fertilizer more efficiently, achieving a higher yield gain per kilogram of applied nitrogen.

To ascertain whether the fertilizer response function at the experiment station differs from that at the farmer's field because of differences in the environment in management and in the level of inputs other than fertilizer, a series of experiments using IR20 was conducted in 12 farmers' fields in the same Gapan (Philippines) study area a year after the surveys. A comparison of these results with those from experiments conducted in the same year (1973/74) at the Maligaya Rice Research and Training Center (Fig. 9, Appendix H) suggests a complementary relationship between nitrogen and the other inputs such as water, weed, and insect control. Management of these factors was generally at a higher level at the experiment station, accounting for the higher response to nitrogen input.

When the most favorable price ratio of nitrogen to rough rice prevailing in Gapan was used to calculate the optimum yield of nitrogen input (Table 9), the optimum level of nitrogen was found to be similar for both farmers' fields and experiment station.

When the estimates were calculated using the least favorable ratio prevailing in Suphan Buri, Thailand, the optimum nitrogen level under farm conditions was considerably lower because of the difference in the slope of the farm response functions. However, the change in the price ratios did not have a major effect on optimum yield levels.

Yields at optimum nitrogen (Table 9) and also at no applied nitrogen (Appendix H) in farmers' fields in Gapan were about half those of the experiment station. The efficiency of fertilizer use measured in kg N/kg paddy rice is also half as great.

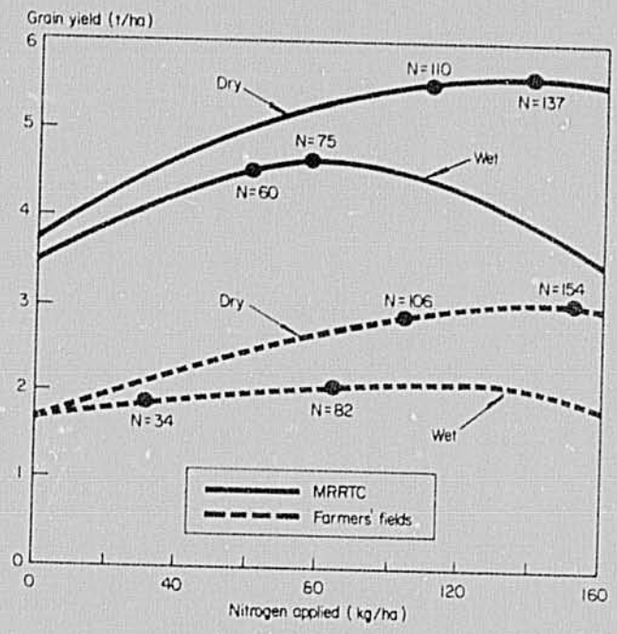
The reasons for the yield gap cannot be ascertained from this analysis. A large

Table 8. Economic optimum yield and nitrogen input at nearest experiment station and village average yield and nitrogen input for modern rice varieties, by season, in selected areas of Asia, 1967/75.

Village location and season	Nearest experiment station[a]		Village average		Difference	
	Yield (t/ha)	N (kg/ha)	Yield (t/ha)	N (kg/ha)	Yield (t/ha)	Nitrogen (kg/ha)
India						
Nainital, U. Pradesh						
Wet	5.7	38	4.5	69	1.2	−31
Varanasi, U. Pradesh						
Wet	3.9	58	3.6	110	0.3	−52
Cuttack, Orissa						
Wet	8.3	99	3.0	53	5.3	46
Dry	8.4	182	3.9	95	4.5	87
West Godavari, A. Pradesh						
Wet	3.8	0	4.1	70	−0.3	−70
Dry	5.7	133	5.4	127	0.3	6
Shimoga, Mysore						
Wet	5.6	158	5.3	145	0.3	13
N. Arcot, Tamil Nadu						
Wet	5.1	132	4.8	132	0.3	0
Dry	4.0	102	5.0	106	−1.0	−4
Indonesia						
West Java						
Wet	5.8	88	3.2	96	2.6	−8
Malaysia						
Kelantan						
Wet	3.2	55	2.3	50	0.9	5
Dry	3.7	52	2.3	53	1.4	−1
Thailand						
Suphan Buri						
Wet	3.7	56	2.8	13	0.9	43
Dry	5.3	82	2.8	12	2.5	70
Philippines						
Nueva Ecija						
Wet	3.8	41	2.8	71	1.0	−30
Dry	5.5	131	2.6	82	2.9	49
Leyte						
Wet	4.3	89	2.7	31	1.6	5.8
Dry	4.6	41	2.5	28	2.1	13

[a] Experiment stations are identified in Appendix D. Optimum yield and nitrogen are based on prevailing prices in each area (see Appendices E and F). The nitrogen input and corresponding yield are estimated to give a 2-to-1 return for added fertilizer expenditure at the margin.

number of factors could be responsible including differences in environment and in crop management. The level of efficiency was higher for the dry than for the wet season. The results obtained from experiments in farmers' fields were



9. Response to nitrogen of IR20 under experiment station (Maligaya Rice Research and Training Center) and farmers' field conditions, Nueva Ecija, Philippines, 1973/74 wet and dry seasons.

Table 9. Comparison of the optimum yield of rice IR20 and nitrogen input for farmers' fields and experiment stations, using prices for Gapan, Philippines, and for Suphan Buri, Thailand, 1973/74.[a]

Site, season	Yield (t/ha)	Nitrogen (kg/ha)	Kg grain/kg N
	Price for Gapan, Philippines		
Farmers' fields[b]			
Wet season	2.1	82	5.8
Dry season	3.1	154	9.4
Experiment station[c]			
Wet season	4.4	74	14.3
Dry season	6.4	173	20.8
	Price for Suphan Buri, Thailand		
Farmers' fields			
Wet season	1.9	34	8.2
Dry season	2.9	106	11.8
Experiment station			
Wet season	4.3	60	16.7
Dry season	6.3	151	23.2

[a]One kg N in 1973/74 cost 1.7 kg paddy in Gapan and 6.5 kg paddy in Suphan Buri. [b]In Gapan, Nueva Ecija, Philippines. [c] Maligaya Rice Research and Training Center, Muñoz, Nueva Ecija, Philippines.

consistent with the level of efficiency for low-response villages reported previously (Table 4).

CONCLUSIONS

There is a high positive correlation between the village average yield and the level of applied nitrogen. Villages with a high level of applied nitrogen had a high percentage of area in modern varieties (MV). Some villages with low nitrogen input, such as those in southern Philippines (Mindanao), had a high percentage of areas in MV. In other low-nitrogen villages, such as those in eastern India, (Orissa and Andhra Pradesh), MV were generally not planted in the wet season. The factors affecting the level of fertilizer use are discussed in detail in the next chapter.

At a given level of fertilizer input, MV consistently gave higher yields than LV in all but one village. The data do not suggest, however, that village average yield could be increased by applying more fertilizer to MV. The individual village response curves are highly variable. The efficiency of fertilizer use, measured in kilograms of paddy per kilogram of applied nitrogen, is higher in the dry than in the wet season.

The yield potential of MV at the 12 experiment stations near the survey villages ranged from 4.5 to 6.5 t/ha. The maximum yield in the wet season in the monoculture rice areas tended to be about 4.5 t/ha. Maximum yields in the dry season in the mixed-farming areas approached 6.5 t/ha. The yield maximum of the LV ranged from 3.2 to 4.7 t/ha.

Experimental-yield response to nitrogen differed with variety, location, season, and from year to year. Year-to-year variation in yield response was particularly great in the monoculture rice villages during the wet season.

The optimum economic yields at the experiment station were consistently higher than average yields in the related village and frequently exceeded village yields by 2 t/ha. While this suggests that there is considerable potential for increasing yields with existing technology, the factors explaining this yield gap could not be identified in this study. Both environmental and management factors could be important.

Future research should attempt to identify those constraints to higher farm yield that can be corrected or overcome by either farmer or group action, or by change in government policies.

APPENDIX A. Average yield and nitrogen input, Selected areas in Asia, 1971/72.

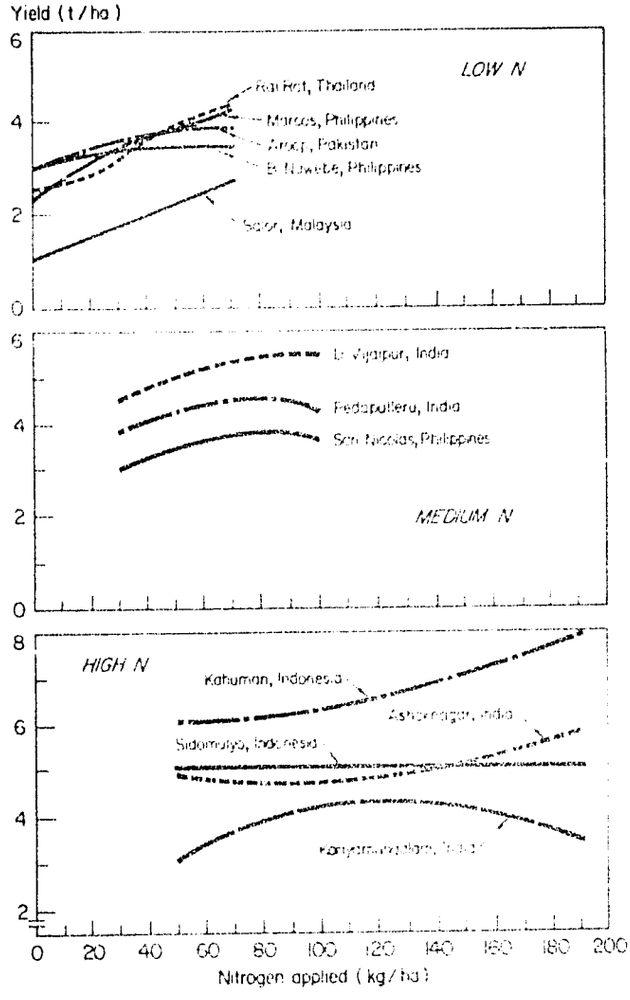
Location	Rice area (ha)	Wet season					Dry season				
		% rice area in MV	Yield[a] (t/ha)		Nitrogen (kg/ha)		% rice area in MV	Yield (t/ha)		Nitrogen (kg/ha)	
			MV	Others	MV	Others		MV	Others	MV	Others
Monoculture villages											
India											
Kandarpur, Orissa	0.6	15	2.5(3.0)	2.5	61	44	97	3.6	2.9	97	52
Korpada, Orissa	0.6	15	1.2(3.0)	2.2	45	34	89	4.2	2.9	94	65
Pedapulleru, A Pradesh	4.4	9	4.1	3.1	70	38	44	5.4	2.4	127	63
Indonesia											
Nganjat, C. Java	0.5	39	3.6	3.9	89	72	63	5.9	5.3	91	57
Cidahu, W. Java	0.5	50	2.3(3.2)	3.0	96	85	45	3.9	3.0	96	86
Malaysia											
Salor, Kelantan	0.8	22	2.4	2.5	53	55	89	2.4	2.0	56	48
Meranti, Kelantan	0.9	32	2.2	2.1	48	46	67	2.1	1.8	50	46
Thailand											
Rai Rot, Suphan Buri	5.3	41	3.2	2.4	16	4	96	3.1	—	16	—
Nong Sarai, SuphanBuri	6.0	21	2.4	1.6	9	5	96	2.4	—	8	—
Sa Kraohom	5.4	4	1.8	1.1	1	0	—	—	—	—	—
Philippines											
San Nicolas, Nueva Ecija	2.5	100	1.7(3.5)	—	91	—	100	3.4	—	101	—
Malimba, Nueva Ecija	3.1	95	0.5(2.1)	—	52	—	98	1.7	—	64	—
Mahipon, Nueva Ecija	3.8	75	0.6(1.9)	1.1	29	17	—	—	—	—	—
Marcos, Leyte	0.4	100	3.5	—	28	—	100	3.1	—	27	—
Tabang, Leyte	0.7	100	1.3(1.9)	—	41	—	100	1.9	—	32	—
Canipa, Leyte	0.8	97	2.0(2.6)	—	23	—	100	2.6	—	24	—
Sinayawan, Davao	2.1	100	2.6	—	26	—	100	2.3	—	16	—
Bulucaon, Cotabato	1.8	100	2.9	—	10	—	100	3.4	—	5	—
Beynte Nuwebe,Cotabato	1.9	100	3.3	—	37	—	100	2.7	—	16	—
Average[b] -1	19	59	2.3(2.8)	2.3	43	36	87	3.2	2.9	54	60
-2	17	61	2.4(2.9)		47		87				
-3	9	27	2.7(3.0)	2.6	54	43	71	3.9	2.9	87	60

(continued on opposite page)

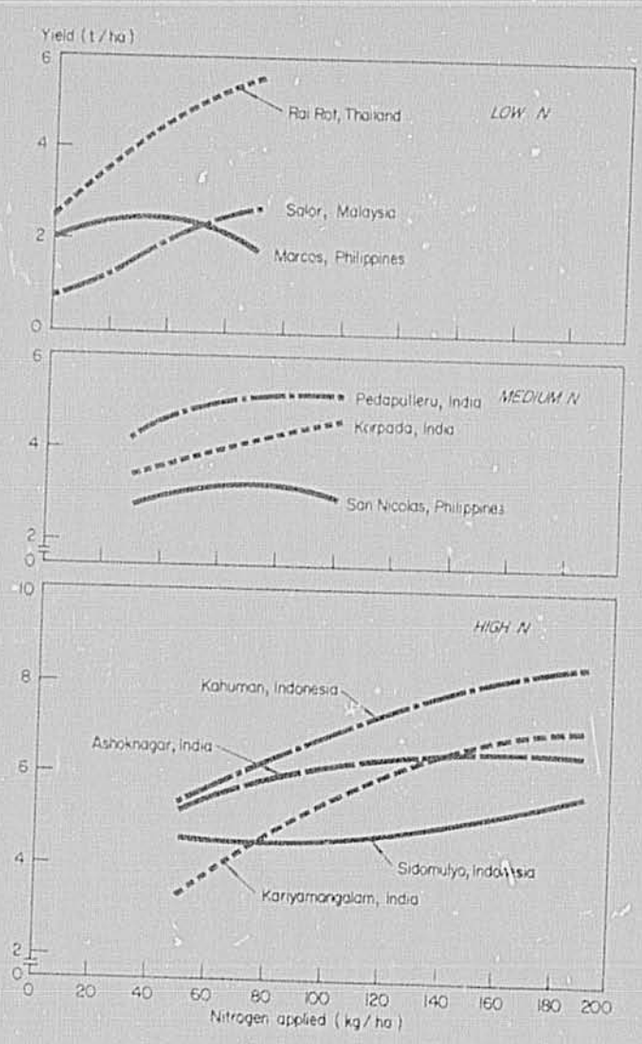
APPENDIX A continued

Location	Rice area (ha)	Wet season: % rice area in MV	Wet season: Yield[a] (t/ha) MV	Wet season: Yield[a] (t/ha) Others	Wet season: Nitrogen (kg/ha) MV	Wet season: Nitrogen (kg/ha) Others	Dry season: % rice area in MV	Dry season: Yield (t/ha) MB	Dry season: Yield (t/ha) Others	Dry season: Nitrogen (kg/ha) MV	Dry season: Nitrogen (kg/ha) Others
				Mixed-farm villages							
India											
Tarna, U. Pradesh	0.6	85	3.6	1.1	133	29	—	—	—	—	—
Dhanpur-Vijaypur, U. Pradesh	4.0	73	4.5	2.5	69	26	—	—	—	—	—
Barain, U. Pradesh	0.7	16	3.5	1.3	86	83	—	—	—	—	—
Hosahally, Mysore	1.9	88	5.6	3.4	140	60	100	5.8	—	135	—
Ashoknagar, Mysore	2.1	62	5.4	2.7	156	50	100	5.9	—	148	—
Gajanur, Mysore	1.7	88	4.8	2.3	138	50	97	4.3	—	125	—
Manmalai, T. Nadu	0.7	70	5.7	2.9	154	74	86	5.6	3.6	133	59
Kariyamangalan, T.Nadu	1.4	50	4.0	2.9	127	52	100	5.3	—	110	—
Palvarthuvenran, T.Nadu	1.3	49	4.8	3.5	116	48	44	4.1	3.3	76	38
Indonesia											
Sidomulyo, E. Java	0.4	97	5.1	—	143	—	94	4.8	4.5	133	100
Kahuman, C. Java	0.6	66	6.9	6.6	114	101	12	6.5	6.5	121	94
Pluneng, C. Java	0.5	91	5.6	4.4	126	87	86	6.1	4.0	128	61
Philippines											
Capayuran, Cotabato	1.3	100	2.6	—	12	—	100	2.9	—	8	—
Maluao, Cotabato	1.6	90	1.6	1.2	0	0	84	1.9	1.1	0	0
Cabpangi, Cotabato	1.4	82	1.0	0.9	0	0	100	0.7	—	0	—
Pakistan											
Aroop, Punjab	3.7	40	3.2	2.1	30	11	—	—	—	—	—
Maraliwala, Punjab	5.9	49	2.4	1.4	37	19	—	—	—	—	—
Average[b] –1	17	70	4.1	2.6	93	46	84	4.5	3.8	93	59
–2	15	68	4.5		105		82	5.1		112	
–3	13	64	4.6	2.8	110	53	64	5.4	4.4	113	70

[a]Data in parentheses are based on "normal" yields in 7 monoculture villages which suffered serious damage due to tungro virus and gall midge. MV = modern varieties. [b]Average – 1 = includes all villages; Average – 2 = excludes 4 poorly irrigated and rainfed villages. Average – 3 = excludes 4 poorly irrigated and rainfed villages and includes only villages that planted both MV and local varieties.



APPENDIX B. Nitrogen response curves for modern varieties in selected villages, 1971/72 wet season.



APPENDIX C. Nitrogen response curves for modern varieties in selected villages, 1971/72 dry season.

APPENDIX D. **Experiment stations and their location and distance from the study area.**

Study area	Nearest experiment station station	Approximate distance from study area (km)
India		
West Godavari A. Pradesh	Maruteru Agricultural Research Station, A. Pradesh	50
Nainital District, W. Uttar Pradesh	Pantnagar Research Station, U. Pradesh	30
Varanasi District, E. Uttar Pradesh	Uttar Pradesh Rice Research Experiment Station, Faizabad, U. Pradesh	175
Cuttack, Orissa	Central Rice Research Institute, Cuttack, Orissa	15
North Arcot, Tamil Nadu	Tamil Nadu Paddy Breeding Station, Coimbatore, Tamil Nadu	250
Shimoga, Mysore	Mandya Experiment Station, Mandya, Mysore	200
Indonesia		
Subang, West Java	Pusakanegara Experiment Station	20
Sidoarjo, East Java	Mojosari Experiment Station	40
Malaysia		
Kelantan, West Malaysia	Muda (Kedah) West Malaysia	200
Thailand		
Don Chedi, Suphan Buri	Suphan Buri Experiment Station, Suphan Buri	20
Philippines		
Gapan, Nueva Ecija	Maligaya Rice Research and Training Center, Nueva Ecija	60
Baybay, Leyte	Visayas Rice Experiment Station, Iloilo	250

APPENDIX I. **Production function by variety and year at twelve experiment stations in Asia, 1967/75 wet season.**[a]

		Maximum[b]	
		Y	N
INDIA			
Maruteru Agricultural Research Station, Andhra Pradesh			
IR8/Jaya			
1967	$Y = 2269 + 17.33N - 0.079N^2$	3219	110
1968	$= 5001 + 19.45N - 0.038N^2$	—	—
1970	$= 2292 + 8.37N - 0.043N^2$	2699	97
1971	$= 2285 + 12.05N - 0.046N^2$	3074	131
1972	$= 4013 + 22.76N - 0.128N^2$	5025	89
Av. 1967–68, 1970–72	$Y = 3172 + 15.99N - 0.067N^2$	4126	119
Mahsuri			
1971	$Y = 4832 - 1.71N - 0.046N^2$	4832	0
1972	$= 4121 - 8.34N - 0.061N^2$	4121	0
1973	$= 3348 + 1.89N - 0.015N^2$	3408	63
1974	$= 3378 - 20.13N + 0.046N^2$	—	—
1975	$= 3587 + 26.59N - 0.343N^2$	4102	39
Av. 1971–75	$Y = 3853 - 0.336N - 0.084N^2$	3853	0
Pantnagar Research Station, Western Uttar Pradesh			
IR8/Jaya			
1967	$Y = 5910 + 15.91N - 0.042N^2$	7417	189
1968	$= 4620 + 48.24N - 0.152N^2$	8449	159
1971	$= 4121 + 24.72N - 0.101N^2$	5634	122
1972	$= 5261 + 45.87N - 0.164N^2$	8468	140
1973	$= 3753 + 25.33N - 0.102N^2$	5326	124
Av. 1967–68, 1971–73	$Y = 4733 + 32.00N - 0.112N^2$	7019	143
IR20			
1971	$Y = 2772 + 25.72N - 0.097N^2$	4477	133
1972	$= 4076 + 27.23N - 0.064N^2$	—	—
Av. 1971–72	$Y = 3424 + 26.47N - 0.080N^2$	5614	165
U.P. Rice Experiment Station, Eastern Uttar Pradesh			
IR8/Jaya			
1967	$Y = 2757 + 18.84N - 0.020N^2$	—	—
1968	$= 3309 + 29.43N - 0.070N^2$	—	—
1969	$= 1282 + 31.66N - 0.094N^2$	3948	168
1970	$= 2158 + 35.34N - 0.096N^2$	5410	184
Av. 1967–70	$Y = 2376 + 28.82N - 0.070N^2$	—	—
Ratna			
1971	$Y = 3172 + 34.52N - 0.154N^2$	5111	112
1972	$= 2764 + 38.61N - 0.145N^2$	5334	133
1973	$= 2566 + 9.69N - 0.200N^2$	2683	24
Av. 1971–73	$Y = 2834 + 27.61N - 0.166N^2$	1148	83
Central Rice Research Institute, Orissa			
IR8/Jaya			
1967	$Y = 3561 + 21.72N - 0.056N^2$	5667	194
1968	$= 3738 + 16.74N - 0.075N^2$	4672	112
1969	$= 2644 + 35.73N - 0.115N^2$	5419	155
1971	$= 1735 + 15.92N - 0.064N^2$	2725	124
1972	$= 4137 + 8.28N - 0.034N^2$	4641	122
Av. 1967–69, 1971–72	$Y = 3163 + 19.68N - 0.069N^2$	4566	143

(continued on next page)

APPENDIX E **continued**

		Maximum[b]	
		Y	N
	Tamil Nadu Paddy Breeding Station, Coimbatore		
IR8/Jaya			
1967	$\hat{Y} = 2312 + 29.12N - 0.057N^2$	—	—
1968	$= 2849 + 26.20N - 0.049N^2$	—	—
1969	$= 4049 + 19.25N - 0.038N^2$	—	—
1970	$= 4321 + 21.99N - 0.055N^2$	6519	200
1971	$= 4576 + 18.57N - 0.045N^2$	—	—
1972	$= 3971 + 15.79N - 0.040N^2$	5529	197
1973	$= 3486 + 28.16N - 0.065N^2$	—	—
Av. 1967–73	$\hat{Y} = 3652 + 22.72N - 0.050N^2$	—	—
IR20			
1971	$\hat{Y} = 3804 + 19.25N - 0.041N^2$	—	—
1972	$= 2769 + 24.69N - 0.081N^2$	4650	152
Av. 1971–72	$\hat{Y} = 3287 + 21.97N - 0.061N^2$	5265	180
CO32			
1967	$\hat{Y} = 2299 + 35.57N - 0.129N^2$	4751	138
1968	$= 3382 + 32.12N - 0.134N^2$	5307	120
1969	$= 4024 + 27.11N - 0.113N^2$	5650	120
Av. 1967–69	$\hat{Y} = 3235 + 31.60N - 0.125N^2$	5232	126
	Mandya Experiment Station, Mysore		
IR8/Jaya			
1967	$\hat{Y} = 1055 + 10.63N - 0.011N^2$	—	—
1968	$= 3200 + 29.84N - 0.105N^2$	5320	142
1969	$= 3833 + 21.15N - 0.055N^2$	5866	192
1971	$= 3670 + 47.87N - 0.141N^2$	7733	170
1972	$= 3224 + 21.51N - 0.015N^2$	—	—
1973	$= 3193 + 29.46N - 0.069N^2$	—	—
Av. 1967–69, 1971–73	$\hat{Y} = 3029 + 26.74N - 0.066N^2$	—	—
	INDONESIA		
	Pusakanegara Experiment Station, West Java		
PB5			
1970	$\hat{Y} = 4560 + 16.25N - 0.059N^2$	5679	138
1971	$= 4507 + 24.53N - 0.088N^2$	6216	139
Av. 1970–71	$\hat{Y} = 4534 + 20.39N - 0.073N^2$	5958	140
	Modjosari Experiment Station, East Java		
PB5			
1970	$\hat{Y} = 4351 + 10.51N + 0.022N^2$	4351	0
	MALAYSIA		
	Muda Project in Kedah, West Malaysia		
Bahagia (IR5)			
Av. 1968–71			
Class I (soil)	$\hat{Y} = 3402 + 16.74N - 0.054N^2$	4699	155
Class II	$= 2638 + 11.26N - 0.026N^2$	—	—
Class III	$= 2362 + 9.32N - 0.034N^2$	3001	137
Class IV	$= 2425 + 11.37N - 0.050N^2$	3071	114
Av. Class I — IV	$\hat{Y} = 2707 + 12.17N - 0.041N^2$	3610	148

Note: Muda Project covers the period 1968–71 only.

(continued on opposite page)

APPENDIX I—continued

		Maximum[b]	
		Y	N
	THAILAND		
	Suphan Buri Experiment Station, Don Chedi		
RD1			
1969	$\hat{Y} = 2075 + 37.84N - 0.103N^2$	5550	184
1970	$= 3503 + 23.32N - 0.099N^2$	4876	118
1974	$= 1948 + 30.42N - 0.256N^2$	2852	59
Av. 1969–70, 1974	$\hat{Y} = 2509 + 30.77N - 0.157N^2$	4017	98
	PHILIPPINES		
	Maligaya Rice Research & Training Center, Central Luzon		
IR8			
1968	$\hat{Y} = 3542 + 23.40N - 0.067N^2$	5586	175
1969	$= 5056 + 15.04N - 0.055N^2$	5159	14
1970	$= 4361 + 21.40N - 0.178N^2$	5004	60
1971	$= 2348 + 16.78N - 0.114N^2$	2965	74
1972	$= 3424 + 0.15N - 0.043N^2$	3424	2
1973	$= 3357 + 26.00N - 0.175N^2$	4323	74
1974	$= 2421 + 10.86N - 0.084N^2$	2772	65
1975	$= 2889 + 16.07N - 0.039N^2$	—	—
Av. 1968–75	$\hat{Y} = 3425 + 16.17N - 0.156N^2$	3844	52
IR20			
1968	$\hat{Y} = 4036 + 33.08N - 0.137N^2$	6032	121
1969	$= 4458 + 30.49N - 0.138N^2$	6142	110
1970	$= 4316 + 36.52N - 0.227N^2$	4508	80
1971	$= 3196 + 30.91N - 0.182N^2$	4508	85
1972	$= 3424 + 26.55N - 0.177N^2$	4420	75
1973	$= 3357 + 26.90N - 0.167N^2$	4440	81
1974	$= 2125 + 32.18N - 0.209N^2$	3364	77
1975	$= 2628 + 21.34N - 0.072N^2$	4209	148
Av. 1968–75	$\hat{Y} = 2442 + 29.75N - 0.164N^2$	4791	91
Peta			
1968	$\hat{Y} = 4010 + 15.48N - 0.070N^2$	4866	111
1969	$= 4091 - 19.93N + 0.073N^2$	4091	0
1970	$= 2951 - 18.54N + 0.038N^2$	—	—
1971	$= 3029 - 10.84N - 0.031N^2$	3029	0
1972	$= 3141 - 5.36N + 0.001N^2$	3141	0
1973	$= 1843 - 14.86N + 0.079N^2$	1843	0
1974	$= 1650 - 5.74N + 0.020N^2$	1650	0
1975	$= 2887 - 2.81N - 0.024N^2$	2887	0
Av. 1968–75	$\hat{Y} = 2950 - 7.12N - 0.001N^2$	2950	0
	Visayas Rice Experiment Station, Visayas		
IR8			
1968	$\hat{Y} = 2950 + 34.58N - 0.076N^2$	—	—
1969	$= 4032 + 17.99N - 0.108N^2$	4781	83
1970	$= 2192 - 0.86N + 0.191N^2$	2192	0
1971	$= 3908 + 8.37N - 0.081N^2$	4124	52
1972	$= 3079 + 32.65N - 0.161N^2$	4734	101
1973	$= 3468 - 1.92N + 0.050N^2$	3468	0
1974	$= 2968 + 23.18N - 0.085N^2$	4548	136
1975	$= 3478 + 40.87N - 0.228N^2$	5310	90
Av. 1968–75	$\hat{Y} = 3259 + 19.38N - 0.084N^2$	4377	115

(continued on next page)

APPENDIX E **continued**

		Maximum[b]	
		Y	N
IR20			
1968	$\hat{Y} = 3170 + 25.75N - 0.025N^2$	3833	52
1969	$= 4989 + 55.13N - 0.285N^2$	7655	97
1970	$= 3103 + 72.00N - 0.492N^2$	5737	73
1971	$= 4039 + 31.01N - 0.180N^2$	5374	86
1972	$= 3563 + 30.66N - 0.127N^2$	5413	121
1973	$= 3543 + 43.10N - 0.167N^2$	6324	129
1974	$= 2848 + 53.59N - 0.297N^2$	5265	90
1975	$= 3278 + 51.45N - 0.306N^2$	5441	84
Av. 1968–75	$\hat{Y} = 3567 + 47.68N - 0.274N^2$	5641	87
Peta			
1968	$\hat{Y} = 2598 + 19.53N + 0.023N^2$	2598	0
1969	$= 4439 - 14.36N + 0.033N^2$	—	—
1970	$= 3433 - 12.16N + 0.016N^2$	—	—
1971	$= 4756 - 8.07N - 0.011N^2$	4756	0
1972	$= 3634 + 21.83N - 0.113N^2$	4688	96
1973	$= 4564 + 3.97N - 0.036N^2$	4629	43
1974	$= 2881 + 6.59N - 0.085N^2$	3009	39
1975	$= 3225 + 15.80N - 0.157N^2$	3622	50
Av. 1968–75	$\hat{Y} = 3691 + 4.029N - 0.041N^2$	3790	49

[a]The maximum yield (Y) and nitrogen input (N) at maximum yield are calculated from the fertilizer-response function of this form:

$$Y = a + b_1N + b_2N^2$$

Where Y denotes kilograms of rice per hectare and N denotes kilograms of nitrogen per hectare.

[b]From the estimated coefficients of this functions, we can calculate the following:

$$\text{Maximum } N = -\frac{b_1}{2b_2}$$

$$\text{Maximum } Y = a - \frac{b_1^2}{4b_2}$$

A dash (—) indicates that the calculated maximum N level exceeds 200 kg/ha.

APPENDIX F. **Production function by variety and year at twelve experiment stations in Asia, 1967/75 dry season.**[a]

		Maximum[b]	
		Y	N
INDIA			
Maruteru Agricultural Research Station, Andhra Pradesh			
IR8/Jaya			
1968	$\hat{Y} = 3774 + 37.88N - 0.122N^2$	6714	155
1969	$= 1442 + 47.33N - 0.105N^2$	—	—
1970	$= 3583 + 28.18N - 0.099N^2$	5588	142
1972	$= 2110 + 34.59N - 0.098N^2$	5162	176
1973	$= 3018 + 38.14N - 0.148N^2$	5475	129
Av. 1968–70, 1972–73	$\hat{Y} = 2785 + 37.22N - 0.114N^2$	5823	163
Ratna			
1971	$\hat{Y} = 2497 + 25.15N - 0.020N^2$	—	—
1972	$= 2446 + 30.70N - 0.105N^2$	4690	146
1973	$= 2925 + 20.49N - 0.054N^2$	4869	190
1974	$= 3878 + 23.34N - 0.080N^2$	5580	146
Av. 1971–74	$\hat{Y} = 2936 + 24.92N - 0.065N^2$	5324	192
Central Rice Research Institute, Orissa			
IR8/Jaya			
1968	$\hat{Y} = 3013 + 50.12N - 0.094N^2$	—	—
1969	$= 3767 + 48.46N - 0.132N^2$	8215	184
1971	$= 3410 + 47.56N - 0.126N^2$	7898	189
Av. 1968–69, 1971	$\hat{Y} = 3397 + 48.71N - 0.117N^2$	—	—
Ratna			
1971	$\hat{Y} = 3168 + 26.85N - 0.053N^2$	—	—
1972	$= 3748 + 21.79N - 0.083N^2$	5174	131
Av. 1971–72	$\hat{Y} = 3458 + 24.32N - 0.068N^2$	5632	179
Tamil Nadu Paddy Breeding Station, Coimbatore			
IR8/Jaya			
1967	$\hat{Y} = 2771 + 24.25N - 0.036N^2$	—	—
1968	$= 2711 + 25.36N - 0.029N^2$	—	—
1969	$= 3776 + 13.71N - 0.040N^2$	4951	171
1972	$= 4104 + 21.48N - 0.017N^2$	—	—
1973	$= 4627 + 26.32N - 0.072N^2$	7032	183
Av. 1967–69, 1972–73	$\hat{Y} = 3598 + 22.23N - 0.039N^2$	—	—
ADT-27			
1967	$\hat{Y} = 1504 + 21.20N - 0.065N^2$	3693	163
1968	$= 3093 + 20.64N - 0.070N^2$	4614	147
1969	$= 3196 + 11.77N - 0.041N^2$	4041	144
Av. 1967–69	$\hat{Y} = 2751 + 17.87N - 0.059N^2$	3783	100
INDONESIA			
Pusakanegara Experiment Station, West Java			
PB5			
1971	$\hat{Y} = 4266 + 26.39N - 0.040N^2$	—	—
1973	$= 4608 + 2.43N - 0.043N^2$	4642	28
Av. 1971–73	$\hat{Y} = 4437 + 14.30N - 0.038N^2$	5782	188
Modjosari Experiment Station, East Java			
1971	$\hat{Y} = 3583 + 28.53N - 0.004N^2$	—	—
1973	$= 2746 + 23.82N - 0.051N^2$	—	—
Av. 1971, 1973	$\hat{Y} = 3164 + 21.18N - 0.028N^2$	—	—

(continued on next page)

APPENDIX F **continued**

		Maximum[b]	
		Y	N
	MALAYSIA		
	Muda Project in Kedah, West Malaysia		
Bahagia (IR5)			
Av. 1969–70			
Class I (soil)	$\hat{Y} = 3176 + 9.85N - 0.038N^2$	2808	128
Class II	$= 3357 + 13.94N - 0.076N^2$	4008	93
Class III	$= 3133 + 18.86N - 0.089N^2$	4136	106
Class IV	$= 2702 + 19.88N - 0.106N^2$	3637	94
Av. Class I—IV	$\hat{Y} = 3092 + 15.65N - 0.077N^2$	3897	105
	THAILAND		
	Suphan Buri Experiment Station, Don Chedi		
RD1			
1970	$\hat{Y} = 2032 + 54.98N - 0.177N^2$	6307	155
1971	$= 4588 + 28.84N - 0.128N^2$	6212	113
1974	$= 2465 + 43.86N - 0.232N^2$	4538	94
Av. 1970–71, 1974	$\hat{Y} = 3028 + 42.56N - 0.179N^2$	5558	119
	PHILIPPINES		
	Maligaya Rice Research & Training Center, Central Luzon		
IR8			
1968	$\hat{Y} = 4890 + 24.98N - 0.063N^2$	7366	198
1969	$= 4324 + 18.81N + 0.026N^2$	4324	0
1970	$= 4362 + 37.54N - 0.168N^2$	6459	112
1971	$= 4233 + 53.08N - 0.232N^2$	7269	114
1972	$= 4581 + 28.03N - 0.163N^2$	5786	86
1973	$= 4033 + 20.10N - 0.056N^2$	5837	179
1974	$= 3713 + 28.48N - 0.086N^2$	6071	166
1975	$= 3752 + 29.28N - 0.096N^2$	5985	152
Av. 1968–75	$\hat{Y} = 4238 + 30.00N - 0.105N^2$	6381	143
IR20			
1970	$\hat{Y} = 3732 + 32.16N - 0.150N^2$	5456	107
1971	$= 4130 + 22.23N - 0.082N^2$	5637	136
1972	$= 4802 + 21.31N - 0.124N^2$	5718	86
1973	$= 3392 + 19.76N - 0.038N^2$	—	—
1974	$= 2802 + 39.76N - 0.106N^2$	6530	188
1975	$= 2838 + 20.62N - 0.018N^2$	—	—
Av. 1970–75	$\hat{Y} = 3616 + 25.97N - 0.086N^2$	5576	151
Peta			
1968	$\hat{Y} = 4406 + 15.62N - 0.118N^2$	4923	66
1969	$= 4939 + 7.92N - 0.150N^2$	5044	26
1970	$= 4368 + 24.43N - 0.150N^2$	5099	60
1971	$= 3937 + 7.02N - 0.116N^2$	4043	30
1972	$= 3746 + 23.93N - 0.200N^2$	4462	60
1973	$= 3199 + 28.00N - 0.165N^2$	4387	85
1974	$= 3195 - 2.86N - 0.011N^2$	3195	0
1975	$= 4000 + 0.33N - 0.056N^2$	4000	3
Av. 1968–75	$\hat{Y} = 3974 + 12.33N - 0.104N^2$	4339	59

(continued on opposite page)

APPENDIX F **continued**

		Maximum[b]	
		Y	N
	Visayas Rice Experiment Station, Visayas		
IR8			
1970	$\hat{Y} = 3631 + 45.17N - 0.148N^2$	7078	153
1971	$= 4471 + 13.51N - 0.074N^2$	5088	91
1972	$= 3021 + 39.31N - 0.088N^2$	—	—
1973	$= 4380 + 4.81N + 0.007N^2$	4380	0
1974	$= 3886 + 8.76N - 0.032N^2$	4486	137
1975	$= 1933 + 19.67N - 0.092N^2$	2984	107
Av. 1970–75	$\hat{Y} = 3517 + 22.67N - 0.075N^2$	5230	151
IR20			
1970	$\hat{Y} = 3394 + 48.88N - 0.171N^2$	6883	143
1971	$= 4681 + 46.83N - 0.212N^2$	7267	110
1972	$= 3573 + 23.29N - 0.051N^2$	—	—
1973	$= 4527 + 21.65N - 0.052N^2$	—	—
1974	$= 2899 + 17.47N - 0.042N^2$	—	—
1975	$= 3110 + 12.29N - 0.042N^2$	4001	145
Av. 1970–75	$\hat{Y} = 3697 + 28.40N - 0.095N^2$	58[illegible]	149
Peta			
1970	$\hat{Y} = 2676 - 7.40N - 0.038N^2$	2676	0
1971	$= 4401 - 33.24N + 0.118N^2$	4401	0
1972	$= 2834 + 4.21N - 0.097N^2$	2880	22
1973	$= 4111 - 20.73N + 0.021N^2$	4111	0
1974	$= 2011 - 16.22N + 0.105N^2$	2011	0
1975	$= 3142 - 18.52N + 0.049N^2$	3142	0
Av. 1970–75	$\hat{Y} = 3196 - 15.32N + 0.026N^2$	3196	0

[a]The maximum yield (Y) and nitrogen input (N) at maximum yield are calculated from the fertilizer response function of this form:

$$Y = a + b_1N + b_2N^2$$

Where Y denotes kilograms of rice per hectare and N denotes kilograms of nitrogen per hectare.

[b]From the estimated coefficients of this functions, we can calculate the following:

$$\text{Maximum } N = -\frac{b_1}{2b_2}$$

$$\text{Maximum } Y = a - \frac{b_1^2}{4b_2}$$

A dash (–) indicates that the calculated maximum N level exceeds 200 kg/ha.

APPENDIX G. **Average yields of IRRI released varieties (R), nonreleased lines and other semidwarf varieties (NR), and traditional tall varieties (T) at three levels of applied nitrogen fertilizer in IRRI Agronomy Department trials of promising lines and international variety trials, 1966/73.**

	Av. yields (t/ha)								
	No nitrogen applied			Lowest applied nitrogen[a]			Highest applied nitrogen[b]		
	R	NR	T	R	NR	T	R	NR	T
				Dry season					
1973	3.3	3.9	3.6	4.2	4.9	3.6	5.8	6.2	3.4
1972	4.4	4.3	4.4	5.7	5.9	3.8	6.9	7.0	1.8
1971	5.7	5.2	5.4	7.7	7.0	3.8	8.4	7.5	0.7
1970	4.7	4.5	4.6	6.1	6.3	4.6	7.8	7.3	2.4
1968	3.9	3.8	3.9	5.1	4.9	4.9	7.5	7.1	5.7
1967	5.9	5.8	5.2	6.7	6.5	5.6	8.9	8.0	5.6
1966	7.2	6.0	6.1	8.6	7.8	5.9	8.6	5.1	3.3
X dry	5.0	4.8	4.7	6.3	6.2	4.6	7.7	6.9	3.3
				Wet season					
1973	3.1	3.7	1.3	3.4	3.9	1.8	3.9	4.0	1.3
1972	3.7	4.1	3.3	4.5	4.7	3.9	5.0	5.4	4.5
1971	3.7	3.2	1.3	4.1	3.4	1.4	5.8	4.1	0.8
1970	4.5	4.3	2.8	5.0	4.7	1.5	5.1	4.8	0.9
1969	5.4	5.0	3.0	5.6	5.4	2.3	5.2	5.5	2.7
1968	4.1	4.3	3.9	4.8	5.2	3.1	6.1	6.1	2.1
1967	3.7	3.2	3.1	4.2	3.6	3.2	5.1	4.7	3.0
1966	5.6	4.4	3.4	5.5	4.7	3.6	4.9	3.6	1.6
X wet	4.2	4.0	2.8	4.6	4.5	2.6	5.1	4.8	2.1
X both	4.6	4.4	3.7	5.4	5.3	3.5	6.2	5.8	2.7

[a]Lowest rates in dry season were 60 kg N/ha in 1971, 1972, 1973 and 1966; 50 kg N/ha in 1970; 30 kg N/ha in 1968 and 1967. Lowest rates in wet season were 30 kg N/ha in 1970/73; 25 kg N/ha in 1969; 20 kg N/ha in 1967 and 1968; 15 kg N/ha in 1966. [b]Highest rates in dry season were 150 kg N/ha in 1971, 1972, 1973; 140 kg N/ha in 1970; 120 kg N/ha in 1968 and 1967; 240 kg N/ha in 1966. Highest rates in wet season were 120 kg N/ha in 1970-1973; 100 kg N/ha in 1969; 80 kg N/ha in 1967 and 1968; 105 kg N/ha in 1966.

APPENDIX H. **Production function from experiment station versus farmers' fields, Philippines, 1973/74.**[a]

Experiment Station: Maligaya Rice Research and Training Center, Central Luzon Variety: IR20

Year	Season	
1973	Wet	$\hat{y} = 3357 + 26.9N - 0.17N^2$
1974	Dry	$= 2802 + 39.8N - 0.11N^2$

Farmers' fields, Gapan, Nueva Ecija
Variety: IR20

Year	Season	
1973	Wet	$\hat{y} = 1611 + 9.9N - 0.05N^2$
1974	Dry	$= 1604 + 17.1N - 0.05N_2$

[a]The maximum yield (Y) and nitrogen input (N) at the maximum yield are calculated from the fertilizer response function of this form:

$$Y = a + b_1 N + b2N^2$$

Where Y denotes kilogram of rice per hectare and N denotes kilograms of nitrogen per hectare.

Factors affecting fertilizer consumption

CRISTINA C. DAVID

Regression analysis was used to identify the factors that explain the variation in level of fertilizer consumption among villages and farms. Differences in the physical environment among villages and between seasons may account for a major portion of the variation. Additionally, the fertilizer-rice price ratio and the proportion of area planted to modern varieties had significant bearing on the ariation. The estimated long-run price elasticity of demand for fertilizer is −0.9, while the short-run elasticity estimates ranged from −0.2 to −0.6. Differences in irrigation and other environmental factors explain the largest portion of the gap between "average" and "heaviest" using fertilizer villages.

IN THE PREVIOUS CHAPTER, the close correlation between the yield of rice and fertilizer input was examined, and some factors associated with the wide variation in fertilizer use were identified. An econometric analysis of the sources of variation in fertilizer consumption among the 36 villages surveyed is undertaken in this chapter to identify more clearly the economic, environmental, institutional, and technological variables that affect the level of fertilizer use.[1]

Although the application of fertilizer is known to be critical for the realization of the yield potential of modern rice varieties (MV), few empirical analyses of factors affecting fertilizer use in developing countries are available. A knowledge of the relative contributions of various factors affecting fertilizer consumption can provide a guide to the allocation of scarce agricultural and public resources. With MV, fertilizer policy has become a major focus in overall national agricultural programs in Asian nations. Sharp fluctuations in world fertilizer prices from 1973 to 1975 raised an important policy question:

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[1] Much of the analysis is based on the author's Ph.D. dissertation. See Cristina C. David, "A Model of Fertilizer Demand in the Asian Rice Economy: A Micro-Macro Analysis." Unpublished Ph.D. thesis, Stanford University, December 1975. See also Cristina C. David, "Fertilizer Demand in the Asian Rice Economy," *Food Research Institute Studies*, Vol. 15, No. 1 (1976).

should the government subsidize agricultural research, irrigation, and other factors to increase the productivity of fertilizer, or alternatively should fertilizer prices be subsidized?

To answer such questions, one must have a clear understanding of the factors affecting fertilizer demand. Most empirical models explaining fertilizer demand have been based on the assumption of constant production technology. In fact, a common approach in estimating the price elasticity of demand for fertilizer is to derive it indirectly from the profit maximization conditions based on fertilizer response functions estimated from experimental data. In the previous chapter, however, a high degree of diversity in the response functions reported from farm experiments and from the village surveys was noted, not only at different locations but also for the same location at different times. Thus, considerable arbitrariness is involved in selecting the appropriate fertilizer response function. Moreover, it is not possible to take into account other factors, such as risk or lack of knowledge, which influence the level of fertilizer consumption and prevent farmers from maximizing profits.

The approach used in this chapter is to estimate the fertilizer demand function directly where factors affecting yield response to fertilizer, such as the diffusion of MV and the quality of irrigation, are explicitly specified in the model. Actual differences in fertilizer demand across time, farm, village, or country are influenced by factors other than prices, such as MV, use of other inputs complementary to fertilizer, and the existence of supervised credit schemes, which reduce the effective price of fertilizer to farmers. Changes in some of these factors may, of course, have been related indirectly to government efforts in promoting the use of MV.

CONCEPTUAL FRAMEWORK

The use of cross-section data to estimate fertilizer demand function requires the coverage of a relatively wide geographical range to obtain adequate variation in the variables specified in the model, especially prices. The survey data collected from 36 villages scattered throughout South and Southeast Asia provided, therefore, a unique opportunity for quantitative analysis of the factors responsible for variations in fertilizer consumption.

Fertilizer response functions among the studied villages appear to be highly variable. Differences in yield response to fertilizer are normally associated with differences in such physical factors as soil type, or variety. However, environmental differences among villages also include a wide range of factors: physical environment, the institutional structure of farming, management capacity and knowledge of new inputs, and the cost and availability of inputs and new technology.

These differences in fertilizer response function are illustrated hypothetically (p_1, p_2, p_3) together with their corresponding demand schedules (d_1, d_2, d_3) in Figure 1A and 1B. The level of fertilizer inputs is, therefore, related not

1. Hypothetical shifts in fertilizer response functions (A) and their corresponding demand schedules (B).

only to the relative price of fertilizer to rice, but also to factors that explain the difference in the yield response of fertilizer from one village to another. As the response function shifts upward because of the introduction of MV, improved irrigation, and other factors that raise the productivity of fertilizer, the demand function shifts to the right.

When no explicit consideration is given to the phenomena associated with the response and demand functions, the demand curve D will be estimated leading to an overestimate of the price elasticity of demand for fertilizer. For many Asian countries, the shift in fertilizer response function occurred at the rate of 10 to 15% a year between 1968 and 1972. In the present analysis, however, d_1, d_2, and d_3 (Fig. 1B) represent differences in demand functions among villages, rather than differences for the same location at different points in time.

The measure of demand responsiveness to changes in prices, i.e., price elasticity of demand for fertilizer, obtained from estimates of demand function, is a critical item of information in evaluating the effects of price policies. But the elasticity of demand with respect to variables other than prices is equally important in determining the appropriate policy to raise fertilizer demand.

THE DEMAND MODEL

The demand model was developed to explain the wide variation in fertilizer application per hectare across villages and farms in terms of differences in the fertilizer:rice price ratio and in the variables representing differences in the

fertilizer response functions and in the credit constraint facing the farmers. Empirical estimation of the model allowed the

- identification of factors that explain the variation in fertilizer consumption;
- estimation of the *price elasticity* of demand for fertilizer or percent change in fertilizer consumed due to a 1% change in price (Fig. 1B);
- determination of the relative contribution of each of the explanatory factors in the model to the gap in fertilizer consumption between the "average" and "heaviest" users.

The analysis covered data from 33 villages for the wet season only. Three villages where no fertilizer was applied were excluded in the estimation (Appendix A). A combination of village and farm level observations are utilized. The estimating equation is expressed in log linear form as follows:

$$\log F_{ij} = \log a_0 + a_1 \log P_i + a_2 M_{ij} + a_3 \log W_i$$

$$+ a_4 \log N_i + a_5 R_i + a_6 \log V_{ij} + e$$

where i denotes village and j farm; F is fertilizer applied in kilograms per hectare nutrients (NPK), and F_{ij} refers to fertilizer consumption of farm j in village i; P is the ratio of price of nitrogen to paddy; M is the proportion of total rice area planted to modern varieties; W is the index of quality of irrigation; N is the level of nitrogen (in kilograms per hectare) required to obtain a maximum yield as indicated by the experimental response function from the experiment station nearest each village; R is the proportion of total annual rainfall in the 2 months prior to harvest; V is the gross value of production in US$/farm; and e is the statistical error term.

The proportion of the area planted to modern varieties (M) is a measure of the extent of adoption of technological innovations that raise the fertilizer response function.

The index of quality of irrigation (W) was constructed by village. The index is based primarily on the available description of the irrigation system in the village, and the proportion of farmers reporting problems in irrigation due to either lack of water or poor drainage. The values range from 1 to 5, with 1 indicating high quality and 5 indicating poor irrigation or rainfed condition.

To further explain the variable N, it should be noted that the results of experiments investigating the yield response of MV to nitrogen in experiment stations throughout Asia revealed variations in the amount of nitrogen required to achieve maximum yield among locations largely because of differences in soil and climatic factors. In India, for example, soils tend to be older and less fertile than in the Philippines. Although maximum yields do not seem to differ greatly between countries, these maxima are obtained at almost double the rate of fertilizer input in India (previous Chapter, Fig. 4).

The variable R reflects the rainfall situation in the 2 months prior to harvest. If irrigation or water availability is not a constraint, then high rainfall, which is

associated with low solar energy, tends to depress the use of fertilizer. Alternatively, when drought is a critical problem, a positive relationship exists between rainfall and fertilizer demand.

The variable V is intended to reflect the farmer's liquidity position. Farmers with a large gross value of production are presumably better able to purchase cash inputs such as fertilizer.

STATISTICAL RESULTS

The regression coefficients estimated for various specifications of the model (Table 1) reveal a high R^2 for regression based on cross-section farm survey data. The inclusion of variables representing shifts in the response function improves the goodness of fit markedly and the higher t-values for these variables indicate a greater precision of fit relative to the coefficient of price in the regression. The signs for all variables are in accord with expectations. The rainfall variable is positive and thus seems to reflect an adequacy of water, rather than an adequacy of solar energy, as a critical constraint during the period prior to harvest.

In the previous chapter (Fig. 2), the use of MV was not shown to be highly correlated with applied fertilizer among villages. However, the highly significant coefficient of M in the model indicates that among farms within a village, there is a positive association between variety and fertilizer.

These results strongly support the hypothesis that rice farmers' demand for

Table 1. Fertilizer demand function estimated from villages and farm-level observations in 33 villages in Asia, 1971/72 wet season.[a]

Variable	Model specifications		
	A	B	C
Fertilizer: rice price ratio	0.863 (−7.874)	−0.381 (−3.444)	−0.225 (−1.993)
Modern varieties		0.472 (12.196)	0.457 (11.868)
Maximum nitrogen		1.989 (10.475)	1.687 (8.737)
Irrigation		−0.803 (−8.240)	−0.942 (−9.481)
Rainfall		3.481 (22.635)	3.444 (22.570)
Value of output			0.153 (5.957)
Constant	2.035	3.113	2.870
R^2	0.170	0.505	0.517

[a]Figures in parentheses are *t*-values.

fertilizer responds to a change in the relative price of fertilizer to rice.[2] The coefficients for the price ratio represent the price elasticity of demand for fertilizer. When the variables representing shifts in the fertilizer response function are included (Specification C), the elasticity of demand is −0.225. This implies that with all other factors held constant within a village, a 10% increase in the price ratio will result in a 2.25% decline in fertilizer consumption. The more elastic response of fertilizer demand to changes in the price ratio where the variables representing shifts are omitted (−0.863 in Specification A) reflects a long-run elasticity estimate for an across-village fertilizer response function as depicted hypothetically by D in Figure 1B.

The estimates of price elasticities by the author using these and other data sources and alternative model specifications are discussed in greater detail in C. Crisostomo David (1975, 1976). The estimates of the elasticities for the fertilizer:rice price ratio using an alternative model and data sources are summarized in Appendix E. The alternative model is described in Appendix B. The alternative data sources included 1) Asian aggregate data consisting of time series observations of rice production, crop area, fertilizer input, proportion of crop area planted to MV, and fertilizer and rice prices from 1950 to 1972 across 12 Asian rice-growing countries, and 2) a Laguna, Philippines, survey of 150 farms that generated cross-section and time series data from 1966 to 1971.

The consistency of the estimated elasticities from these various data sources is marked. The long-run elasticity of demand for fertilizer is only from −0.8 to −0.9. The variability of the short-run elasticity is greater, ranging from −0.2 to −0.6 (excluding the Laguna, Philippines, estimates). Production response to fertilizer in these analyses is low (1 kg nutrient/10 kg or less of rough rice); this concurs with previous observations that fertilizer efficiency on farmers' fields is low.

SOURCES OF VARIATION IN FERTILIZER DEMAND

An assessment of the contribution of each of the explanatory variables to the gap in fertilizer consumption between the "average" and the "heaviest" users (Table 2) shows that the level of fertilizer used by the top four villages is approximately double that for all villages. Among villages, the important variables explaining the difference in fertilizer consumption are irrigation quality (W), the nitrogen required to get maximum yield (N), and rainfall (R). These variables are closely associated with the physical environment (soil, water, solar energy), which contributes to differences in the fertilizer response functions among villages. While irrigation can be improved, it cannot be

[2] The implicit assumption in this analysis is that farmers respond symmetrically to a 1% increase in fertilizer price and a 1% decrease in rice price. The evidence on this is not conclusive. For further discussion, see Cristina C. David, "Fertilizer Demand in the Asian Rice Economy," *Food Research Institute Studies*, Vol. 15, No. 1 (1976).

Table 2. Percent contribution of factors explaining differences in level of fertilizer use between the average and top four villages, 33 villages in Asia, 1971/72.

Variable	Mean		% contribution to change in NPK input
	Average village	Top 4 villages	
Fertilizer: rice price ratio	3.2	3.0	4
Modern varieties (proportion)	0.6	0.78	25
Maximum nitrogen (kg N/ha)	126	180	77
Irrigation (index)	2.7	2.0	47
Rainfall (proportion)	0.23	0.17	−68
Value of output ($/farm)	485	1208	15
Fertilizer per hectare (kg NPK/ha)	63	130	

assumed that over the long run, those villages average or below in fertilizer input can approach the level of the top four.

The negative contribution of rainfall R indicates that rainfall is lower than average in the high-fertilizer-using villages (Table 2). However, the irrigation quality is high in these four villages, and thus the response of the rice crop to fertilizer may even be greater.

The rate of adoption of modern varieties (M) in the top four villages is substantially higher than the average, but the relationship between MV and fertilizer use across villages is not significant. This reflects, in part, the fact that the present MV are suited to only a portion of the rice-growing environment. However, with farm-level observations introduced into the model, the proportion of the area in MV explains a quarter of the gap between "average" and "heaviest" fertilizer-using villages.

CONCLUSIONS

Raising the fertilizer response function by improving the quality of irrigation or by developing MV suitable to a wider range of environmental conditions is not necessarily the logical policy implications of these analyses. The large contribution of these factors, however, suggests that their relative cost vis-a-vis changing the fertilizer price ratio should be considered in designing policies to raise fertilizer application on rice farms. More detailed information and a different type of methodology are required to determine the relative cost of alternative policies to increase fertilizer demand.

The time factor confronting the policy maker is a critical consideration in the choice of policy alternatives. Price policy may be preferred because of its short-term impact on fertilizer demand, as compared with policies which shift the fertilizer response function.

The data available for this analysis are perhaps better suited for identifying factors which explain variation in fertilizer consumption among villages over a wide range of environmental conditions rather than among farms within a

village. Differences in the physical environment explain, to a large extent, variation among villages in fertilizer consumption, and the gap between "average" and "heaviest" fertilizer-using villages. However, it should not be concluded from this analysis that price, credit availability (or liquidity position), and other non-environmental factors are unimportant in explaining the level of nitrogen consumption and yields on Asian farms. The explanation of among-farm variation in fertilizer consumption within the village can be better understood by reading the village case studies in *Changes* (1975) and the reports in the second half of this volume.

APPENDIX A. **Village-level observations of variables used in model, villages ranked from high to low based on level of NPK applied, 36 Asian villages, 1971/72 wet season.**

Village	NPK applied (kg/ha) (F_i)	Ratio of price of nitrogen to paddy (P_i)	Percent area in MV (M_i)	Index of irrigation (W_i)	Maximum nitrogen (kg/ha) (N_i)	Proportion of total rainfall 2 months before harvest (R_i)	Yield (t/ha) (Y_i)
Hosahally, Mysore	256	3.0	88	2.0	180	11	5.6
Gajanur, Mysore	254	2.8	88	2.0	180	11	4.8
Manmalai, Tamil Nadu	222	2.9	70	2.0	180	28	5.7
Ashoknagar, Mysore	213	2.9	62	2.0	180	11	5.4
D. Vijaypur, U. Pradesh	150	4.0	75	3.0	150	16	4.7
Sidomulyo, East Java	145	4.0	95	2.0	120	25	5.1
Kariyamangalam, Tamil Nadu	145	2.8	50	2.0	180	28	4.0
Kahuman, Central Java	138	2.5	66	1.0	120	30	6.9
Pluneng, Central Java	122	2.8	91	1.0	120	21	6.1
Palvarthuvenran, Tamil Nadu	119	3.0	49	3.0	180	28	4.8
Tarna, U. Pradesh	112	4.1	95	3.0	180	18	3.6
Salor, Malaysia	111	3.8	22	3.0	90	43	2.4
San Nicolas, Nueva Ecija	100	1.7	100	2.0	90	32	3.5
Meranti, Malaysia	96	3.8	32	3.0	90	43	2.2
Nganjat, Central Java	94	2.5	30	1.0	120	29	3.6
Cidahu, West Java	89	3.8	26	2.0	120	28	3.2
Kandarpur, Orissa	63	3.0	15	3.0	120	31	3.0
Barain, Uttar Pradesh	61	4.1	50	5.0	180	18	3.5
Malimba, Nueva Ecija	60	1.7	96	3.0	90	32	2.1
Korpada, Orissa	55	3.0	15	3.0	120	31	3.0
Mahipon, Nueva Ecija	51	1.7	75	5.0	90	32	1.9
Pedapulleru, A. Pradesh	48	3.4	9	3.0	120	27	4.1
Tab-ang, Leyte	43	2.2	100	3.0	90	23	1.9
Beynte Nuwebe, Davao	35	2.8	100	4.0	90	22	3.3
Marcos, Leyte	30	2.2	100	3.0	90	23	3.5
Maraliwala, Punjab	29	4.2	49	2.0	150	33	2.4
Canipa, Leyte	24	2.2	100	3.0	90	23	2.6
Rai Rot, Don Chedi	20	6.4	41	3.0	120	8	3.2
Aroop, Punjab	19	4.7	40	2.0	150	33	3.2
Capayuran, Cotabato	14	3.5	100	4.0	90	18	2.6
Nong Sarai, Don Chedi	13	6.5	21	4.0	120	8	2.4
Bulucaon, Cotabato	12	3.4	100	3.0	90	18	2.9
Sinayawan, Davao	11	2.8	100	4.0	90	22	2.6
Sa Krachom, Don Chedi	0	6.7	4	5.0	120	8	1.8
Cabpangi, Cotabato	0	3.5	82	5.0	90	18	1.0
Maluao, Cotabato	0	3.4	90	5.0	90	18	1.6

APPENDIX B. **An alternative model.**

The alternative model consists of two equations:

$$(1)\quad \log Q_{ij} = \log c_o + c_1 \log H_{ij} + c_2 \log F_{ij} + c_3 M_{ij} + \sum_{2}^{33} \alpha_j D_j + \sum_{2}^{33} \beta_j D_j \log F_{ij} + u_{ij} \qquad \text{(rice production function)}$$

$$(2)\quad \log F_{ij} = \log d_o + d_1 \log P_j + d_2 \log I_j + d_3 E_j + d_4 M_{ij} + d_5 \log V_{ij} + u_{ij} \qquad \text{(fertilizer demand function)}$$

where:

c_o and d_o are constants
i = the ith farm ($i = 1, 2, \ldots n_j$)
j = the jth village ($j = 1, 2 \ldots 33$).
Y = yield of rough rice in t/ha.
Q = production of rough rice in t/farm.
H = crop area in ha.
N = nitrogen (N) in kg/ha.
F = fertilizer (NPK) in kg/ha.
M = percent of area in modern varieties.
D_j = intercept dummy where D_2 is equal to 1 for village 2 and 0 otherwise; D_3 is equal to 1 for village 3 and zero otherwise, etc..
$D_j \log F_{ij}$ = slope dummy variables to distinguish intervillage differences in the production elasticity of fertilizer.
P = price per kg N as a percent of price per kg rough rice.
I = value of intercept by village based on estimate of production function (equation 1): $\log I_1 = \log c_o$, $\log I_2 = \log c_o + \hat{\alpha}_2$, $\log I_3 = \log c_o + \hat{\alpha}_3$ etc..
E = value of slope by village based on the estimate of the production function (equation 1): $E_1 = \hat{c}_2$, $E_2 = \hat{c}_2 + \hat{\beta}_2$, $E_3 = \hat{c}_2 + \hat{\beta}_3$ etc..
V = gross value of production in $ per farm, and
u = distributed term.

This model might be viewed as recursive in that the results of the production function — intercept and elasticity estimates for each village — become variables in the demand function. The fertilizer-response function is estimated first by covariance analysis, assuming an unrestricted Cobb-Douglas production function (Equation 1). The somewhat oversimplified representation of the production relationship of rice cultivation was dictated by the availability of farm input data.

The omission of inputs such as labor and fixed capital affects the goodness of fit and results in a specification bias in the estimated coefficients to the extent that included variables are intercorrelated with excluded variables. An obviously important omitted variable, labor, is expected to be highly colinear with land, which means the estimated coefficient from land includes a significant part of the production response to labor. This is not a serious limitation, however, because the main interest of the study is the production response to fertilizer.

Covariance analysis to account for differences in the response coefficients by village removes much of the specification bias in the coefficient of the β arising from the omitted variables positively correlated with fertilizer (e.g., water control, soils) since a major portion of the variation in the variables is between location rather than between farms in a given location. The estimation of fertilizer response parameters, α_i and β_i, from covariance analysis in the first part (corresponding to the hypothetical fertilizer response function $_1, p_2, p_3$, in Figure 1A) are included as independent variables in equation 2.

This demand specification (equation 2) may suffer from errors-in-variables problems. Because both the production function and the demand function have been fitted to the same set of data, the estimated intercept terms and production elasticities of fertilizer from equation 1 — now employed as explanatory variables — are stochastic variables, possibly not independent of the disturbance term in demand equation. If this is the case, ordinary least square regression leads to inconsistent (hence, biased and often inefficient) estimates of the regression coefficients.

The error-in-variables problem is not encountered in our original model. Here explanatory variables are substituted for the estimate of the fertilizer response parameters.

STATISTICAL RESULTS

Appendix C, D, and E provide regression results for the alternative demand model. Estimates of the intercept and slope coefficients are derived from the rice production function. These estimates are shown for three forms of the production function (PI-2, PI-3, PI-4) in Appendix C for only the Asian farm survey. The villages characterized by lower intercepts — Mahipon, Meranti, and Nong Sarai — have relatively low yields. Conversely, villages characterized by the highest yields — Palvarthuvenran, Manmalai villages in Mysore, Dhanpur-Vijaypur, and most of the Indonesian villages — have higher short-run response functions. The values of the intercept in PI-2 between these two groups range from almost 0 in Nong Sarai to 0.58 in Hosahally, which implies a range in yield from 0.15 to 2.0 t/ha.

The figures under PI-3 show that the response coefficients of fertilizer vary also by village. The addition of modern varieties in equation PI-4 gives practically the same estimates of the production elasticity of fertilizer but slightly higher intercept levels. The pattern of values of the intercept in PI-3 and PI-4 follows rather closely that in PI-2. These range from a low of −0.6 in Mahipon to about 0.6 in some of the villages in India and Indonesia, and the production elasticity with respect to fertilizer ranges from −0.02 in Maraliwala to 0.38 in Mahipon.

The coefficients of the fertilizer demand were estimated using the estimates for α and β from equation 1 as dependent variables in equation 2. The results show that prices and the variables representing shifts in the fertilizer response function including proportion of area under modern varieties are highly significant factors explaining variations in the rate of fertilizer application in the Asian rice economy. The long-run price elasticity of demand shown in equation DI-1, DII-1, and DIII-1 in Appendix E ranges from −0.80 to −0.87 for the three different data sources. The short-run price elasticity of demand shown in equation DI-4, DII-3, and DIII-4 ranges from −0.27 to −0.71.

APPENDIX C. **Village-specific coefficients of the rice production function estimated from farm data of 33 selected villages in Asia, 1971/72 wet season.**[a]

	PI-2	PI-3		PI-4	
	log *a*	log *a*	Fertilizer	log *a*	Fertilizer
		PHILIPPINES			
Gapan, Nueva Ecija					
Mahipon[b]	0.036	−0.645	0.386	−0.650	0.373
			(4.439)		(.283)
Malimba	0.152	0.000	0.164	0.051	0.165
	(8.464)	(2.420)	(−1.904)	(2.249)	(−1.775)
San Nicolas	0.344	0.151	0.183	0.102	0.183
	(9.051)	(2.638)	(−1.565)	(2.492)	(−1.457)
Baybay, Leyte					
Canipa	0.144	0.169	0.070	0.120	0.071
	(2.805)	(3.837)	(−3.071)	(3.623)	(−2.935)
Marcos	0.295	0.287	0.106	0.238	0.106
	(6.987)	(4.370)	(−2.608)	(4.156)	(−2.477)
Tab-ang	0.184	0.110	0.095	−0.159	0.095
	(3.959)	(2.487)	(−2.888)	(2.277)	(−2.746)
Pigcawayan, Cotabato					
Bulucaon	0.367	0.364	0.096	0.316	0.097
	(8.348)	(4.832)	(−3.033)	(4.620)	(−2.890)
Capayuran	0.310	0.327	0.067	0.279	0.068
	(6.363)	(4.672)	(−3.268)	(4.459)	(−3.128)
Hagonoy, Davao del Sur					
Beynte Nuwebe	0.381	0.437	0.050	0.340	0.050
	(8.764)	(5.172)	(−3.648)	(4.960)	(−3.500)
Sinayawan	0.232	0.182	0.131	0.131	0.131
	(4.937)	(3.831)	(−2.538)	(3.615)	(−2.383)
		INDIA			
North Arcot, Tamil Nadu					
Kariyamangalam	0.300	0.111	0.172	0.035	0.192
	(7.126)	(2.938)	(−1.992)	(2.652)	(−1.674)
Palvarthuvenran	0.411	0.406	0.097	0.333	0.117
	(8.988)	(3.379)	(−2.186)	(3.155)	(−1.926)
Manmalai	0.439	0.720	0.040	0.633	0.018
	(11.143)	(5.559)	(−3.957)	(5.192)	(−3.601)
Cuttack, Orissa					
Kandarpur	0.187	0.205	0.082	0.201	0.079
	(4.045)	(4.105)	(−3.190)	(4.027)	(−3.078)
Korpada	0.144	0.162	0.079	0.157	0.076
	(2.047)	(3.919)	(−3.417)	(3.926)	(−3.297)
Shimoga, Mysore					
Gajanur	0.485	0.586	0.037	0.547	0.036
	(13.628)	(5.878)	(−3.874)	(5.709)	(−3.741)
Hosahally	0.575	0.658	0.045	0.625	0.040
	(13.239)	(6.184)	(−3.755)	(6.053)	(−3.663)
Ashoknagar	0.462	0.435	0.109	0.419	0.109
	(10.399)	(5.107)	(−3.052)	(5.063)	(−3.012)

(continued on opposite page)

APPENDIX C continued

	PI-2	PI-3		PI-4	
	log *a*	log *a*	Fertilizer	log *a*	Fertilizer
Nainital & Varanasi, U. Pradesh					
Dhanpur Vijaypur	0.501	0.382	0.125	0.464	0.087
	(12.544)	(3.358)	(−2.069)	(3.659)	(−2.297)
Tarna	0.314	0.369	0.060	0.326	0.060
	(6.895)	(4.238)	(−2.969)	(4.082)	(−2.833)
Barain	0.185	0.161	0.100	0.153	0.095
	(3.957)	(3.528)	(−2.711)	(3.536)	(2.793)
West Godavari, A. Pradesh					
Pedapulleru	0.372	0.427	0.065	0.430	0.063
	(12.065)	(5.175)	(−3.612)	(5.218)	(3.483)
PAKISTAN					
Gujranwala, Punjab					
Aroop[c]				0.160	0.048
Maraliwala[c]				0.565	−0.915
INDONESIA					
Subang, West Java					
Cidahu	0.231	0.192	0.125	0.184	0.118
	(5.390)	(3.997)	(2.670)	(3.899)	(2.600)
Sidoarjo, East Java					
Sidomulyo	0.482	0.611	0.016	0.562	0.017
	(11.926)	(5.500)	(−3.469)	(5.301)	(−3.336)
Klaten, Central Java					
Nganjat	0.341	0.223	0.188	0.214	0.182
	(7.787)	(3.953)	(−1.888)	(3.942)	(−1.825)
Kahuman	0.550	0.553	0.086	0.528	0.081
	(13.345)	(5.300)	(−2.843)	(5.232)	(−2.754)
Huneng	0.522	0.482	0.122	0.435	0.123
	(12.673)	(4.608)	(−2.193)	(4.438)	(−2.076)
WEST MALAYSIA					
Kelantan					
Salor	0.144	0.057	0.140	0.019	0.156
	(3.410)	(2.986)	(−2.297)	(2.845)	(−2.017)
Meranti	0.037	−0.182	0.218	−0.200	0.221
	(−0.144)	(1.945)	(−1.520)	(1.897)	(−1.370)
THAILAND					
Don Chedi, Suphan Buri					
Rai Rot	0.297	0.377	0.047	0.366	0.043
	(7.056)	(4.810)	(−3.675)	(4.795)	(−3.582)
Nong Sarai	−0.007	−0.171	0.248	−0.177	0.244
	(−1.188)	(2.289)	(−1.533)	(2.289)	(−1.423)

[a]Figures in parentheses are *t*-values. Those in brackets are also *t*-values which provide a test of significance of the difference between the coefficient for village and the coefficient for the base village, Mahipon. [b]Mahipon has been assigned as the base village in the covariance analysis specification. [c]Coefficients were estimated based on separate regressions.

APPENDIX D. **Rice production functions estimated from the Asian farm survey, Asian aggregate data, and Laguna survey using alternative model.**[a]

	Log *a*	Land	Fertilizer varieties	Modern	Chemicals	R^2
			Asian farm survey			
PI-1	0.204	0.813	0.124	—	0.754	
		(57.261)	(13.933)			
PI-2	0.036[b]	0.837	0.095	—	—	0.862
		(48.128)	(10.971)			
PI-3	−0.645[b]	0.842	0.386[b]	—	—	0.869
		(43.403)	(4.439)			
PI-4	−0.650[b]	0.841	0.373[b]	0.048	—	0.870
		(43.372)	(4.283)	(2.497)		
			Asian aggregate data			
PII-1	0.089	0.859	0.143	—	—	0.946
		(62.857)	(15.072)			
PII-2	−1.793[c]	1.444	0.073	—	—	0.991
		(14.047)	(7.302)			
PII-3	−1.402[c]	1.286	0.106[c]	—	—	0.995
		(15.197)	(4.105)			
PII-4	0.702[c]	0.684[c]	0.100[c]	0.155	—	0.996
		(3.629)	(2.486)	(3.220)		
			Laguna farm survey			
PIII-1	3.420	0.712	0.056	—	—	0.375
		(20.673)	(4.838)			
PIII-2	3.292[d]	0.723	0.030	—	0.090	0.502
		(20.660)	(2.508)		(5.122)	
PIII-3	3.259[d]	0.701	0.068[d]	—	0.083	0.512
		(19.695)	(2.751)		(4.674)	
PIII-4	3.202[d]	0.704[d]	0.057[d]	0.084	0.153[d]	0.531
		(9.244)	(2.218)	(3.638)	(4.677)	

[a]Figures in parentheses are *t*-values. The second equation in each set of four includes the intercept dummy for each village, the third equation includes intercept and slope dummy for fertilizer, and the fourth equation includes the intercept and steps dummy variables plus the variable for proportion of area planted to modern varieties. [b]Pertains to Mahipon (Philippines), the base village assigned in the covariance analysis. [c]Pertains to the Philippines, the base country assigned in the covariance analysis. [d]Pertains to 1966, the base year assigned in the covariance analysis.

APPENDIX E. **Fertilizer demand functions estimated from the Asian farm survey, Asian aggregate data, and Laguna, Philippines, survey with use of an alternative model.**[a]

	Log *a*	Fertilizer-rice price	Fertilizer response coefficient: Intercept	Production elasticity	Modern varieties	Value of output	R^2
			Asian farm survey				
DI-1	2.035	−0.863 (−7.874)	—	—	—	—	0.170
DI-2	1.562	−0.691 (−6.245)	0.584 (7.368)	2.326 (8.739)	—	—	0.252
DI-3	1.520	−0.650 (−.5528)	0.580 (7.307)	2.336 (8.768)	0.038 (0.037)		0.253
DI-4	1.302	−0.598 (−5.057)	0.540 (6.728)	2.294 (8.620)	0.373 (1.014)	0.091 (3.224)	0.262
			Asian aggregate data				
DII-1	2.003	−0.870 (−3.490)	—	—	—	—	0.064
DII-2	1.339	−0.482 (−2.754)	0.428 (1.517)	5.874 (5.163)	—	—	0.564
DII-3	0.577	−0.274 (−2.010)	−0.217 (−0.967)	1.890 (1.991)	0.949 (11.014)	—	0.742
			Laguna survey				
DIII-1	2.005	−0.800 (−14.586)	—	—	—	—	0.217
DIII-2	−3.731	−0.560 (−9.972)	1.680 (10.878)	2.951 (9.777)	— —	— —	0.326 0.326
DIII-3	−3.747	−0.556 (−9.787)	1.676 (10.778)	2.940 (9.638)	—	0.009 (0.252)	0.326
DIII-4	0.343	−0.709 (−12.828)	0.436 (2.325)	0.223 (0.576)	0.287 (10.448)	0.003 (0.098)	0.410

[a]Figures in parentheses are *t*-values.

Equity implications of technology changes

RANDOLPH BARKER and ROBERT W. HERDT

The use of potentially labor-saving inputs such as herbicides, tractors, and threshers has increased in some areas studied. The adoption of modern rice varieties has been accompanied by an increase in labor use per hectare on most farms. However, no clear relationship was found between the adoption of labor-saving practices and a change in labor use. Small farms have lagged significantly behind large farms in the adoption of labor-saving innovations, but not in the adoption of technology that would increase yields and income. However, in a third of all villages, a higher percentage of small farms reported problems in obtaining inputs, and a smaller percentage reported a higher profit from rice and a higher level of living. In the survey villages in India, Indonesia, and Pakistan, large farmers consistently used high levels of fertilizer and obtained higher yields.

A NUMBER OF PRODUCTION practices are frequently associated with the introduction of modern rice varieties (MV). They include potentially yield-increasing inputs, such as fertilizer and insecticides, and potentially labor-saving inputs, such as tractors and threshers. In the face of a rapidly growing population and a growing number of landless laborers, there is general concern that increased mechanization will aggrevate the employment problem and cause a less favorable income distribution.

Another issue related to income distribution is the plight of the small farmers, which has been the subject of numerous research projects, conferences and workshop, as well as the major focus of the activities of action agencies. In the context of technological change, it has been alleged that the new rice technology benefits the large farmers at the expense of the small farmers.

These two equity issues are examined in this chapter. The first section deals with the relationship between the adoption of the new technology and labor

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use. The second section is concerned with the relationship between farm size, and access to the benefits from the new rice technology.

CHANGES IN FARMING PRACTICES AND LABOR USE

The survey data on changes in labor input are limited because detailed records on labor use were not included in the study. Adoption of modern inputs has been affected considerably by the differences in national policies and in farm size and labor availability. Villages in this section were grouped by country even though the villages selected are *not* representative of the country.

Adoption of modern practices. Fertilizer, insecticides, and hand weeding are common in all the study areas (Table 1). However, herbicides, rotary weeders, tractors, and threshers (all of which might be considered labor-saving practices) are popular in some areas, but not in others. Tractors were used on more than half of the farms surveyed in Malaysia, Pakistan, and the Philippines, but were almost completely absent in Java. Herbicides were used on 65% of the Philippine farms surveyed, but were rarely used in the other survey villages.

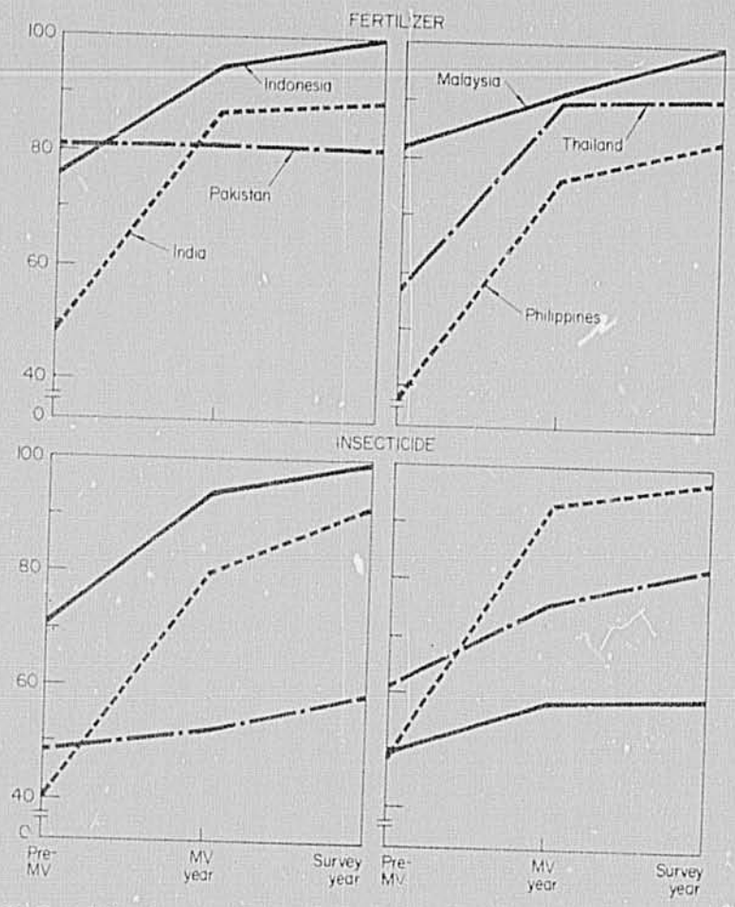
The governments of India, Indonesia, and the Philippines have strongly supported the use of modern, yield-increasing inputs (Fig. 1). In Java, Indonesia, particularly, small farm size and the pressure to increase yields compelled most farmers to use fertilizer and insecticides even before the introduction of MV. However, in the survey villages in these three countries, a still substantial increase in the adoption of these inputs accompanied the introduction of MV. At least 88% or more of the farmers studied in these three countries were using fertilizers and insecticides at the time of the survey, except that in the Philippines 72% of the farmers were using fertilizer (Table 1). (The cumulative rate of adoption over time is shown separately for each input, by country, in Appendix A to E.)

The widespread concern by farmers that insect and disease damage was a major constraint to increased yields (Table 2) helps to explain the rapid rise in insecticide use in the survey villages in the Philippines and India (Fig. 1). In

Table 1. Percent adopters of specific rice farming practices in 32 villages in Asia, 1971/72.

Country	Villages (no.)	Adopters (%)						
		Fertilizer	Insecticide	Herbicide	Hand weeding	Rotary weeding	Tractor	Thresher
India	12	99	88	0	81	11	26	9
Indonesia	5	99	92	0	87	87	2	0
Malaysia	2	93	45	6	n.a.[a]	n.a.	96	0
Pakistan	2	76	58	0	82	0	73	0
Philippines	9	72	97	65	97	49	58	63
Thailand	2	69	71	8	36	0	25	44

[a]Not available.



1. Cumulative rate of adoption by country, of specific yield-increasing practices among those that tried modern varieties at 3 stages: pre-MV, MV year, and during survey year. Selected countries in Asia.

fact, insect and disease damage was regarded as a problem more often than was obtaining fertilizer or credit. Farmers considered the MV more susceptible than local varieties (LV) to insects and diseases.

The rate of adoption of potentially labor-saving technology is not commensurate with the adoption of yield-increasing inputs (Fig. 2). A strong association between the adoption of MV and the adoption of herbicides, tractors, and mechanical threshers appeared only in the villages surveyed in the Philippines. Tractors were already widely used before the introduction of MV in Pakistan, where investment in tractors followed the profitable introduction of the tube well irrigation in the early 1960's. In Malaysia, a sharp increase in tractor use followed the adoption of the new varieties. Only a modest increase in tractor

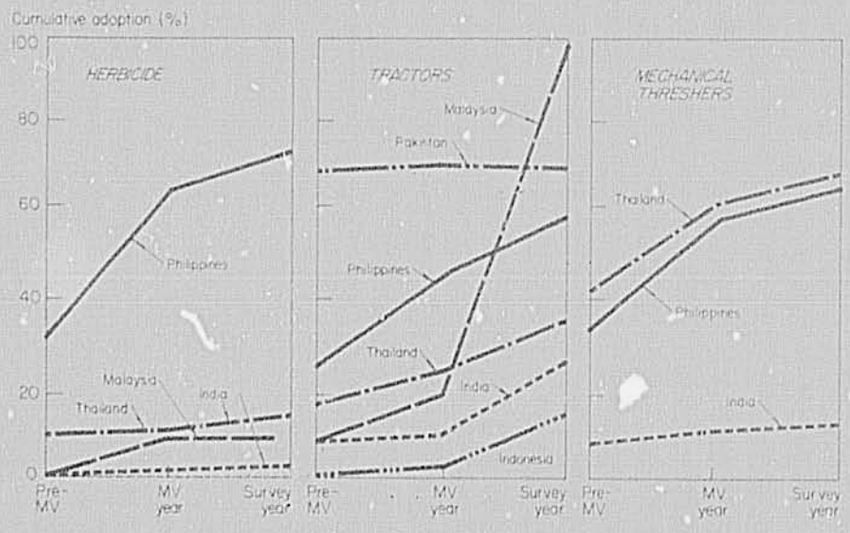
Table 2. Percentage of farmers indicating that obtaining credit or fertilizer or that damage caused by insects and diseases was a major constraint to higher rice yields in 32 villages in Asia, 1971/72 wet season.

Survey country	Villages (no.)	Farmers (%) citing: Obtaining fertilizer	Farmers (%) citing: Obtaining credit	Farmers (%) citing: Insect and disease damage
India	12	39	22	77
Indonesia	5	16	17	52
Malaysia[a]	2	70	33	n.a.
Pakistan	2	2	1	41
Philippines	9	20	21	83
Thailand	2	52	n.a.	53

[a]Dry season. n.a. = not available.

use was noted in the survey villages in Indonesia, India, and Thailand, where most farmers still do not use tractors. In fact, in Java, Indonesia, tractor adoption was very low, and herbicide and mechanical threshers were not used at all.

Adoption of modern practices and changes in labor use. In nearly all the study areas, a substantial number of farmers indicated an increase in the use of family and hired labor for pre-harvest and harvest operations after the intro-



2. Cumulative rate of adoption by country, of specific potential labor-saving practices among those that tried modern varieties at 3 stages: pre-MV, MV year, and during survey year. Selected countries in Asia.

Table 3. Farms reporting changes in labor requirements after the introduction of modern rice varieties in 29 Asian villages, 1971/72.

Country	Villages (no.)	Farms (%) reporting											
		Preharvest labor						Harvest & post harvest labor changes					
		Family labor		Hired labor[a]				Family labor		Hired labor[a]			
				Within		Outside				Within		Outside	
		More	Less	More	Less	More	Less	More	Less	More	Less	More	Less
India	9[b]	27	2	82	3	65	0	n.	a.	n.a.		n.a.	
Indonesia	5	26	2	18	12	7	4	11	1	30	1	15	0
Pakistan	2	8	0	2	0	0	0	40	6	81	8	7	2
Malaysia	2	51	18	36[c]	5[c]	—	—	77	4	30[c]	7[c]	—	—
Philippines	9	57	15	65	7	20	7	48	18	49	14	16	6
Thailand	2	36[d]	—	—	—	—	—	58[d]	—	—	—	—	—
Average[e]		39	8	56	6	31	4	41	11	46	9	15	4

[a] From within or outside the village. n.a. = not available. [b] Exludes the Uttar Pradesh villages. [c] Includes hired labor from outside the village. [d] Represents increase in total labor requirements. [e] Average weighted by number of villages in each country; excludes Thailand.

duction of MV; only a few reported a decrease (Table 3). The notable exceptions were the two villages in Pakistan where changes in the cropping pattern and labor use were most likely associated with the introduction of tube wells and tractors, which preceded the MV. More farmers reported an increase in hired labor than in family labor in most of the study villages.

Although both MV and LV were common in the India, Indonesia, and Pakistan sites, no relationship could be discerned between the area planted to MV and increase in preharvest labor. It is not MV *per se*, but other inputs that result in a change in labor input. Only some of these inputs, however, are associated directly with the adoption of MV.

The presence of so many closely associated changes makes it impossible to learn from these data the true relationship between the introduction of a single input and the change in labor. On the balance, labor use has probably increased. Additionally, the role of such potentially labor-saving inputs as herbicides and tractors merits further investigation.

Data on tractor adoption were cross tabulated with reported changes in labor use in the Indian and Philippine villages (Table 4). Farmers were classified as either adopters in 1967/72 (period of MV adoption) or non-adopters (adopters prior to 1967 were omitted from the comparison). (The actual number of tractor adopters by category is shown in Appendix F.)

The precentage of farmers reporting a decrease in labor use was consistently higher among non-tractor users. In the Philippine villages, the percentage of farmers reporting an increase in labor use was higher among tractor users. Apparently, tractor adoption has tended to accompany the adoption of other practices that require an increased amount of labor.

Herbicides were widely used only in the Philippine study villages (Table 1).

Table 4. Percent of tractor adopters 1967/72, and non-adopters reporting an increase, no change, or a decrease in family and hired labor for villages in India and the Philippines, 1971/72.[a]

Adoption status	Farmers (%) reporting			
	Increase in labor use	No change	Decrease in labor use	Total
		INDIA (12 villages)		
		Family labor		
Adopter 1967/72	5.8	94.2	0	100
Non-adopter	44.1	53.1	2.8	100
		Hired in village		
Adopter 1967/72	51.8	48.2	0	100
Non-adopter	73.7	14.0	12.3	100
		Hired outside village		
Adopter 1967/72	60.6	39.4	0	100
Non-adopter	60.2	18.2	21.6	100
		PHILIPPINES (9 villages)		
		Family labor		
Adopter 1967/72	76.2	17.8	6.0	100
Non-adopter	53.8	16.3	29.9	100
		Hired labor in village		
Adopter 1967/72	74.5	22.4	3.1	100
Non-adopter	52.1	18.9	29.0	100
		Hired labor outside village		
Adopter 1967/72	32.1	60.7	7.2	100
Non-adopter	21.3	18.5	60.2	100

[a]Actual numbers in Appendix F.

In the Philippines, surveys have been conducted over a rather broad geographic area in Central Luzon and Laguna, and in the general vicinity of the Gapan survey site to monitor a group of 76 farms for the changes occurring in labor inputs and other farming practices. One of these surveys on methods of weed control revealed that the expansion in herbicide use between 1966 and 1970 was concomitant with an increased labor use for weeding.[1]

In 1966, only 14% of the 76 farms surveyed used herbicides. Weeding took only 5 man days/ha, 2 man-days of which was supplied by hired labor. In 1970, 38% of the 76 farms used herbicides and used 11 man-days/ha for weeding, 4 man-days of which was supplied by hired labor.

Farmers did some hand weeding because they found that herbicides alone frequently did not provide adequate weed control. Thus, the introduction of herbicides could have enhanced rather than replaced weeding labor. In areas where weeding labor was more readily available, herbicides, if adopted, would tend to substitute for labor.

[1] S.K. De Datta and R. Barker, "Economic evaluation of modern weed control techniques in rice." Pages 205-228 in J.D. Fryer and S. Matsunaka, eds. *Integrated control of weeds*. University of Tokyo Press, Tokyo, 1977.

SMALL FARMERS AND CHANGING RICE TECHNOLOGY

The poverty of small farmers is a result of the small size of their holdings—they control few resources and so their incomes are low. Often, the rates of return to the few resources they control are also low. Additionally, they may be underemployed because the farms they operate are too small to fully utilize their labor resources. Technological change has the potential to overcome both problems; however, there is concern that recent changes in agricultural technology, which have generated technological innovations that cannot be adopted by small farmers, may have aggravated these problems rather than alleviated them.[2]

This section compares the impact of technological change on small farms with that on large farms. First, farm size is considered in an *absolute*, as opposed to *relative*, context, i.e., without reference to the size of neighboring farms. Second, the relationship between *relative* farm size and new technology is examined by dividing farms into large and small within each village. While labor-saving technology is more likely to be found on large farms, in many locations the adoption of yield-increasing technology appears to be constrained by *relative* not *absolute* farm size. Hence a person's access to the new technology and to the associated modern inputs is dictated by his power position relative to his neighbors within the village.

Farm size and the adoption of modern inputs. The analysis in this chapter covers 30 village; six were excluded because the farms were not sampled randomly. Both farm size *per se* and farm size among rice-growing villages varied markedly in the study. The average farm was largest in the villages in Thailand and smallest in Java, Indonesia (Table 5). The variability in size was greatest for the Indian villages of Pedapulleru and Hosahally, where the farm size ranged from less than 0.5 ha to over 10 ha.

Rice farms in general are very small. In one-third of the villages, most farms were less than 1 ha each; in about 50%, the majority were less than 2 ha each; and in two-thirds, the majority of farms were less than 3 ha each. In eight villages, more than 20% of the operating units were less than 0.3 ha each. At the other extreme, the area of 80% of the farms in three villages in Thailand was 4 ha or more. If absolute farm size limits the adoption of new technology, the farmers in the first set of villages will be greatly disadvantaged relative to the second group. (The distribution of farm operational units by farm size for village survey data and for national statistics is shown in Appendix G to K.)

The relationship between absolute farm size and the adoption of six modern practices was assessed. Cumulative frequency functions show the percentage of farms in the three size groups that had adopted each innovation in the indicated year (Table 6, Fig. 3). (Some may have subsequently stopped using the innova-

[2] R.W. Herdt and R. Barker, "Small Rice Farms and Changing Rice Technology," *Journal of Agricultural Economics and Development*, vol. 6 no. 1 (January 1976), pp. 23-43.

Table 5. Cumulative distribution of operating units (rice-growing farms) by size in 30 villages in Asia, 1971/72.

Location	Av. farm size (ha)	Distribution (%)								
		Less or equal 0.3 ha	0.31–0.49 ha	0.50–0.90 ha	1.0–1.9 ha	2.0–2.9 ha	3.0–3.9 ha	4.0–4.9 ha	5.0–9.9 ha	10 ha and over
Cidahu, Indonesia	0.5	38	54	82	97	100				
Nganjat, Indonesia	0.5	36	76	85	100					
Korpada, India	0.6	27	44	79	98	100				
Kahuman, Indonesia	0.6	25	49	81	100					
Kandarpur, India	0.6	23	54	79	100					
Sidomulyo, Indonesia	0.5	24	66	98	100					
Tab-ang, Philippines	1.2	23	27	52	79	95	100			
Pluneng, Indonesia	0.5	21	33	89	100					
Barain, India	1.2	7	14	39	72	90	100			
Marcos, Philippines	1.5	4	12	39	77	91	95	97	100	
Pedapulleru, India	4.7	4	7	16	39	59	65	73	87	100
Salor, Malaysia	0.9	4	23	66	99	100				
Meranti, Malaysia	1.0	4	17	58	94	99	100			
B. Nuwebe, Philippines	1.7	1	3	15	60	90	99	100		
Tarna, India	1.2	0	7	37	74	86	95	100		
Gajanur, India	2.4	0	6	23	52	73	88	94	100	
Canipa, Philippines	1.7	0	4	16	63	90	98	100		
Nong Sarai, Thailand	7.8	0	2	2	4	6	8	23	83	100
Ashoknagar, India	2.8	0	2	10	26	58	78	94	100	
Hosahally, India	4.8	0	2	7	14	40	47	61	93	100
Sinayawan, Philippines	2.2	0	1	15	57	79	88	93	100	
Maluao, Philippines	2.9	0	0	8	44	80	88	92	100	
Capayuran, Philippines	1.9	0	0	3	45	83	97	100		
Malimba, Philippines	3.1	0	0	2	11	44	88	92	100	
Bulucaon, Philippines	2.0	0	0	0	28	98	100			
San Nicolas, Philippines	2.5	0	0	0	20	54	92	96	100	
Mahipon, Philippines	3.8	0	0	0	4	18	61	83	100	
Rai Rot, Thailand	7.0	0	0	0	4	4	17	23	85	100
Sa Krachom, Thailand	7.8	0	0	0	2	7	18	25	75	100
Cabpangi, Philippines	3.9	0	0	0	0	40	46	92	100	

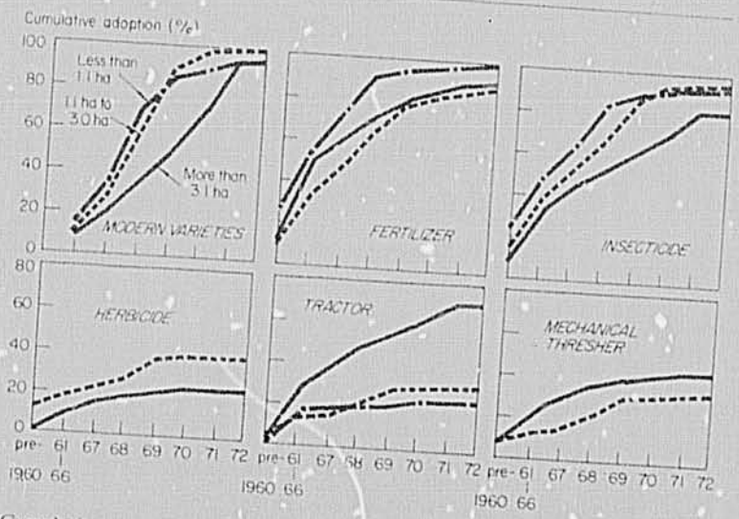
tion.) The small farmers in the study sample adopted MV, fertilizer, and insecticides before the farmers in the medium and large size farms, with more than 80% eventually adopting in all three groups. In contrast, small farmers did not adopt herbicides or mechanical threshers, while 30 to 40% of those in large and medium farms adopted them. Tractors were adopted by 70% of the large farms in the sample, by about 30% of the medium size units, and by 25% of the small units.

Farm size is much more variable than family size (Introduction, Table 1). The large farm operator has the option of hiring labor or using labor-saving technology. Whether the more rapid adoption of labor-saving technology on the larger farms is a reflection of any shortage of hired labor in peak work periods is difficult to say. But the tendency to encourage mechanization through subsidized loans in some countries suggests that the rate of mechanization in some areas may be influenced by the capital bias in national policies.

These data do not support the hypothesis that small farmers have in general

Table 6. Cumulative rate of adoption of some improved rice culture practices by farmers in selected areas in Asia, 1971/72.

Practice, farm size	Cumulative rate (%) of adoption							
	1900–1960	1961–1966	1967	1968	1969	1970	1971	1972
			HYV					
1 ha or less	0	13	35	69	85	89	93	93
1.1 to 3.0	0	9	27	56	89	98	99	99
over 3 ha	0	7	19	34	49	68	92	92
			Fertilizer					
1 ha or less	23	55	73	92	96	97	98	98
1.1 to 3.0	10	34	48	64	78	83	86	88
over 3 ha	14	50	61	73	81	86	90	91
			Insecticide					
1 ha or less	23	49	64	84	89	92	93	93
1.1 to 3.0	12	39	53	67	87	94	95	95
over 3 ha	6	32	45	52	62	70	83	83
			Herbicide					
1 ha or less	0	0	0	0	0	0	0	0
1.1 to 3.0	12	18	23	27	38	39	40	40
over 3 ha	1	8	15	18	21	23	23	23
			Tractor					
1 ha or less	0	18	19	20	21	25	25	25
1.1 to 3.0	6	13	16	21	29	31	32	32
over 3 ha	3	27	39	48	56	63	71	71
			Mechanical thresher					
1 ha or less	0	0	1	1	1	1	1	1
1.1 to 3.0	8	12	15	22	31	32	33	33
over 3 ha	9	21	30	35	39	41	44	44

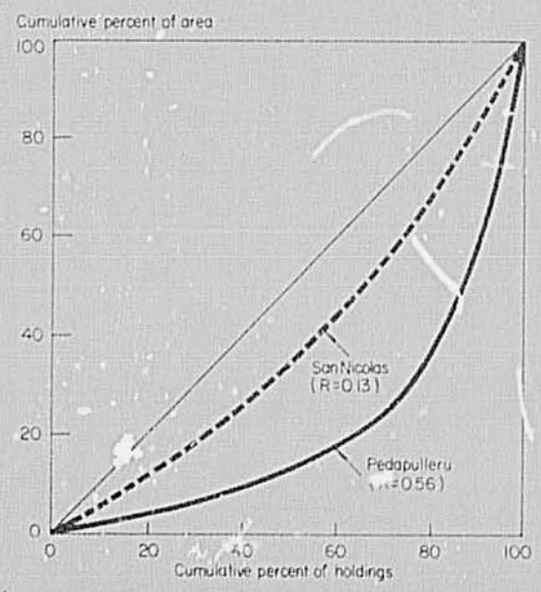


3. Cumulative percentage of farms in three sizes classes adopting specific innovations. Farms in 30 selected villages in Asia.

lagged behind large farmers in the adoption of technology that would increase their yields, income and employment. However, related requirements of the new technology may limit small farmers who may, for example, have more difficulty obtaining credit or fertilizer. They may have less favorable natural resource endowments and, as a consequence, may be more restricted by lack of water or the presence of uncontrolled insects and pests. *Relative* farm size within a community and the degree of concentration of ownership may be more relevant than *absolute* farm size when considering access to and benefits from the new rice technology.

Effect of relative farm size. The hypothesis that small farms within a village have significantly more problems in obtaining inputs and have benefited less than large farms from the introduction of MV was tested. Villages were ranked according to the degree of dispersion in the size of farm operating units within the village. The Gini coefficient, a measure of the degree of dispersion, was computed for each village. Seven size categories ranging from small (less than 0.3 ha) to large (over 5 ha) were established. The Lorenz curve was drawn by plotting the cumulative percentage of area against cumulative percentage of holdings in each size category (Fig. 4, Appendix L). The Gini coefficient or ratio is the area between the Lorenz curve and the diagonal as a percentage of the total area under the diagonal. (See Appendix M for the computational procedure.)

If all the operating units were of equal size, the Gini coefficient would be



4. Lorenz curves showing percent distribution of holdings for Asian villages having the highest and lowest Gini ratios.

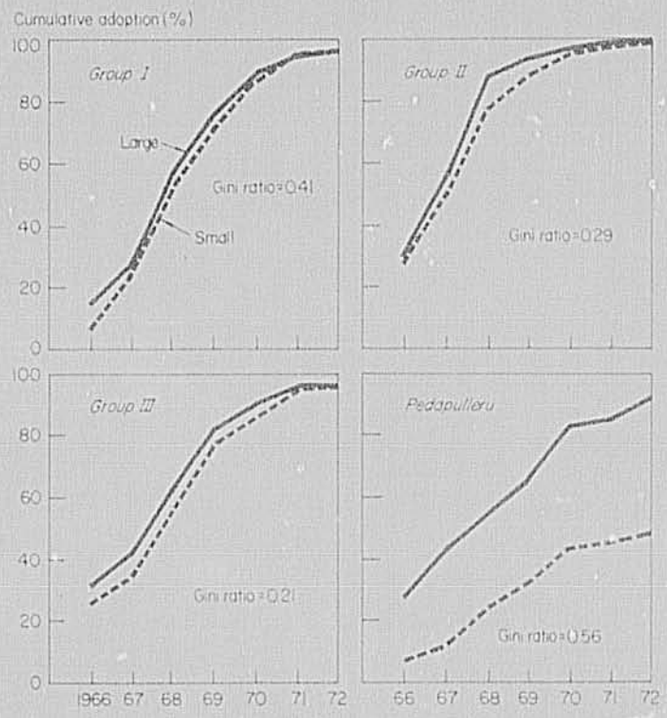
zero. Alternatively, if the bulk of landholdings were operated in a very few large units but there were many small holdings, the coefficient would approach 1 as a maximum. The highest coefficient was 0.56 for Pedapulleru (a village in the West Godavari delta, Andhra Pradesh, India) where approximately 20% of the largest farmers operate 60% of the land (Appendix N). The lowest coefficient was in San Nicolas, a village in Central Luzon, Philippines. This village has a high rate of tenancy, and tenant-operated units are of fairly uniform size. Variability in size of the farm operating unit is only one measure of equity in resource ownership; tenancy is another.

When villages were ranked from high to low according to Gini ratio (Table 7), no relationship could be discerned between the Gini ratio (equality in size of

Table 7. Size and tenure status of rice farms, ranked from high to low Gini coefficient, in 30 villages in Asia, 1971/72.

Village, country	Gini coefficient	Av. size of farm (ha)	Tenure status[a]	
			Pure owners (%)	Pure tenant (%)
		Group I		
Pedapulleru, India	0.56	4.7	41	32
Maluao, Philippines	0.46	2.9	44	53
Tab-ang, Philippines	0.43	1.2	33	57
Barain, India	0.43	1.2	100	0
Tarna, India	0.42	1.2	100	0
Marcos, Philippines	0.38	1.5	14	86
Sinayawan, Philippines	0.38	2.2	14	86
Gajanur, India	0.38	2.4	n.a.	n.a.
Cidahu, Indonesia	0.36	0.5	90	1
Nganjat, Indonesia	0.34	0.5	80	4
		Group II		
Hosahally, India	0.34	4.8	n.a.	n.a.
Kandarpur, India	0.32	0.6	49	9
Korpada, India	0.32	0.6	62	5
Kahuman, Indonesia	0.30	0.6	67	2
B. Nuwebe, Philippines	0.28	1.7	8	92
Meranti, W. Malaysia	0.27	1.0	43	17
Canipa, Philippines	0.27	1.7	17	77
Ashoknagar, India	0.27	2.8	n.a.	n.a.
Sa Krachorn, Thailand	0.25	7.8	64	13
Bulucaon, Philippines	0.25	2.0	6	91
		Group III		
Pluneng, Indonesia	0.25	0.5	71	2
Sidomulyo, Indonesia	0.25	0.5	86	7
Nong Sarai, Thailand	0.24	7.8	66	5
Salor, W. Malaysia	0.24	0.9	58	11
Capayuran, Philippines	0.22	1.9	14	86
Cabpangi, Philippines	0.22	3.9	100	0
Malimba, Philippines	0.20	3.1	9	59
Rai Rot, Thailand	0.18	7.0	75	6
Mahipon, Philippines	0.17	3.8	25	26
San Nicolas, Philippines	0.13	2.5	16	56

[a]n.a. = not available



5. Gini coefficients, farm size, and year of adoption of modern varieties in groups of villages in Asia.

operating units) and the average farm size in a village. For example, the Gini ratio was high in a village with a large average farm size such as Pedapulleru, India, and also in a village with small average farm size such as Cidahu, Indonesia. In Rai Rot, Thailand, on the other hand, the Gini coefficient was low and the farm size large; in Sidomulyo, Indonesia, the Gini coefficient was low and the farm size small.

Villages were grouped into three categories of 10, based on the level of the Gini coefficient (Table 7). Next, all farmers in each village were classified into "large" and "small," based on the median farm size in that village. Then, the degree to which the access to new inputs and benefits from the new technology was related to farm size and dispersion in size of operating units (as measured by the Gini coefficient) was determined.

Examination of the cumulative percentage of adoption of MV over time for each of the three village groups (Fig. 5) revealed that even in Group I with a high Gini coefficient, the difference in the rate of adoption of new varieties between small and large farms was not significant. However, in Pedapulleru, which has the highest Gini coefficient, the difference between small and large farms was marked.

Table 8. Average percentage of rice farms, ranked by Gini coefficient,[a] in each of three village groups reporting obtaining fertilizer or credit as a constraint. Selected areas of Asia, 1971/72.

Village group	Gini coefficient	Av. size of farm (ha)	Farms (%) reporting constraint			
			Fertilizer		Credit	
			Small	Large	Small	Large
I	0.43	2.1	61	47	49	40
II	0.30	1.7	30	35	29	26
III	0.21	2.9	47	50	44	42

[a]Based on villages in each group with 10% or more of farmers reporting a problem in obtaining fertilizer or credit. See Appendix O.

Farmers in each village were asked whether difficulty in obtaining fertilizer or credit was a major constraint in obtaining higher yields. In approximately one third of the villages, farmers reported little or no problem in obtaining fertilizer on credit. This is perhaps not surprising because the villages were selected on the basis of suitability for the adoption of MV, and access to inputs was one criterion. Among the remaining two-thirds of the villages, where fertilizer and credit availability was identified by farmers as a problem in at least 10% of the cases, the percentage of small and large farmers reporting this problem was estimated. There was a high degree of variability in response by farm size among villages (Appendix O). In Group I (high Gini coefficient), however, a significantly higher number of small than large farmers reported problems (Table 8). In the two other groups, farm size was not an important factor.

The farmers were asked whether profits from rice and the level of living were higher now than in the period after the introduction of MV (Table 9, Appendix P). About two-thirds reported higher profits from rice, but the number reporting a higher level of living was considerably lower. Significantly fewer small farmers than large farmers in Group I reported a higher level of living.

Perhaps the most important indication of the effect of farm size is the comparison of actual production and input use on large versus small farms. Yield per hectare and NPK per hectare are reported for small and large farms

Table 9. Average percentage of farms in each of the three village groups reporting higher profit from rice or level of living, ranked by Gini coefficient,[a] selected areas of Asia, 1971/72.

Village group	Gini coefficient	Av. size of farm (ha)	Farmers reporting increase (%)			
			Profit from rice		Level of living	
			Small	Large	Small	Large
I	0.41	1.8	50	64	42	59
II	0.29	2.4	62	71	57	60
III	0.21	3.2	76	73	71	71

[a]Ten villages in each group ranked according to Gini coefficient. See Appendix P.

Table 10. Yield and NPK input on large versus small farms in 32 Asian villages, 1971/72 wet season.

Location	Yield (t/ha)			NPK (kg/ha)		
	Large farms	Small farms	Difference[b]	Large farms	Small farms	Difference[b]
India						
D. Vijaypur, U. Pradesh	6.5	5.2	1.3	229	94	135**
Tarna, U. Pradesh	4.5	4.0	0.5	144	114	30
Barain, U. Pradesh	4.7	4.2	0.5	121	92	29
Kandarpur, Orissa	3.7	2.4	1.3*	116	53	63**
Korpada, Orissa	2.5	1.7	0.8**	99	50	49**
Pedapulleru, A. Pradesh	3.8	3.0	0.8	62	49	13**
Gajanur, Mysore	5.3	4.2	0.9*	187	150	37
Hosahally, Mysore	4.7	3.6	1.1	138	89	49
Ashoknagar, Mysore	3.4	2.5	0.9	132	107	25
Kariyamangalam, Tamil Nadu[a]	4.1	3.9	0.2	222	224	−2
Palvarthuvenran, Tamil Nadu[a]	4.7	5.0	−0.3	206	206	0
Manmalai, Tamil Nadu[a]	6.8	5.5	1.3*	375	232	143**
Indonesia						
Nganjat, Central Java	4.5	2.5	2.0*	111	55	56*
Kahuman, Central Java	8.0	5.1	2.9*	160	107	53
Pluneng, Central Java	5.2	4.3	0.9	112	88	24
Sidomulyo, East Java	4.9	4.2	0.7**	123	93	30
Cidahu, West Java	3.9	2.5	1.4**	122	80	42**
Malaysia						
Salor, Kelantan	2.4	2.6	−0.2	106	114	−8
Meranti, Kelantan	1.9	2.1	−0.2	81	98	−17
Pakistan						
Aroop, Punjab[a]	3.8	3.6	0.2	39	27	12
Maraliwala, Punjab[a]	3.0	3.0	0	53	35	18*
Philippines						
San Nicolas, Nueva Ecija	2.4	3.4	0	92	86	6
Malimba, Nueva Ecija	2.1	2.2	0.1	64	63	1
Canipa, Leyte	1.9	2.3	−0.4	18	28	−10*
Marcos, Leyte	2.9	3.7	−0.8	30	30	0
Tab-ang, Leyte	1.2	1.9	−0.7	40	45	− 5
Bulucaon, Cotabato	2.7	3.3	−0.6	11	13	− 2
Capayuran, Cotabato	2.1	2.5	−0.4	14	11	3
Beynte Nuwebe, Davao	3.0	3.2	−0.2	40	40	0
Sinayawan, Davao	2.9	2.2	0.7	25	19	6
Thailand						
Rai Rot, Suphan Buri	4.0	4.2	−0.2	37	39	− 2
Nong Sarai, Suphan Buri	2.8	2.6	0.2	28	23	5

[a]HYV adopters only. [b]*Statistically significant at 5% level. **Statistically significant at 1% level.

by village (Table 10). It is frequently hypothesi[illegible]t as a result of greater intensity in labor use, small farms will obtain higher yields than will large farms. On the other hand, large farms will be expected to use more fertilizer per hectare than small farms, perhaps offsetting this yield advantage.

Differences by country were striking. In India, Indonesia, and Pakistan, fertilizer input and yield were consistently higher for the large farms, and the differences were frequently statistically significant. In the Philippines,

Table 11. Ratio of rice farm owners to tenants reporting availability of fertilizer or credit as a constraint in the wet season, selected villages in Asia, 1971/72.[a]

Location	Owners as % of tenants	Farmers reporting constraints (%)			
		Fertilizer		Credit	
		Owners	Tenants	Owners	Tenants
Meranti, W. Malaysia	250	72	19	35	42
Pedapulleru, India	130	41	—	12	—
Mahipon, Philippines	100	0	6	6	4
Maluao, Philippines	80	9	44	46	62
Tab-ang, Philippines	60	100	100	5	3
San Nicolas, Philippines	30	11	9	22	32
Canipa, Philippines	20	20	8	10	15

[a]Only villages with more than 15% pure tenants or pure owners were selected.

Malaysia, and Thailand, on the other hand, the differences in yield and fertilizer input were not significant, and yields in small farms tended to be somewhat higher than those on large farms. Villages in the latter group of countries tend to have smaller Gini coefficients (Table 7).

Although the villages are not representative of the countries in question, the results are consistent and suggest that the implications for new technology with respect to small farmers differ markedly from one country to another.

Closely related to the question of farm size is the issue of the tenure. It might be argued in the Philippine case, for example, where tenancy rates are extremely high, that the major inequity exists between landowner and tenant rather than between large and small farmers.

In some cases, small owner-operators and tenants farmed side by side in the same village. In each of the study villages, all farms tended to be either predominantly owner operated or tenant operated. However, seven villages had at least 15% pure owners and pure tenants. It was hypothesized that in these villages, gains from the new technology would be greater for the owner-operators than for the tenants. In Meranti, W. Malaysia, and Pedapulleru, India, where the owner group was dominant, the proportion of owners reporting benefits from the new technology was larger than that of tenants (Table 11, 12). But in the Philippine villages, where tenants are frequently the dominant group in the village and the farm size of owner-operators is comparable with that of the tenants, no such pattern was found.

CONCLUSIONS

A wide variation in the rate of adoption of inputs appears to exist among areas. Fertilizer and insecticide adoption for modern varieties (MV) was high in most areas, while the use of tractors, threshers, and herbicides, was not. Labor use reportedly increased on many farms after the introduction of MV; an increase in hired labor was more frequent than an increase in family labor. No clear

Table 12. Ratio of owners to tenants reporting increased profits from rice and level of living with the introduction of modern rice varieties, selected villages in Asia, 1971/72.[a]

Location	Owners as % of tenants	Farms reporting increase in (%)			
		Profit from rice		Level of living	
		Owners	Tenants	Owners	Tenants
Meranti, W. Malaysia	250	64	28	57	17
Pedapulleru, India	130	44	10	21	14
Mahipon, Philippines	100	78	74	78	74
Maluao, Philippines	80	87	75	87	85
Tab-ang, Philippines	60	38	64	27	41
San Nicolas, Philippines	30	100	93	89	93
Canipa, Philippines	20	78	69	56	41

[a]Only villages with more than 15% pure tenants and pure owners were selected.

relationship was apparent between a change in farm labor and the adoption of modern practices. A more thorough investigation of the impact of new technology on employment requires more information than that within the scope of this study.

Small farms have lagged behind large farms in the adoption of technology that would reduce labor, but not in the adoption of technology that would raise yields and income. Farms were divided into large and small, based on relative size in each village. The notion that "the rich get richer and the poor get poorer" is questionable because nearly all farms, large and small, reported either an increase or no change in profits from rice and in the level of living. However, the benefits from the new technology were clearly associated with farm size in some villages. In the Indian, Indonesian, and Pakistan sites, large farmers applied more fertilizer and obtained higher yields than did small farmers. In contrast, fertilizer input and yields in the Philippines, Malaysia, and Thailand did not differ significantly by farm size. This suggests that institutional differences in rural and farm organization influence the relationship between the introduction of new technology and farm size.

APPENDIX A. **Cumulative reported rate of adoption of fertilizer use in 31 selected Asian villages, 1971/72.**

Country	Villages (no.)	Farms (%) that tried using fertilizers								Users in 1972	
		1900-1960	1961-1966	1967	1968	1969	1970	1971	1972	Wet	Dry
India	11[a]	6	41	60	70	91	97	98	100	99	100
Indonesia	5	32	75	81	94	99	99	99	99	99	96
Pakistan	2	27	62	65	72	79	80	81	81	76	n.a.[b]
Philippines	9	15	33	51	67	77	80	83	84	72	76
Thailand	2	2	20	27	38	50	61	76	82	69	82
Malaysia[c]	2										

[a] Excludes Barain which was classified as poorly irrigated in the initial phase of the study. [b] Not available. [c] Date of adoption of fertilizer use in the two Malaysian villages was not available.

APPENDIX B. **Cumulative reported rate of adoption of insecticide use in 31 selected Asian villages, 1971/72.**

Country	Villages (no.)	Farms (%) that tried using insecticides								Users in 1972
		1900-1960	1961-1966	1967	1968	1969	1970	1971	1972	
India	11[a]	3	31	48	63	80	89	91	91	88
Indonesia	5	31	68	74	92	93	96	96	96	92
Pakistan	2	4	9	9	25	42	55	58	58	58
Philippines	9	16	43	59	75	89	95	97	97	97
Thailand	2	5	32	39	42	50	56	76	76	71
Malaysia[b]	2								45	45

[a] Excludes Barain which was classified as poorly irrigated in the initial phase of the study. [b] Date of adoption of insecticide use in the 2 Malaysian villages was not available.

APPENDIX C. **Cumulative reported rate of adoption of herbicide use in 31 selected Asian villages, 1971/72.**

Country	Villages (no.)	Farms (%) that tried using herbicides							Users in 1972		
		Pre-1966	1967	1968	1969	1970	1971	1972	Herbicide	Hand weeding	Rotary weeding
India	11[a]	1	1	2	2	2	2	2	0	81	11
Indonesia	5	0	0	0	0	0	0	0	0	87	87
Pakistan	2	0	0	0	0	0	0	0	0	82	0
Philippines	9	32	45	51	67	71	72	72	65	97	49
Thailand	2	4	6	6	7	10	10	10	8	36	0
Malaysia[b]	2							8	6	0	0

[a] Excludes Barain which was classified as poorly irrigated in the initial phase of the study. [b] Date of adoption of herbicide use in the 2 Malaysian villages was not available.

APPENDIX D. **Cumulative reported rate of adoption of tractor use in 31 selected Asian villages, 1971/72.**

Country	Villages (no.)	Farms (%) that tried using tractors								Users in 1972
		1900-1960	1961-1966	1967	1968	1969	1970	1971	1972	
India	11[a]	0	9	11	13	20	22	27	27	26
Indonesia	5	0	0	1	3	5	14	15	15	2
Pakistan	2	3	46	57	67	72	73	73	73	73
Philippines	9	10	24	37	46	57	61	61	61	58
Thailand	2	0	5	6	9	15	22	33	33	25
Malaysia[b]	2								96	96

[a]Excludes Barain which was classified as poorly irrigated in the initial phase of the study. [b]Date of adoption of tractor use in the 2 Malaysian villages was not available.

APPENDIX E. **Cumulative reported rate of adoption of mechanical threshers for rice in 31 selected Asian villages, 1971/72.**

Country	Villages (no.)	Farms (%) that tried using mechanical threshers								Users in 1972
		1900-1960	1961-1966	1967	1968	1969	1970	1971	1972	
India	11[a]	0	7	8	9	9	9	9	9	9
Indonesia	5	0	0	0	0	0	0	0	0	0
Pakistan	2	0	0	0	0	0	0	0	0	0
Philippines	9	19	27	38	50	62	65	65	66	63
Thailand	2	1	6	11	27	38	45	55	55	44
Malaysia[b]	2	0	0	0	0	0	0	0	0	0

[a]Excludes Barain which was classified as poorly irrigated in the initial phase of the study. [b]Date of adoption of mechanical thresher use in the two Malaysian villages was not available.

APPENDIX F. **Number of tractor adopters 1967/72, prior to 1967, and non-adopters reporting an increase, no change, or a decrease in family and hired labor for villages in India and the Philippines.**

Adoption status	India (12 villages)			Philippines (12 villages)		
	Increase	No change	Decrease	Increase	No change	Decrease
			Family labor			
Adopter 1967–72	8	131	0	77	18	6
Adopter pre-1967	19	48	1	109	54	40
Non-adopter	192	231	12	135	41	75
			Hired in village			
Adopter 1967–72	74	69	0	73	22	3
Adopter pre-1967	58	19	5	150	42	12
Non-adopter	375	71	62	124	45	69
			Hired outside village			
Adopter 1967–72	86	56	0	9	17	2
Adopter pre-1967	58	10	3	58	29	28
Non-adopter	278	84	100	23	20	65

APPENDIX G. **Cumulative distribution of operating units by farm size for 30 Asian rice villages, 1971–72.**

Location	Gini coefficient	0.3 ha or less	0.3–0.49 ha	0.5–0.9 ha	1–1.9 ha	2–2.9 ha	3–3.9 ha	4–4.9 ha	5–9.9 ha	10 ha and over
		Cumulative percent								
India										
Perlapulleru	0.56	4	7	16	39	59	65	73	87	100
Tarna	0.42	0	7	37	74	86	96	100		
Baraun	0.42	7	14	39	72	90	100			
Gopanur	0.38	0	6	23	52	73	88	94	100	
Hosahally	0.34	2	7	14	40	47	61	93	100	
Ashoknagar	0.27	0	2	16	26	58	78	94	100	
Kandarpur	0.32	23	54	79	100					
Kottpada	0.32	27	44	79	98	100				
Indonesia										
Nganjat	0.34	36	76	85	100					
Kahuman	0.30	25	49	81	100					
Pluneng	0.25	21	33	89	100					
Sidomulyo	0.25	24	66	98	100					
Cidahu	0.36	38	54	82	97	100				
West Malaysia										
Salot	0.24	4	23	66	89	100				
Meranti	0.27	4	17	58	94	99	100			
Thailand										
Ban Rot	0.18	0	0	0	4	4	17	23	85	100
Nong Sarai	0.24	0	2	2	4	6	8	23	83	100
Sa Kracham	0.25	0	0	0	2	7	18	25	75	100
Philippines										
San Nicolas	0.13	0	0	0	20	54	92	96	100	
Mahroba	0.20	0	0	2	11	44	87	92	100	
Mahipon	0.17	0	0	0	4	18	63	83	100	
Catupa	0.27	0	4	16	63	90	98	100		
Marcos	0.38		12	39	77	91	95	97	100	
Tabang	0.43		27	52	79	95	100			
B. Nowebe	0.28		3	15	60	90	99	100		
Sinayawan	0.35	0	1	15	57	79	88	93	100	
Bobucaon	0.25	0	0	0	28	98	100			
Maluao	0.46	0	0	8	44	80	88	92	100	
Capayuran	0.22	0	0	3	45	83	97	100		
Calpangi	0.22	0	0	0	0	40	46	92	100	

APPENDIX II. Cumulative distribution of area by farm size for 30 Asian rice villages, 1971/72.

Location	Gini coefficient	0.3 ha or less	0.31 0.49 ha	0.5 0.9 ha	1 1.9 ha	2 2.9 ha	3 3.9 ha	4 4.9 ha	5 9.9 ha	10 ha and over
		Cumulative percent								
India										
Pedapulleru	0.56	0[a]	1	2	7	17	21	28	50	100
Tarna	0.42	0	2	13	42	57	76	100		
Barain	0.43	1	3	14	39	63	100			
Gajanur	0.38	0	1	7	25	46	67	79	100	
Hosahally	0.34	0	0	1	3	16	21	34	82	100
Ashoknagar	0.27	6	1	3	11	38	61	85	100	
Kandarpur	0.32	7	27	56	100					
Korpada	0.32	9	2	57	93	100				
Indonesia										
Nganjat	0.34	12	45	55	100					
Kahuman	0.30	8	24	65	100					
Pluneng	0.25	8	17	74	100					
Sidomulyo	0.25	10	46	95	100					
Cidahu	0.36	14	25	57	91	100				
West Malaysia										
Salor	0.24	1	10	46	97	100				
Meranti	0.27	1	6	46	85	97	100			
Thailand										
Rai Rot	0.18	0	0	0	1	2	7	11	76	100
Nong Sarai	0.24	0	0	0	1	2	2	11	66	100
Sa Krachom	0.25	0	0	0	1	2	7	11	56	100
Philippines										
San Nicolas	0.13	0	0	0	10	47	86	92	100	
Malimba	0.20	0	0	1	5	31	76	82	100	
Mahipon	0.17	0	0	0	2	10	48	73	100	
Canipa	0.27	0	1	6	42	78	94	100		
Marcos	0.38	1	2	15	50	73	83	88	100	
Tabang	0.43	8	6	18	51	85	100			
B. Nuwebe	0.28	0	0	4	38	79	96	100		
Sinayawan	0.38	0	0	5	28	52	65	75	100	
Bulucaon	0.25	0	0	0	16	95	100			
Maluao	0.46	0	0	2	17	44	53	57	100	
Capayuran	0.22	0	0	1	27	72	94	100		
Cabpangi	0.22	0	0	2	17	44	53	57	100	

[a]Less than 1%.

APPENDIX I. **Farm operating units by farm size group, selected Asian countries, 1971/72.**

Country	Farm operating units (%) by size group									
	-0.5 ha	0.5-1.0 ha	1.1-2.0 ha	2.1-3.0 ha	3.1-5.0 ha	5.1-10.0 ha	10.1-20.0 ha	Over 20.0 ha	Total farms	Year
India[a]	18.3	21.6	22.4	12.4	14.8	5.9	3.6	1.0	49,874	1961
Indonesia[b]	43.6	26.5	18.2	5.7	3.5	1.8	0.5	0.2	12,236	1963
Pakistan[b]	15.2	17.6	16.6	12.0	15.6	15.0	8.0	[c]	4,860	1960
Thailand[d]	10.2	8.3	21.8	16.9	19.7	18.0	4.9	0.2	3,214	1963
Philippines[e]	4.1	7.4	29.6	21.2	18.7	13.4	4.6	1.0	2,166	1960
Malaysia (West)[b]	10.2	35.1	22.0	16.0	12.7	2.9	0.9	0.2	450	1960
Total farms	15,640	15,469	15,662	8,513	9,649	4,790	2,512	565	72,800	
% of total	21.5	21.3	21.6	11.7	13.3	6.6	3.4	0.8	100.0	
% of area	1.9	5.6	12.1	11.0	21.2	18.7	19.7	9.8	100.0	

[a]Source: Directorate of Economics and Statistics, "Indian Agriculture in Brief," 11th ed.[b] Source: FAO report on the 1960 World Census of Agriculture.[c] Included in previous size class.[d] Source: National Statistical Office, Statistical Yearbook, Thailand No. 29, 1970-71. [e]Source: Bureau of Census and Statistics, 1960 Census of Agriculture.

APPENDIX J. **Farm area by farm size group, selected Asian countries, 1971/72.**

Country	Farm area (%) by size group									
	0.5 ha	0.5-1.0 ha	1.1-2.0 ha	2.1-3.0 ha	3.1-5.0 ha	5.1-10.0 ha	10.1 20.0 ha	Over 20.0 ha	Total area (thousand ha)	Year
					Percent of area					
India[a]	1.3	5.5	12.2	11.3	23.0	16.8	17.9	11.9	132,686	1961
Indonesia[b]	11.4	17.3	22.8	12.5	12.3	11.2	6.9	5.6	12,884	1963
Pakistan[b]	0.7	2.8	6.0	7.2	15.0	25.6	42.7	[c]	19,800	1960
Thailand[d]	1.4	1.2	9.7	10.9	21.8	34.1	18.9	2.0	11,149	1963
Philippine[d]	0.3	1.3	10.2	12.9	18.4	23.7	15.3	17.9	7,773	1960
Malaysia (West)[b]	1.4	13.8	17.4	19.9	26.7	10.7	6.5	3.5	906	1960
Total farms	3,503	10,425	22,404	20,444	39,227	34,558	36,489	18,148	185,198	
% of total	1.9	5.6	12.1	11.0	21.2	18.7	19.7	9.8	100.0	

[a]Source: Directorate of Economics and Statistics, "Indian Agriculture in Brief, 11th ed.. [b]Source: FAO report on the 1960 World Census of Agriculture; [c]Included in previous size class; [d]Source: National Statistical Office, Statistical Yearbook, Thailand No. 29, 1970-71. [e]Source: Bureau of Census and Statistics, 1960 Census of Agriculture.

APPENDIX K. **Comparison of average size distribution of holdings according to survey data (1971/72) and all farms based on FAO data, selected Asian countries.**

Farm size (ha)	Philippines				India				Indonesia				Malaysia				Thailand			
	Survey data		FAO data		Survey data		FAO data		Survey data		FAO data		Survey data		FAO data		Survey data		FAO data	
	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
	Cumulative percent																			
less or equal 0.3	3	0	0	0	10	1	0	0	34	14	0	0	4	1	0	0	0	0	0	0
0.31 — 0.49[b]	4	0	4	0	18	2	23	2	30	30	44	10	20	9	15	1	0	0	9	1
0.5 — 0.9	13	3	12	2	33	5	41	7	68	68	70	26	62	41	36	5	0	0	19	3
1.0 — 1.9	41	18	41	12	52	12	63	19	97	98	88	46	97	91	67	15	3	1	40	12
2.0 — 2.9	70	47	62	25	66	22	75	30	100	100	94	57	100	99	83	25	5	2	52	23
3.0 — 3.9	87	69	74	35	75	31	82	39			96	63		100	89	30	13	6	65	33
4.0 — 4.9	95	83	81	43	81	39	87	47			97	68			94	35	23	12	76	50
5.0 & over	100	100	100	100	93	65	95	69			100	100			100	100	81	66	100	100
10.0 & over					100	100	100	100									100	100		
Gini coefficient	0.34		0.48		0.58		0.59		0.32		0.58		0.26		0.71		0.21		0.40	

[a]From FAO Annual Production Yearbook based on country Censuses of Agriculture, 1960. [b]For FAO data, figures are for farm size range of less than 0.5 ha. [c]For India and Thailand, figures are for farm size range 5.0–9.9 ha.

APPENDIX L. **Comparison of country averages of interpolated values for individual Lorenz curves from survey of rice villages, 1971/72, and FAO data on all farms.**

Cumulative % of holdings	Philippines		India		Indonesia		Malaysia		Thailand	
	Survey data	FAO data	Survey data	FAO data	Survey data	FAO data	Survey data	FAO data	Survey data	FAO data
10	4	3	2	1	3	2	3	0	4	2
20	9	5	6	2	7	3	8	2	9	4
30	16	7	11	4	12	5	14	4	15	7
40	20	11	17	7	19	9	22	6	23	12
50	29	17	24	11	27	13	30	8	32	19
60	38	24	34	17	36	19	39	12	42	27
70	49	31	44	25	46	25	50	17	52	39
80	61	42	58	35	59	36	64	23	65	54

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APPENDIX L **continued**

Cumulative % of holdings	Philippines		India		Indonesia		Malaysia		Thailand	
	Survey data	FAO data	Survey data	FAO data	Survey data	FAO data	Survey data	FAO data	Survey data	FAO data
90	77	57	74	54	75	50	80	31	79	71
95	86	74	84	69	85	61	89	35	88	81
100	100	100	100	100	100	100	100	100	100	100
Gini coefficient	0.29	0.48	0.35	0.59	0.32	0.58	0.27	0.71	0.25	0.40

APPENDIX M **Calculation of Lorenz curve and Gini ratio of concentration, farm size, and number of holdings, Pedapulleru, Andhra Pradesh, India.**

Farm size (ha)	No. of holdings (H)	% distribution of holding $\left(\frac{H}{N} \times 100\right)$	Cumulative % distribution of holdings X	Aggregate area	% distribution of aggregate area	Cumulative % distribution of aggregate area (Y)	X + 1	Y + 1	Y(X + 1)	X(Y + 1)	[Y(X + 1) −X (Y + 1)]
0.3 or less	7	4	4	0	0	0[b]					
0.31 — 0.49	6	3	7	8.74	1	1	4	0	0	0	0
0.5 — 0.9	17	9	16	8.74	1	2	7	1	4	0	4
1.0 — 1.9	42	23	39	43.70	5	7	16	2	14	16	−2
2.0 — 2.9	37	20	59	87.41	10	17	39	7	112	78	34
3.0 — 3.9	11	6	65	34.96	4	21	59	17	663	413	250
4.0 — 4.9	15	8	73	61.18	7	28	65	21	1239	1105	134
5.0 — 9.9	26	14	87	192.30	22	50	73	28	1820	1533	287
10.0 & over	24	13	100	437.05	50	100	87	50	3650	2436	1214
Total	185	100		874.10	100		100	100	8700	5000	3700
											5621

[a]Gini ratio $= (R) = \frac{1/2 \sum Y(X+1) - X(Y+1)}{5000}$

$R = \frac{1/2\ (5621)}{5000} = 0.56$

[b]Less than 1%.

APPENDIX N. **Distribution of ownership holdings ranked by Gini coefficient for selected farm villages in Asia.**[a]

Location	Gini coefficient	Cumulative % of farm area at cumulative % of holdings: 10	20	30	40	50	60	70	80	90	95	100
						India						
Andhra Pradesh												
Pedapulieru	.56	1	3	6	10	13	18	27	40	57	75	100
Orissa												
Kandarpur	.32	3	6	11	18	24	33	44	58	75	85	100
Korpada	.32	3	6	11	18	25	35	45	60	75	85	100
						Indonesia						
Central Java												
Nganjat	.34	2	5	10	17	25	33	42	54	65	78	100
West Java												
Cidahu	.36	2	5	9	14	20	29	39	54	72	83	100
						Malaysia						
Kelantan												
Salor	.24	3	8	15	23	30	40	50	65	80	89	100
Meranti	.27	3	8	14	21	30	38	50	64	80	89	100
						Thailand						
Suphan Buri												
Rai Rot	.18	4	10	16	25	33	44	55	68	82	90	100
Nong Sarai	.24	4	10	16	24	33	41	51	63	76	85	100
Sa Krachom	.25	3	7	14	21	30	40	50	63	79	88	100
						Philippines						
Nueva Ecija												
San Nicolas	.13	3	10	18	21	35	45	57	69	83	90	100
Malimba	.20	5	11	19	26	35	45	55	66	80	89	100
Mabipon	.17	5	12	19	22	35	45	56	68	83	89	100
Leyte												
Marcos	.38	2	5	10	15	22	31	41	53	71	82	100
Canipa	.27	4	9	14	20	29	38	49	63	79	87	100
Tab-ang	.43	2	5	9	13	19	28	40	55	75	85	100
Davao												
Beynte Nuwebe	.28	3	8	14	21	30	39	50	60	80	89	100
Sinayawan	.38	3	12	12	17	23	30	40	52	69	80	100
Cotabato												
Bulucaon	.25	4	9	18	23	37	42	59	70	84	90	100
Mean		3	8	13	19	28	36	47	60	76	86	100
				India								
Uttar Pradesh												
Dhanpur-Vijaypur	.28	3	7	13	20	27	35	44	57	75	85	100
Mysore												
Gajanur	.38	2	6	11	17	24	33	43	55	71	81	100
Hosahally	.34	2	6	11	13	26	44	55	69	83	90	100
Ashoknagar	.27	3	8	15	22	30	40	51	64	79	86	100
				Indonesia								
East Java												
Sidomulyo	.25	4	10	17	24	30	40	51	62	80	89	100
Central Java												
Pluneng	.25	4	9	15	23	32	42	51	62	77	86	100
Kahuman	.30	3	6	10	17	25	35	47	62	79	88	100

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APPENDIX N **continued**

Location	Gini coefficient	Cumulative % of farm area at cumulative % of holdings										
		10	20	30	40	50	60	70	80	90	95	100
					Philippines							
Cotabato												
Capayuran	.22	4	10	16	24	33	43	54	67	81	90	100
Cabpangi	.22	5	11	18	24	34	44	55	68	82	90	100
Maluao	.46	3	6	11	15	20	28	35	44	55	65	100
Mean		3	8	14	20	28	38	49	61	76	85	100

[a]Values are cumulative % farm areas at specified cumulative % of holdings interpolated from individual Lorenz curve of each village. Farm size grouping different for each village.

APPENDIX O **Percent of farms reporting availability of fertilizer or credit as a constraint in the wet season, 30 Asian rice villages.**

Village country	Gini coefficient	Av size of farms (ha)	Farms reporting constraint (%)			
			Fertilizer		Credit	
			Small	Large	Small	Large
		Group I				
Pedapulleru, India	0.56	4.7	67	41	18	3
Maluao, Philippines	0.46	2.9	18	35	64	47
Tab-ang, Philippines	0.43	1.2	—	—	7	0
Barain, India	0.43	1.2	100	68	100	81
Tarna, India	0.42	1.2	83	60	65	50
Marcos, Philippines	0.39	1.5	0	6	—	—
Sinayawan, Philippines	0.36	2.2	38	31	39	12
Gajanur, India	0.38	2.4	8	8	0	4
Cidahu, Indonesia	0.36	0.5	—	—	—	—
Nganjat, Indonesia	0.34	0.5	5	6	10	12
		Group II				
Hosahally, India	0.44	4.8	19	9	14	5
Kandarpur, India	0.32	0.6	13	26	13	22
Korpada, India	0.32	0.6	23	35	29	30
Kahuman, Indonesia	0.30	0.6	50	46	29	18
B. Nuwebe, Philippines	0.28	1.7	35	27	47	41
Meranti, W. Malaysia	0.27	1.0	53	62	36	20
Canipa, Philippines	0.27	1.7	15	4	8	22
Ashoknagar, India	0.27	2.8	0	12	35	32
Sa Krachom, Thailand	0.25	7.8	9	5	—	—
Bulucaon, Philippines	0.25	2.0	—	—	—	—
		Group III				
Pluneng, Indonesia	0.25	0.5	22	54	29	48
Sidomulyo, Indonesia	0.25	0.5	—	—	—	—
Nong Sarai, Thailand	0.24	7.8	27	14	—	—
Salor, W. Malaysia	0.24	0.9	92	77	31	37
Capayuran, Philippines	0.22	1.9	50	28	64	50
Cabpangi, Philippines	0.22	3.9	100	100	67	35
Malimba, Philippines	0.20	3.1	23	25	38	50
Rai Rot, Thailand	0.18	7.0	8	0	—	—
Mahipon, Philippines	0.17	3.8	7	0	7	0
San Nicolas, Philippines	0.13	2.5	13	4	32	29

APPENDIX P. **Percent of farms reporting increase in profit from rice and level of living, 30 Asian villages ranked by Gini coefficient.**

Village country	Gini coefficient	Av size of farms (ha)	Farms reporting increase in (%)			
			Profit from rice		Level of living	
			Small	Large	Small	Large
		Group I				
Pedapulleru, India	0.56	4.7	18	50	9	31
Maluao, Philippines	0.46	2.9	88	75	81	90
Tab-ang, Philippines	0.43	1.2	54	56	30	42
Barain, India	0.43	1.2	69	81	31	65
Tarna, India	0.42	1.2	91	85	57	85
Marcos, Philippines	0.38	1.5	54	39	31	52
Sinayawan, Philippines	0.38	2.2	17	47	9	40
Gajanur, India	0.38	2.4	91	83	91	100
Cidahu, Indonesia	0.36	0.5	57	58	45	44
Nganjat, Indonesia	0.34	0.5	64	61	36	37
		Group II				
Hosahally, India	0.34	4.0	100	83	100	94
Kandarpur, India	0.32	0.6	63	89	37	56
Korpada, India	0.32	0.6	87	92	48	52
Kahuman, Indonesia	0.30	0.6	90	100	80	76
B. Nuwebe, Philippines	0.20	1.7	27	38	40	40
Meranti, W. Malaysia	0.27	1.0	51	23	40	15
Canipa, Philippines	0.27	1.7	72	70	41	48
Ashcknagar, India	0.27	2.8	60	75	100	100
Sa Krachorn, Thailand	0.25	7.8	18	55	23	36
Bulucaon, Philippines	0.25	2.0	55	83	64	79
		Group III				
Pluneng, Indonesia	0.25	0.5	95	100	86	96
Sidomulyo, Indonesia	0.25	0.5	94	76	76	82
Nong Sarai, Thailand	0.24	7.8	48	75	39	68
Salor, W. Malaysia	0.24	0.9	83	83	80	75
Capayuran, Philippines	0.22	1.9	100	85	100	95
Cabpangi, Philippines	0.22	3.9	55	50	59	38
Malimba, Philippines	0.20	3.1	58	58	42	50
Rai Rot, Thailand	0.18	7.0	58	35	62	39
Mahipon, Philippines	0.17	3.8	71	80	74	77
San Nicolas, Philippines	0.13	2.5	94	92	90	92

PART 2:
SPECIAL REPORTS FROM THE VILLAGES

Response to the impact of the new rice technology by farm size and tenure - Andhra Pradesh, India [1]

G. PARTHASARATHY AND D.S. PRASAD

Differences in response to the new rice technology between seasons persisted and were more significant than farm size and tenure. However, there was a significant association between farm size and adoption of modern varieties in both the wet and dry season when cultivators were classified into groups that farm less than or more than 4 ha. Although there was no firm evidence of deterioration in the living standards of small farmers, small tenants, and laborers, the relative distribution of incomes appeared to have worsened. The new technology was not followed by an increase in intensity of cropping, and therefore the beneficial effects on employment were limited.

THE EARLY OPTIMISM that technological change and modern inputs were all that was required for agricultural growth is giving way to a more sober assessment of the constraints to growth imposed by economic and social factors.[2] There is now a much better appreciation of the environmental constraints. The point of view of the "environmentalists" is ably stated by Barker and Mangahas in relation to changes in rice farming in an article presented at the International

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[1] An earlier version of this article was published in *The Developing Economies*, Vol. 12, No. 2 (Institute of Developing Economies, Tokyo, Japan, June 1974), pp. 182–198.

[2] The early optimism is expressed in a paper by Norman E. Borlaug, Ignacio Narvaez, Oddvar Aresvik, and R. Glenn Anderson, "A Green Revolution Yields a Golden Harvest," *The Columbia Journal of World Business* (September–October, 1969). The theme of this paper is that technology can be more revolutionary than any "isms."

Theodore Schultz, a pioneer among "Technology Crucial" advocates, said that the surest route to progress is to develop supply and to teach people how to use a more profitable set of factors. Theodore W. Schultz, *Transforming Traditional Agriculture* (Yale University Press, New Haven, 1964), p. vii.

For a criticism of the factual basis of Schultz' work, as well as the influences of the "technology crucial" approach, see K. N. Raj, "Some Questions Concerning Growth, Transformation and Planning of Agriculture in Developing Countries," *Journal of Development Planning*, No. 1, 1969.

Conference of Agricultural Economists held at Minsk.[3] The authors attributed the low response of rice farmers to the new technology, compared with that of wheat growers, to the relatively unfavorable set of environmental conditions facing rice. Rice is subject to floods and droughts, to high humidity during the main growing season, and to more severe attacks by pests and diseases. This observation led to a recognition of complementarity between infrastructure and investments in research, and development of new varieties. There is also a growing skepticism of the assumption that primary emphasis on research and development could provide a relatively inexpensive route to rapid growth of agriculture in developing economies.[4] Institutional changes, too, which were considered of only marginal importance when the experience with the use of technology on farmers' fields was still limited, are now given a more prominent place by economists and policy makers.[5] Barker and Mangahas, however, underplayed the importance of institutions as critical to growth. To quote them:

> "The effect of owner operatorship is generally productive but rather small. From the viewpoint of land reform, it appears that the transfer from share tenancy to owner-operatorship *per se* is of lesser importance than such other aspects of the reform programme as irrigation and extension system to the tenant. Farm size was found to have a very small effect, supporting the contention that no minimum farm size is necessary for new varieties to be economically acceptable."[6]

Their conclusions are based on a study of the response of a sample of farmers in the Philippines, and quite obviously, even the authors will not hold them applicable to all agroeconomic situations. It is also important to recognize that the policy implications they have drawn have validity, even in the Philippine context, only under the assumption that in the absence of land reform, a more adverse distribution of incomes will not turn into a constraint on growth. Therefore, the responses of different size and tenure groups to new technology and its economic and social effects need to be examined for well-defined agroeconomic situations.

[3] Randolph Barker and Mahar Mangahas, "Environmental and Other Factors Influencing the Performance of New High Yielding Varieties of Wheat and Rice in Asia," in *Policies, Planning, and Management for Agricultural Development, Papers and Reports*, Fourteenth International Conference of Agricultural Economists, Oxford, 1971, pp. 397–410; also in *Comparative Experience of Agricultural Development in Developing Countries of Asia and the Southeast Since World War II*, (The Indian Society of Agricultural Economics, Bombay, October 1972), pp. 225–236.

[4] S. C. Hsieh and V. W. Ruttan, "Environmental, Technological and Institutional Factors in the Growth of Rice Production, Philippines, Thailand and Taiwan," *Food Research Institute Studies*, Vol. 7, No. 3(1967).

[5] The literature on this aspect is quite large. The most passionate advocate of institutional changes in India is Wolf Ladejinsky. See Wolf Ladejinsky, "Ironies of India's Green Revolution," *Foreign Affairs, an American Quarterly Review*, Vol. 48, No. 4 (July 1970), pp. 758–768. See also G. Parthasarathy, *Green Revolution and Weaker Sections* (Thacker and Co., Bombay, 1971).

[6] Barker and Mangahas, *op. cit.*, p. 405. See also P. K. Mukherjee, "The HYV Programme Variables That Matter," *Economic and Political Weekly*, Vol. 5, No. 13 (March 28, 1970), pp. A15–A22. Mukherjee argued on the basis of P.E.O. data that tenancy is not a variable that matters for adoption of new technology.

Village studies in well-defined settings have two advantages. First, they permit analysis in depth since the analyst gains better insights into the working of different complex forces when the unit of observation is spread over a small area. Second, the influences of other factors — like environment, the nature of extension administration — which need to be separated when a sample spread over a large area is chosen, are minimal, and responses to the variable under examination can be studied with more confidence. An attempt is made in this paper to use the data of Pedapulleru village to test the inferences of Barker and Mangahas in relation to a defined setting. The chosen village — Pedapulleru, West Godavari District, Andhra Pradesh, India — is a canal-irrigated rice village with no other crop in either the wet or dry season, and has fair representation of all the size and tenure groups. No significant difference between tenure or size groups is reported in respect to soil, drainage, and water supply conditions on farms. The environmental disabilities observed, like inadequate drainage, etc., are shared by all groups and are not size or tenure specific.[7]

All the cultivators in the village were surveyed in July 1972, and details relating to size, tenure, adoption of modern varieties (MV), cultural practices, yields, etc., were obtained separately for *kharif* (wet season) traditional varieties (TV), *kharif* MV, *rabi* (dry season) TV, and *rabi* MV for agricultural year 1971/72. A schedule covering occupational details on all residents in the village preceded the farm survey.

The 185 cultivators in the village were classified into six size groups and four tenure groups to observe the variations in response to new technology. The six size groups are

A — less than 1 ha,
B — 1 ha and more but less than 2 ha,
C — 2 ha and more but less than 3 ha,
D — 3 ha and more but less than 4 ha,
E — 4 ha and more but less than 6 ha, and
F — more than 6 ha.

The four tenure groups are

I — pure owner cultivators,
II — owner cultivator-*cum*-rentier,
III — pure tenant, and
IV — owner cultivator-*cum*-tenant

The analysis is presented separately for each season and pertains to 1971/72 *kharif* (wet) and *rabi* (dry). The first part of the paper presents findings on response to new technology, and the second on the economic and social impact of technology by size and tenure.

[7] For a good description of the agroeconomic situation of the district in which the village is situated, see Francine R. Frankel, *India's Green Revolution, Economic Gains and Political Costs* (Princeton University Press, Princeton, New Jersey, 1971), pp. 47–80.

RESPONSES TO NEW TECHNOLOGY

The degree of response to new technology is judged by the number of farmers either totally or partially shifting to MV, area under MV, shift to nontraditional inputs, etc.*

Twelve percent were MV growers in *kharif*, 45% in *rabi*. *Rabi* rates exceeded *kharif* rates in all size and tenure groups (Table 1). It is well known that environmental constraints are more severe in *kharif* than in *rabi*. In this respect, there is no difference between the data we observed and those analyzed by Barker and Mangahas. But the similarity stops here. Even in the seventh year of MV, significant differences were noticed in the rate of adoption between farmers with 4 ha or more and the others (Appendix A, B).

Although inputs are perfectly divisible, adoption is influenced by the perception of and the ability to take risks. Size has a bearing on both factors. Environmental constraints, although shared by all, produce varying reactions depending upon size. What comes out most clearly in the data is that larger farmers with more investible surplus and, therefore, greater ability to undertake risks show higher rates of adoption. Thus, size continues to be a constraint, in spite of what has been said to the contrary, but its influence is less in a season with lower environmental risks. The data also confirm the evidence already accumulated that the rate of early adoption and the proportion of those who ever used MV are significantly higher among the big farmers than among others.* This applies more during *kharif* than during *rabi*.

Chi-square tests of association between size and adoption revealed that the farm size of 4 ha and above was significantly associated with adoption. That was true even when the influence of size on adoption within tenure was separately considered. When association between size and adoption during *rabi* was tested for the size groups of below 2 ha and above 2 ha, no significant associa-

Table 1. Percentage of MV growers to total in each group by size and tenure, Pedapulleru, India, 1971/72.

Tenure	MV growers (%)					
	Kharif			Rabi		
	Below 4 ha	4 ha and above	All farms	Below 4 ha	4 ha and above	All farms
Owners	3	29	15	35	67	51
Pure tenants	4	20	7	32	30	31
All farms	3	27	12	34	61	45

* The term MV used here differs from modern variety used elsewhere in the text since it includes the variety Mahsuri which is considered an MV in the government program, but was developed prior to 1965.

* G. Parthasarathy, "Economics of IR8 Paddy — Factors Influencing Its Adoption in a Tank Irrigated District," *Economic and Political Weekly*, Vol. 4, No. 38 (Sept. 20, 1969), pp. 1519–1523.

Table 2. X^2 significance tests on adopters of MV in Pedapulleru, India, 1971/72

Item	Remarks
Size (ignoring tenancy)	Significant at the 1% level
Tenancy (ignoring size)	Significant in *rabi* at the 5% level
Tenancy within 4-ha size group	Not significant
Tenancy in 4-ha and above size group	Significant in *rabi* at the 5% level
Owners with regard to size	Significant at the 1% level
Tenants with regard to size	Not significant
Below 2 ha and above 2 ha (ignoring tenancy)	Not significant

tion was found. The data suggest that below a particular level, size has no influence on adoption (Table 2).

Association between tenure and adoption was significant at the 5% level, indicating that owners have an edge over tenants. This is true even when size is considered. The result becomes especially meaningful when it is recognized that when MV are grown, the landowner decides on the variety to be adopted and finances the non-traditional inputs.

The results are not significantly different when judged by the proportion of area planted to MV by each group. Even after 7 years only 9% of the area was under MV in *kharif* and 44% in *rabi*. The district picture is not much different —farmers with 4 ha and above retain their advantage compared with the rest in both seasons. Size exercises its influence on adoption; its influence is more prominent on the owner group than on the tenant group (Table 3).

Input use by size and tenure. Chemical fertilizers and pesticides are crucial to the success of the high-yielding-variety program.

The use of nitrogen fertilizer was widespread in the area even before the introduction of MV. More than 60% reported that they used nitrogen prior to 1965–66 and that it was common on all farms even on TV. The use of phosphatic fertilizers was not as universal and was much less common during *kharif* on TV than during *rabi* on TV. More MV growers than TV growers used phosphatic fertilizers. Use of potassium fertilizers was uncommon.

Size and tenure had no influence on the proportion using nitrogen. A slightly lower proportion of tenants applied phosphatic and potassium fertilizers.

Table 3. Percent MV area to total cultivated areas within each group by size and tenure, Pedapulleru, India, 1971/72

	MV area (%)					
	Kharif			Rabi		
Tenure	Below 4 ha	4 ha and above	All farms	Below 4 ha	4 ha and above	All farms
Owners	2	10	9	33	51	48
Pure tenants	3	18	9	28	25	27
All farms	2	11	9	30	48	44

The influence of environment on the level of nitrogen applied is seen on both TV and MV. The level of nitrogen on TV was 79 kg/ha in *rabi*, compared with 37 kg/ha in *kharif*; on MV it was 120 kg N/ha in *rabi* and 64 kg in *kharif*. Use of nitrogen did not show any consistent relationship with size. In all groups the level was close to, or even higher than, the recommended level.

Use of phosphatic fertilizer also showed a significant variation between seasons, being much higher in *rabi* than in *kharif*. The smaller groups recorded levels lower than those of the others. The level of potassium use was very low on all farms, and small farmers used much less than the others.

In conclusion, while the influence of environment on the level of fertilizer use is obvious, one can see that small farmers used less of those inputs that are not yet popular.

A similar picture emerges when the data are classified by tenure. Use of nitrogen was not lower on tenant farms than on others. In the use of potash, the tenants lagged behind others, again confirming that even within the same environment, lags could be expected, depending upon size and tenure, even after years of technological progress.

The increases in the use of pesticides have been more spectacular since the introduction of high yielding varieties. Only one-eight of the current cultivators reported use of pesticides before 1965/66 in *kharif*, but more than 40% used them in *rabi* even before 1965/66. Since then, pesticide use has become almost universal, bordering on 100% in *rabi* for both the TV and the MV crop. Pesticides are less essential for the *kharif* traditional crop, and only 19% of the total cultivators used them. For the *kharif* MV crop 77% used pesticides. In *rabi* the smaller farms and the tenants used less, both on high yielding and traditional varieties. The pattern is consistent. The more recent input is used with a lag, and in smaller quantities, by tenants and small farmers.

Variations in the use of inputs between size and tenure groups are, of course, less significant within a season than between seasons. While this fact is well taken, the policy inference that land reform *per se* is more important than irrigation, extension system, etc., does not automatically follow.

The new technology which helped to give a boost to yield (Table 4) places the person with more investible surplus at an advantage. In addition, the relative advantage of the small man who has more labor has been considerably reduced in the context of new technology. The inverse relationship between yields and size observed in the farm data of the pretechnology era, and which provoked a lively controversy in academic circles, was not found in any pronounced manner, even in respect to TV in this sample. The opposite conclusion also cannot be firmly established. In *rabi* MV with a fair representation of all groups, big farmers showed a trace of superiority over others in yields. The differences in the yields between tenure groups were not obvious.

The big farmers led in using the new technology, were ahead of others in terms of rates of adoption, and used a greater proportion of the package of inputs. It might then be inferred that the rapid progress of technology could be

Table 4. Yields by season of MV and traditional crops, Pedapulleru, India, 1971/72

Item	Khanf		Rabi	
	Yield (t/ha)	Values (Rs/ha)[a]	Yield (t/ha)	Values (Rs/ha)[a]
MV	4.1	2633	6.4	3293
Traditional	3.1	1865	3.9	2019
Difference	1.0	768	2.5	1274
Difference as a percentage over traditional	32%	41%	83%	63%

[a]US$ 1.00 = Rupees (Rs) 11.00

fostered by concentrating on the big farmers. That, however, would be hazardous leap from partial facts to dangerous policy, since welfare implications of new technology could be neglected only at a great social cost.

ECONOMIC AND SOCIAL EFFECTS OF NEW TECHNOLOGY

Changes in agrarian structure. In considering economic and social effects, a study of changes in the agrarian structure of the economy should be given priority, since the distribution of ownership and control over land profoundly influence the distribution of income. The present position of the villages is compared with the position on the eve of the introduction of new technology. There are inherent limitations in the method. First, the analysis is confined to the current residents of the village and does not cover those who left the village for better or for worse. Second, it is difficult to separate the influence of technology from that of other factors. But these limitations did not prove serious for the area under consideration. Emigration and immigration were negligible during the period of the study. This is a rice village exclusively, and the major change since 1965/66 is the introduction of MV.

We start with an analysis of changes in the structure of rural economy, the rural residents being treated only under two categories, cultivators and noncultivators. The latter group includes all those who did not report possession of land. All the residents in the village were classified by their attachment to the land in 1964/65 and 1971/72. Judging the rural economy in this manner reveals a remarkable stability during the 7-year period. Proportions in the two categories showed only negligible changes, although movements from one group to another were in evidence. The movement was confined by and large to the tenant group. Some tenants became landless laborers and a similar number of landless laborers became tenants. These movements indicate the flux behind an apparent stability.

There was no recorded tenurial change among 160 or 171 cultivators between 1964/65 and 1971/72. Only one tenant became an owner. This shows that within the specific socio-economic environment under examination, upward movement of tenants into the owner group is hardly possible.

The proportion affected by changes in area operated is far more significant. Around 40% of the cultivators reported changes in size; the number reporting upward movement was the same as the reporting downward movement. The downward movements were concentrated in the bottom and top groups. The picture became much clearer when cultivators reporting changes in size were identified by tenure groups. The majority of those reporting changes in size were tenants. One concludes that behind the apparent stability there is considerable flux caused mainly by shifts in area under tenancy, suggesting insecurity of tenure.

The stability in the distribution of ownership of land is seen in the number of sale and purchase transactions as well as in the area involved in these transactions over the 7-year period. There were only 8 buyers and 12 sellers. The area reported purchased was only 10 ha and more than half of it was bought by members of the group cultivating 6 ha and more. The sale recorded by small cultivators was also insignificant. Compared with the small, the big farmers had more sales. But purchase transactions showed little evidence of gains by small owners, even though threats of very low government-imposed ceilings in hectarage had existed for some time. Thus, past trends do not show that the operation of the land market will ensure a shift of land ownership even gradually to the small cultivators at any significant rate. At best, threats of a very low land ceiling had the effect of freezing the distribution of landed wealth at the pretechnology position.

Does the lease market at least facilitate a shift of control over land to small cultivators? It does, if the big owners are found to lease out, and the resulting distribution of operated area is much less uneven than is the distribution of owned area. The majority of the big owners do operate their lands, and pure *rentiers* are much more common among the small owners than among the big. Only a minority of the big owners lease out, and only in part. Although the lease market enables the landless to gain control over land, its effect on a wider diffusion of land among rural residents is not significant. The cultivators among the rural residents form a minority, 42%, and the substantial majority among the rest are landless laborers.

In understanding the agrarian structure of an Indian village, caste, which may be less important in other situations, must be considered. Ownership and control of land by a caste group that does not intermarry with members of other caste groups, even within the same economic stratum, superimpose an economic inequality over social inequality, and make inequality more intolerable. For this reason, diffusion of control over land between different caste groups becomes relevant. The "dominant" caste in the village is Kshatriya, since it controls a substantial proportion of village land.[10] When the size of the leased-in area is identified by the caste of the tenant, the bigger tenants are found to be drawn more from the Kshatriya community than from other

[10] For an exposition of the concept of "dominant caste," see M. N. Srinivas, "The Social System of a Mysore Village," in M. Marriott (ed.), *Village India; Studies in the Little Community* (The Univ. of Chicago Press, 1955), p. 1–35.

groups. There is some diffusion of land to others, but on a limited scale.

The analysis of leased-in area by extent of owned area is also revealing. Pure tenants formed the majority[11] (63 out of 98) and accounted for 17% of the leased-in area against 11% of the owner-*cum*-tenants. The owner-*cum*-tenants were found to be a mixed bag drawn from both small and big owners. To the small owners, leasing-in provided an opportunity to make their holdings viable. The character of tenancy of big owners is of a different type. The leased-in area they reported belonged to their kith and kin who live in other places, and in some cases the tenanted land was area given as dowry to daughters. To this extent, the lease market did not help diffusion of control over land among wider groups. In conclusion, while there is evidence of control over land being shared with non-owning groups, its effect of bringing about a better diffusion of control over land is limited.

Changes in rental market. Diffusion of control over land might help the poor in a land-scarce economy. But the benefits of diffusion depend upon the price paid for gaining control. A study of rent, therefore, becomes relevant. Two types of rental payments are in practice in the village — share rents and rents fixed in kind. Rental systems vary between the *kharif* and *rabi* seasons. For TV, the most common practice in *kharif* is payment of a fixed contracted amount of produce in kind, and in *rabi* a contracted share of the gross produce.[12] When the rent is fixed in kind, all the cultivation expenses except land revenue are borne by the tenant. When it is paid as a share of gross produce, only costs of fertilizer and pesticides are borne by the landowner, proportionate to his share in the gross produce. Since 1965/66 there has been a slight swing towards share tenancy even in respect to TV in *kharif*. In *rabi* it was always a share of produce, and it continues to be so. The major change is now in the level of the share paid to the landowner when MV are grown. When TV are grown, two-thirds of the produce is given to the landowner only in a minority of cases. But if the tenant chooses to grow MV, the landlord is given two-thirds of the share in a majority of cases.[13] Thus with increasing production, potential rents

[11] This is in contrast with some findings based on sample studies, which show that the proportion of pure tenants and extent of area under pure tenancy are small. Pure tenancy is in a much more disguised form and possibly does not get reported in sample studies. See Dharm Narian and P. C. Joshi, "Magnitude of Agricultural Tenancy," *Economic and Political Weekly*, Vol. 4, No. 38 (Sept. 27, 1969), pp. A139–A142.

[12] These differences between *kharif* and *rabi* with regard to system of rent payment need explanation. The crop in *kharif* is subject to less environmental risk. The crop in *rabi* is of shorter duration than in *kharif*, involves more cash costs, and is subject to water uncertainty. Therefore, while fixed rent is common in *kharif*, share rent has become universal in *rabi*.

[13] Francine Frankel's account of other areas in the district conform to this. See Francine Frankel, *op. cit.*, p. 64. Commenting on C. H. Hanumantha Rao's thesis that "crop sharing arrangements are extensive under relative economic certainty and fixed contractual payments where the degree of uncertainty is high," Bhagavathi and Chakravarty write that "Rao's thesis would lead to a further refutable hypothesis that as technological possibilities for application of new inputs, such as better seeds and fertilizers, are introduced, sharecropping would give way to other forms of tenurial relationships. With the introduction of these new techniques in India during the last few years, such an empirical test should be feasible." See Bhagavathi and Chakravarty, *India Economic Analysis*.

Facts do not support Rao's contention. There is a shift toward share tenancy, entrepreneurial functions being shifted to the landowner.

For an evaluation of Land Reform Legislation in Andhra Pradesh, see G. Parthasarathy and B. Prasad Rao, *Implementation of Land Reforms in Andhra Pradesh*, (Scientific Book Agency, Calcutta, 1969). See also G. Parthasarathy and K. S. Raju, "Andhra Pradesh (Andhra Area) Tenancy (Amendment) Act, 1970: A Critical Review," *Economic and Political Weekly*, Vol. 6, No. 13 (March 27, 1971), pp. A45–A47.

are revised upward, and the rental market does not automatically ensure the benefits of technology to the tenant. Decision making also shifts more and more to the landlord. He decides on the variety to be grown, supplies a major part of the capital for nontraditional inputs, and provides the finances to the tenant. The tenant becomes indistinguishable from a permanent farm servant, and the tenancy system is nothing but a convenient arrangement under which a big owner who leases out in part relieves himself of the burdens of labor management while performing the major entrepreneurial functions. The new role played by the landowner is in a very large measure attributable to changes in technology, and this provides an explanation for the observed similarity in the level of inputs as well as in yields between owner and tenant groups.

Rents paid per hectare were studied for each season and within each season for TV and MV separately. Rents paid for MV in *rabi* were more than double the rents paid for the TV. Even in *kharif* rents paid for MV were higher. The rent paid with share rents was found to exceed that for fixed in kind. If allowance is made for the expenses shared between landowner and tenant, the landlord's gain in total produce under the two arrangements is similar. For local varieties in *rabi*, pure tenants averaged a yield of 2.7 t/ha and a rent of 1.4 t. For MV the yield was 5.7 t/ha and the rent was 3.7 t. By making the shift, the tenant produced 3 t/ha more and paid 2.3 t in rent, thus gaining 0.7 t. Even after making allowances for additional cash costs, the tenant is a gainer. But if relative shares are examined, more than three-fourths of the additional produce goes to the landowner, and only one-fourth to the tenant, making the relative distribution of income much more uneven.

Credit market. The lease market cannot be expected to operate in favor of tenants in a land-scarce, labor-surplus economy. But we could expect the institutional credit agencies, set up mainly to promote the interest of the weaker sections, to act in their favor. The village has a cooperative credit society, which by business standards is functioning well. The volume of its business has increased considerably since 1965/66. Credit reportedly received from institutions was studied by size and tenure. What comes out prominently is that the big farmers had more than their share of institutional credit, considering total number of cultivators and area. The pure tenants, who accounted for 34% of the cultivators and 17% of the area operated, got almost nothing from institutional sources. Among the owner groups the owner-cum-*rentiers* whose average size of holdings was much more than that of others got far more credit than their proportion of the total area seems to warrant.

The results should not be surprising. Power within the cooperatives is wielded by the dominant caste group, and in it, the big-farmer group. The power within the *panchayat* is also wielded by the same group. The argument runs that it is risky for the institutions to lend to tenants who can offer no security. The landowner could obtain the loan and pass it on to his tenant. The small owner is not considered a good credit risk.[14]

Credit was used by 59% of the MV *kharif* growers, 78% of the *kharif* TV

growers, 21% of the MV *rabi* growers, and 56% of the TV *rabi* growers. The corresponding proportion of growers reporting credit from institutional sources was 46, 24, 35, and 9%, respectively. The role of institutions was much less significant in *rabi* than in *kharif*, and less significant for TV than for MV. It is obvious that institutions continue to account only for a minor proportion of the credit requirements of cultivators. The share of MV growers by size and tenure shows a general bias in favor of the big farmers.

It should not be inferred that tenants and small owners are deprived of credit. Some tenants are apparently provided interest-free loans by the *renters*. Others get credit, but at a cost generally double the rates of institutional credit, while the big farmers obtain the cheap credit supplied by institutions. Credit institutions weaken the bargaining position of tenants vis-a-vis the owners in the rental markets. The higher cost of loan capital reduced the small owners' profit from the new technology.

Product market. The product market apparently shows no discrimination against the tenant and small cultivator. Prices of paddy received are examined by size groups, and by tenure groups for three time periods of sales: 1) immediately after harvest, 2) approximately a month after harvest, and 3) more than a month after harvest. Within each time period, prices did not vary significantly among either size or tenure groups. But when the weighted price received was examined by size and tenure, one could see that the pure tenant, who sold immediately after harvest, received a lower average price. No significant difference was noted between the small and the big farms, indicating that the proportion of sales by time period did not differ by size. A word of caution, however, is necessary. The investigation was conducted in the month of July 1972, 7 months after the *kharif* traditional crop was harvested and 2 to 3 months after the *rabi* traditional crop was harvested. The big farmers still had large stocks of *kharif* traditional crop on hand, which they would sell when the price is high just before the next *kharif* harvest. When supplies fall short of demand, with a guaranteed minimum price operative, marketing is not found to be a constraint even with respect to small farmers and tenants, though the differential with respect to TV and MV continues. The weighted price of MV *rabi* paddy was Rs 61(11 Rs = US $1.00) per (100 kg) while that of TV was Rs 68. But in *kharif*, with the shift from IR8 — a coarse variety considered inferior to the TV Akkullu — to Mahsuri, a finer variety, price differential was not only reduced but MV prices were found to be higher than those for TV. This gave a boost to the shift from Akkullu to Mahsuri (see footnote 8).

Input market. In the input markets in which scarcities occurred, the small farmer and the tenant experienced greater difficulties. A higher proportion of small farmers and tenants reported fertilizers, pests and diseases, and tractor service as constraints (Table 5, 6).

[8] The analysis of Muthiah based on the data of Agro-Economic Centres for several districts shows similar results. C. Muthiah, "The Green Revolution — Participation by Small versus Large Farmers," *Indian Journal of Agricultural Economics*, Vol. 26, No. 1 (Jan.-Mar. 1971), p. 62.

Table 5. Percentage of cultivators to total in the group reporting various inputs as constraints to growth, by size group, Pedapulleru, India, 1971/72.

Constraint	Cultivators (%) with						
	Less than 1 ha	1-1.9 ha	2-2.9 ha	3-3.9 ha	4-5.9 ha	6 ha or more	All farms
				Kharif			
Fertilizer availability	100	100	—	100	67	33	50
Credit	0	50	—	0	33	0	9
Pests and diseases	100	50	—	100	67	93	86
Tractor service	100	50	—	0	67	13	27
				Rabi MV			
Fertilizer availability	60	92	60	43	71	26	50
Credit	60	15	20	0	43	10	18
Pests and diseases	100	100	100	100	100	97	99
Tractor service	60	77	20	71	43	23	43

In brief, the rental market, the market for loanable funds, and the product and input markets could not be expected to work in favor of the small farmer and the tenant. In a rural structure marked by inequalities, all these tend to discriminate against the small farmer and the tenant. Since the new technology can be used more advantageously by those with more investable surplus, it contributes to a sharpening of the existing inequalities even though in absolute terms some benefits go to small farmers and tenants. Because the resource markets work to the advantage of those already wealthy, the entire burden of providing relief from the growing inequality is placed on the labor market.

Labor market. The new technology could mitigate the adverse effects of agrarian structure through the labor market by enabling the laborers to earn a higher real wage and to get more employment.[15]

We do not have time-series of wages for the village. We used the district-level time-series of wages of agricultural labor published by the State government. The index of money wage for males showed a rise from 100 to 115 between 1958/59 and 1964/65, the index of rural retail prices showed a rise from 100 to 130, indicating a fall in real wages during that period. The index of money wages rose from 115 in 1964/65 to 184 in 1968/69, while the index of retail prices rose to 183. The period after 1964/65 was better than the period 1958/59 to 1964/65, although over the period as a whole, the real wages of laborers remained constant.[16] Since 1968/69 there has been a further spurt in

[15] Ch. Hanumantha Rao examined the impact of the Green Revolution on labor's share in output and concluded that "the experience in the IADP districts and with IR8 rice in West Godavari does suggest that the relative share of labour may decline as a result of green revolution." See C. Hanumantha Rao, "Green Revolution and the Labour's share in output," *Agricultural Situation in India*, Vol. 26, No. 5 (August 9, 1971), p. 284.

[16] G. Parthasarathy and G. Dasaradharma Rao, "*Employment and Unemployment of Rural Labour Households*," 1972, (mimeographed).

Table 6. Percentage of cultivators to total in the group reporting various inputs as constraints to growth, by tenure, Pedapullieru, India, 1971/72

Constraints	Cultivators (%)				
	Owner	Owner-cum-rentier	Tenant	Owner-cum-tenant	All farms
			Kharif MV		
Fertilizer availability	50	—	100	40	50
Credit	—	—	25	20	9
Pests and diseases	80	67	100	100	86
Tractor service	20	33	25	40	27
			Rabi		
Fertilizer availability	37	—	100	45	50
Credit	7	—	7	45	18
Pests and diseases	100	100	100	95	99
Tractor service	44	17	60	35	43

the prices of wage goods, and cash wages have shown an increase. While most labor households as well as cultivator households in the village reported no change in cash wages, a few reported an increase in wages and employment for a few operations (Table 7).

In situations where there is a labor surplus, the pressure on the labor market induced by new technology could be seen only in the level of employment, but not in real wages. It is to this we must turn to discover any beneficial impact of technology. Increased employment could be achieved as a consequence of new technology in two ways: the new technology may increase the intensity of cropping since it shortens the duration of the crop period, and labor require-

Table 7. Sample of 15 labor households[a] reporting changes in real wages and employment for males, Pedapullieru, India, 1964/65 and 1971/72

Operation	Labor households					
	Increase		Decrease		No change	
	Wages	Employment	Wages	Employment	Wages	Employment
Preparing nurseries	0	0	1	0	14	15
Puddling	0	0	6	13	9	2
Transplanting	0	0	2	2	13	13
Weeding	0	5	13	0	2	10
Fertilizer application	11	5	1	0	3	0
Pesticide application	14	15	1	0	0	0
Harvesting	6	10	1	0	8	5
Bundling	3	1	1	0	11	14
Threshing	7	0	2	0	6	15
Transportation	3	0	6	0	6	15
Others	3	0	1	0	11	15
Other than agriculture	3	0	1	0	11	15

[a]Drawn on a random basis from all landless labor households in the village.

ments for each crop might increase as a consequence of the shift to MV. The first result is not automatic, but depends upon the availability of water. In the village under examination, water is regulated by the public canal system and is beyond the farmers' control. By tapping groundwater resources, a second crop could be grown even when canal water is not supplied, but in this village no such attempt has been made even by the big farmers. Hence, increased employment is possible only with the second effect — increased labor requirements. We have not collected quantitative data relating to this, but we could envision the situation from the survey data.[17]

Human labor input: man-days/ha 1968/69, both family and hired — West Godavari District

	Participant local	Participant MV
kharif	136	164
rabi	191	220

Labor inputs were more for high yielding varieties — 20% more in *kharif*, and around 16% in *rabi*. But the impact of this rise on overall employment level depends upon the extent of the increase in MV area. Only 23% of the area in *kharif* and *rabi* together has shifted to MV, and benefits of employment via changes in technology are confined to this fraction of the area. No more than 4% increase in overall employment could be attributed to a shift to MV.

Will the beneficial effects of shift to MV continue in the absence of an increase in intensity of cropping? The answer depends upon the nature of the technology. There are eight four-wheeled tractors in the village; seven of them were introduced before 1964/65. Threshing and puddling by tractor were quite common even on small farms before 1965/66. In 1971/72 tractors were almost universally used for those two operations. Less than half of the farmers maintain plow cattle. Tractors are used for transportation. They have affected the number of permanent farm servants. Their adverse effect on casual labor is reported to be only marginal, but one cannot be too sure. Due to the absence of a network of effective repair service, big farmers continue to maintain plow cattle and rely on labor power. But when an effective repair service is built up, adverse effects are bound to be felt by labor unless intensity of cropping or a shift to labor-intensive crops accompanies the use of tractors.

Qualitative data relating to changes in profit from rice cultivation and changes in level of living confirm that the proportion of households reporting increases in profits from rice cultivation is greater among big cultivators and owners (Table 8, 9). The evidence in this village suggests that given an unequal distribution of land, the new technology sharpens inequalities and makes

[17] For details of cost structure based on this survey, see G. Parthasarathy and D. S. Prasad, "Season-Wise Progress of High Yielding Varieties in Andhra Pradesh, Role of Economic Variable", *Economic and Political Weekly*, Vol. 6, No. 39 (Sept. 25, 1971), pp. A117-A122.

Table 8. Percentage of cultivators reporting increase in profits from rice, by size of farms, Pedapulleru, India, 1965/66 to 1971/72.

Item	Cultivators (%)						
	Less than 1 ha	1-1.9 ha	2-2.9 ha	3-3.9 ha	4-5.9 ha	6 ha or more	Overall
Profits from rice	21	14	14	36	35	70	32
Level of living	14	5	5	27	25	39	18

Table 9. Percentage of cultivators reporting increase in profits from rice, by tenure, Pedapulleru, India, 1965/66 to 1971/72.

Item	Cultivators (%)			
	Owner	Owner-*cum*-rentier	Tenant	Owner-*cum*-tenant
Profits from rice	37	36	10	63
Level of living	16	9	14	34

relative distribution of income much worse, since more than 70% of the value per hectare that it added went to owners of land, while wage earners got less than 10% (Table 10).

SUMMARY AND CONCLUSIONS

Analysis of responses by size and tenure led to the following conclusions:

1. Differences in response between seasons persist and are more significant than differences by size and tenure. The association between size and adoption

Table 10. Distribution of excess gross value as a result of shift to MV, Pedapulleru, India, 1971/72.

Item	Kharif		Rabi	
	Amount (Rs)[a]	Percentage	Amount (Rs)[a]	Percentage
Excess gross value per hectare	768		1274	
Due to				
Fertilizer	87	11	146	11
Pesticides	25	3	47	4
Wages[b]	84	11	87	7
Interest on credit taken at 10%	24	3	10	1
Subtotal	220	29	290	23
Residual due to land ownership and management	548	71	984	77

[a]US$1.00 = Rupees (Rs) 11.00. [b]Computed from survey data available at the Agro-Economic Centre, since quantitative data are not available from our survey.

of new technology is not significant at levels below 4 ha. Nor is any significant association observed between adoption of MV and ownership.

2. The most striking result of the observations is the significant association between size and MV adoption in both wet and dry seasons when the data are analyzed by classifying cultivators into groups farming less than 4 ha and those farming more than 4 ha. This implies a stronger response to new technology by farmers with adequate investable surplus.

3. The inverse relationship between size and productivity found in farm management studies of the pretechnology period is not apparent, implying that with the growing importance of nontraditional inputs the small farmer has lost his traditional advantage. But no firm positive relationship is apparent.

The study of social and economic impact of new technology revealed the following:

1. There is no evidence of either reduced or increased concentration of land ownership. The technology helped to tighten the grip of the big farmer on rural economy.

2. The lease market, rental market, credit market, and input market do not operate in the interest of the poorer sectors. Although there is no firm evidence of deterioration in the living standards of small farmers, small tenants, and labor, the relative distribution of incomes appears to have worsened.

3. The effect of technology is more on employment than on real wages. But a big-farm economy tends to foster capital-intensive technology and that might nullify the employment effects. The new technology is not followed by an increase in intensity of cropping and, therefore, beneficial effects on employment are limited.

APPENDIX A. **Distribution of cultivars by size and tenure, Pedapulleru, India, 1971/72.**[a]

Size (ha)	Cultivars (no.)				
	Owner	Owner *cum*-*rentier*	Tenant	Owner-*cum*-tenant	Total
		Kharif season			
Less than 1	20 (1)	1	7	1	29 (1)
1 – 1.9	16 (1)	—	22 (1)	2	40 (2)
2 – 2.9	8	2	18	8	36
3 – 3.9	5	—	3 (1)	3	11 (1)
4 – 5.9	6 (1)	2	5 (1)	7 (1)	20 (3)
6 or more	21 (7)	6 (3)	5 (1)	14 (4)	46 (15)
Total	76 (10)	11 (3)	60 (4)	35 (5)	182 (22)
		Rabi season			
Less than 1	17 (41)	1	5	1 (1)	24 (5)
1 – 1.9	10 (5)	—	19 (7)	2 (1)	31 (13)
2 – 2.9	4	—	11 (2)	8 (3)	23 (5)
3 – 3.9	5 (3)	—	3 (3)	3 (1)	11 (7)
4 – 5.9	4	2 (1)	5 (2)	7 (4)	18 (7)
6 or more	21 (15)	6 (5)	5 (1)	12 (10)	44 (31)
Total	61 (27)	9 (6)	48 (15)	33 (20)	151 (68)

[a]Figures in parentheses indicate growers of high yielding varieties.

APPENDIX B. **Distribution of area by size and tenure, Pedapulleru, India, 1971/72.**[a]

Size group	Area (ha)				
	Owner	Owner-*cum*-*rentier*	Tenant	Owner-*cum*-tenant	Total
		Kharif season			
A	10 (1)	nil	4	1	15 (1)
B	22 (1)	—	31 (2)	4	56 (2)
C	19	4	42	20	86
D	17	—	10 (1)	10	37 (1)
E	29 (3)	9	23 (4)	34 (1)	94 (8)
F	291 (41)	91 (11)	33 (6)	167 (6)	582 (64)
Total	389 (46)	104 (11)	142 (13)	235 (7)	870 (76)
		Rabi season			
A	8 (3)	nil	2	1 (nil)	12 (3)
B	12 (5)	—	26 (8)	4 (2)	41 (14)
C	9	—	26 (3)	14 (4)	48 (8)
D	10 (6)	—	7 (6)	10 (3)	27 (14)
E	17	9 (2)	21 (5)	22 (4)	68 (12)
F	196 (103)	71 (54)	24 (6)	87 (41)	379 (204)
Total	252 (116)	80 (57)	106 (28)	137 (55)	575 (255)

[a]Figures in parentheses indicate area in high yielding varieties.

The relation of farm size to production, land tenure, marketing, and social structure - Central Java, Indonesia

WIDYA UTAMI and JOHN IHALAUW

Extreme population pressures are leading to a number of social changes within the Central Java villages, enabling landowners and village leaders to consolidate their positions at the expense of the tenants and landless laborers. A large and increasing number of families in the three villages surveyed own no rice fields. Among the owners, the size of farm is on the average less than 0.6 ha. The handful of village officials and villagers granted land by the *kasunanan* (principality) have holdings two or three times as large as those of nonofficials, and their land tends to have the best fertility and irrigation. Since there is no possibility of increasing the size of holdings, cropping intensity is being increased through the *petukan* system (five crops of rice in 2 years). The *mrapat* rental system, which virtually relegates the tenant to the status of a laborer, is widely employed. The *tebasan* system of harvest has become popular among owners because it provides them with a larger share of the harvest.

THE REGENCY OF KLATEN (*Kabupaten* Klaten) is one of the areas in Central Java in which the government has extensively applied the new rice technology. That has been done through the *Bimas* program, carried out either by the government alone or as a joint venture by the governments of Indonesia and West Germany.

As in the whole of Java, a primary feature of Klaten is small farm size. Although farm size is a restriction on development, application of the new rice technology still holds promise.

This article is intended to describe the pattern of land ownership and the size of farms in Klaten, especially in the three villages of Nganjat, Kahuman, and

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Pluneng. An attempt will be made to relate farm size to production, land tenure, marketing, and social relationships where the new rice technology has been widely applied by farmers.

LANDOWNERSHIP

Size of landholdings and categories of landownership. To understand the situation and problems of Klaten, consideration should be given to the pattern of landownership. The overall land use in the villages sampled is worth noting first (Table 1).

The primary form of agriculture is rice cultivation. Because irrigation water is available throughout the year, the rice fields play an important role as the main source of income in the villages.

The landownership pattern is fairly complex (Table 2). Distinction must be made among the ownerships of rice field and home lot together, home lot only, rice field only, house on another's land, neither land nor house, and rice field given by the *kasunanan*.[1]

Table 2 shows that in each sample village, the people who own rice fields are outnumbered by nonowners. In Nganjat 136 persons are owners; in Kahuman, 285; and in Pluneng, 160. Those who own no rice field number 174 in Nganjat, 363 in Kahuman, and 353 in Pluneng. If the population growth rate in these

Table 1. Land use in selected villages in Central Java, Indonesia, 1971/72.

Village	Use of land (ha)				
	Rice field	Dry field	Home lot	Others	Total
Nganjat	64.4	0.3	8.3	1.9	74.9
Kahuman	167.0	0.8	22.7	4.5	195.0
Pluneng	99.2	0.1	24.4	0.2	123.9

Table 2. Distribution of land ownership in selected villages in Central Java, Indonesia, 1971/72.

Village	Persons owning (no.)					
	Rice fields and home lot	Home lot only	Rice field only	House on another's land	No land or house	Rice field granted by *kasunanan*
Nganjat	129	51	7	49	74	0
Kahuman	231	145	54	218	0	4
Pluneng	150	133	10	115	105	0

Tani kentjeng are villagers who own both rice fields and home lots; *tani gundul* are villagers who own rice fields; *tani setengah kentjeng* are those who own only home lots; and *pengindung* are those who own houses built on another's land. *Penumpang* are those within the village who own neither land nor house and live with others. *Tani pituwas* are villagers who cultivate rice fields that have been given to them by the kingdom and cannot be inherited.

Table 3. Ownership of rice fields (ha) in selected villages in Central Java, Indonesia, 1971/72.

Village	Village treasury	Village officials' salaries	Given by *kasunanan*	Owned by common villagers	Total (ha)
Nganjat	2.5	8.6	2.6	50.7	64.4
Kahuman	23.7	10.1	3.4	129.8	167.0
Pluneng	3.8	9.2	0.0	80.2	93.2

Table 4. Average size of rice field owned by common villagers (persons owning rice fields and home lot, and rice fields only), by village officials, and by villagers who obtained land from the *kasunanan*, Central Java, Indonesia, 1971/72.

Village	Average size of rice field (ha)		
	Common villagers	Village officials	Villagers who obtained land from the principality
Nganjat	0.4	1.2	0
Kahuman	0.5	1.3	0.9
Pluneng	0.5	1.3	0

villages is also considered, the picture will be clearer. In Nganjat the rate is 2.4% and in Kahuman, 2.2%. In Pluneng no reliable data can be obtained. With such a rapid growth in population there is an increasing tendency toward landlessness; thus the dependence of the landless on their landowners is increased.

Here another aspect should be considered. In terms of rice field ownership, the situation in the sample villages is shown in Table 3.

Tables 2 and 3 indicate that in Nganjat only 136 persons have their own rice fields (50.7 ha); in Kahuman 285 persons own 129.8 ha; and in Pluneng 160 persons own 80.2 ha. The average size of owned rice fields is 0.4 ha in Nganjat, 0.5 ha in Kahuman, and 0.5 in Pluneng (Table 4).

Beside rice fields owned by common villagers there are also rice fields owned by the village from which money to finance collective activities can be earned. There are also rice fields given by the *kasunanan* (principality). In Kahuman four persons cultivate 3.4 ha, or an average of 0.9 each. In Nganjat, 2.6 ha of this type of rice field is used by the village because the holder cannot be found. This particular type of rice field cannot be inherited.

Finally there are plots of village rice fields granted to the village officials in lieu of salaries. In Nganjat, 8.6 ha of village rice fields was given to seven village officials; in Kahuman, 10.1 ha was given to eight; and in Pluneng, 9.2 ha was given to seven.

A clear comparison can be made between the size of rice fields owned by common farmers (both owners of rice field and home lot, and of rice field only) and that operated by the village officials and holders of rice fields given by the *kasunanan* (Table 4).

Table 5. Average size of rice fields owned by common villagers and sample farmers, and average size of rice fields operated by sample farmers in Central Java, Indonesia, 1971/72

Village	Size of rice fields (ha)		
	Owned by common villagers	Owned by sample farmers	Operated by sample farmers
Nganjat	0.4	0.4	0.5
Kahuman	0.5	0.5	0.6
Pluneng	0.5	0.5	0.5

To summarize and further explain the data in Table 4:

1. The average size of rice fields granted to the village officials is between two and three times the size of that owned by common villagers (both owners of rice field and home lot together, and of rice field only).
2. In Kahuman the average size of rice fields granted by the principality is more than one-and-a-half times that owned by the common villagers.
3. Plots of rice fields given to the village officials are usually the best in fertility and irrigation.
4. The rice fields owned by common villagers in Nganjat consist of three plots in three different blocks; in Kahuman and Pluneng, two plots in two different blocks.

The greater size of rice fields owned by village officials and by holders of plots given by the *kasunanan* gives them advantages, which will be elaborated on later.

Farm size. Data on farm size were collected from the village farmers who had been planting modern varieties (MV) since 1968, when MV were introduced. The samples were constructed so that households could be classified according to various forms of tenure, i.e. owner, sharecropper, lessee, combination of sharecropper and lessee, and farm laborer. The samples numbered 60 in Nganjat and Kahuman, and 66 in Pluneng. The sample data are compared with data from the entire village (Table 5).

It is obvious that farm size in the villages sampled is permanently restricted to around 0.5 ha. The application of new rice technology is promising, but since farm size is restricted it is interesting to see what is happening in practice.

CONSEQUENCES OF FARM SIZE

We have shown that in the Regency of Klaten and especially in the sample villages, farm size is very small. This condition affects production practices, land-tenure systems, marketing practices, and positions of the village officials within the villages. A discussion of the impact of farm size on each of those areas follows.

Production practices. As a consequence of small farm size, the farmer gets a limited production even though the average yield per hectare is high (Table 6).

Table 6. Farm size and yield in selected villages in Central Java, Indonesia, 1971/72.

Village	Av. operated farm size (ha)	Av. yield (t/ha) (wet stalked paddy)	Av. yield (t/holding) (wet stalked paddy)
Nganjat	0.5	5.9	2.7
Kahuman	0.6	6.5	3.9
Pluneng	0.5	6.1	3.1

To increase production, two steps can be taken. First, expand the rice area. For farmers as individuals, this can be done through leasing or sharecropping more rice land (compare second and third columns of Table 5). But for the village as a whole, expanding the rice area is impossible (Table 1).

The second way of increasing production is by increasing the yield per hectare. That can be achieved through crop intensification efforts, including the use of MV, chemical fertilizers and pesticides, and improvement of farm practices and of the irrigation system. But because farm size is limited, the possible increase in total production is also limited.

The short growth duration of MV and the availability of irrigation water throughout the year encourage the farmers to try new ways of increasing yield. They have managed to increase the yield not only for each unit of rice area, but also for each unit of time. An effort has been made to increase the cropping intensity by applying the *petukan* system.[2]

Through *petukan*, the farmers use a small part of the rice field as a seedbed for the next rice crop, even before the first crop is harvested. The land is prepared immediately after harvest. The farmer can get five rice crops in 2 years instead of two rice crops per year.

Various systems of land tenure. Before further discussion of land tenure, it is worth noting that on the average 72.6% of the farmers operate their own farms (80% in Nganjat, 66.7% in Kahuman, and 71.2% in Pluneng). The rest are tenants, landless, and farmers who lease or sharecrop in addition to working their own land. The amount of land leased or sharecropped in the sample is relatively small, about 0.1 ha (compare second and third columns, Table 5).

In the three villages, land tenure can be classified into leasing or renting, sharecropping, and another system which is a combination of the two. Leasing between farmers is usually for more than one cropping season. For longer periods, the rental for each cropping season is lowered, e.g. the price for 10 cropping seasons is less than twice the price for five cropping seasons. In addition, the price also depends on the condition of the land, the relationship between the owner and the tenant, and the urgency of the owner's need for money. The agreement usually provides that the owner will pay the land tax

[2] The *petukan* system is explained more fully in our main report The International Rice Research Institute, *Changes in rice farming in selected areas of Asia* (Los Baños, Philippines, 1975), p. 153.

and obligates the tenant to give a certain amount of paddy to the owner at harvest time. The amount is not seen as a share of the yield; it is given merely to show the tenant's respect for the owner. If the lease is for more than 10 cropping seasons, the agreement must be made before the village chief or the village officials. Some farmers, however, refuse to do so (even though they know that it is for their own security) because that will oblige them to give a certain percentage of the rental price to the village.

Some villages in the Klaten Regency, including Kahuman and Pluneng, have been chosen by the *PNP Tembakau* (The State's Plantation Enterprise in Tobacco) to be planted with tobacco. The order is given through *Pemerintah Daerah* (the local government) to the villages. The area planted with tobacco covers about 50% of the rice area in each village. This means that the farmers have to use about 50% of their operating area for the *PNP Tembakau*. For a period of 7 months, *PNP Tembakau* gives them a rental of US$157 for each hectare.[3]

There are three distinct forms of sharecropping: *maro*, *mertelu*, and *mrapat*:

Maro literally means "to divide into two equal parts." In this system, the tenant bears the cost of all the inputs — seed, fertilizer, and labor cost — and the owner pays the tax. Each gets half of the yield. Actually, the system occurs only under special circumstances, for example between father and son, between brothers, or between the village and the heads of neighborhood councils (*Wanra* or *Ketua* R.K.) who are allowed to cultivate the village rice field as a reward for their service to the village. In the last instance, half of the yield goes to the village and is used for financing village needs (building roads or schools, etc.). In some cases, brothers may inherit a piece of land, but because it is so small, they find that it is not practical to divide it further. They register the land collectively. One of them cultivates the land under the *maro* system; he takes half the yield and the other brothers together get the other half.

Mertelu, which means "to divide into three equal parts," is more common than *maro*. The tenant bears the cost of all the inputs (except the tax) and gets one-third of the harvest. The other two-thirds goes to the owner. The system occurs between common farmers and also in village rice fields cultivated by common farmers.

[3] This rental can be compared with the earnings from rice. To simplify the picture, a 2-year period is used as the basis for the calculation. Looking at the comparison this way, it appears that one harvest of dry-season rice is eliminated due to tobacco planting. For purposes of comparison the data from the village of Kahuman, in which the yield per hectare of the modern variety is 6.5 t wet stalked paddy, are used.

Revenue: 6.5 × $42.17		= $274.11
Cost: — Paid labor	$15.04	
Inputs	27.33	
	42.37	
Unpaid labor:	21.69	
Total		64.06
Farmer's income:		$210.05

The data show that farmers experience a loss of $53.05 due to tobacco planting. The result confirms farmer's complaints — as expressed to us — against the use of their rice fields for tobacco planting.

As the need for more rice land becomes greater, the position of the landowners also becomes stronger. Consequently, the tenure arrangement becomes more beneficial to the owner. This is shown in *mrapat*, "to divide into four equal parts." This system has become the most common in the villages. The tenant provides only labor to cultivate the land, and nonlabor inputs are purchased by the owner. At harvest time, the tenant, who acts more as a contracted farm laborer, gets only one-fourth of the yield.

Another system, *sromo*, is officially forbidden by the agrarian law because it weakens the tenant's position. But because the need for land keeps increasing, the system can still be found in the villages. The tenant has to give a certain amount of money in advance, called *sromo*, to get a right to cultivate the land. The amount of money, which is determined in an agreement, depends on the time of payment and on the inputs to be provided by the tenant. Usually, the tenant's share is half of the yield, but it can be modified according to the arrangement.

To clarify the systems mentioned above, an illustration based on a *patok* (0.12 ha of rice field) planted with Radjalele variety in the village of Nganjat is presented below. From that *patok* it was estimated that 7 quintals (1 quintal = 100 kg) of wet stalked paddy was harvested under the *tebasan* system. It was sold for US$33.73. The cost per *patok* was as follows:

Labor	
Paid	
Unpaid	US$3.46
Seed	2.60
Fertilizer	0.57
Urea	
TSP	1.44
Insecticide	0.36
	0.24
Total	US$8.67

Under the first three systems of sharecropping, the returns vary according to the share of the revenue: one-half, one-third, or one-fourth (Table 7). Under the system of *sromo*, there are variations depending on the agreement related to the inputs and *sromo*. If the inputs are purchased by the tenant, *sromo* is small; but if the owner has to purchase the inputs, *sromo* is high.

A comparison among *maro*, *mertelu*, *mrapat*, and *sromo* shows that under *maro* the tenants get higher incomes (Table 7). This explains why *maro* is limited to relatives. As the number of farm laborers has increased, it is now more common to find *mrapat* in the sample villages. Under this system, the owner employs farm laborers in the cheapest way.

Even though *sromo* gives the tenants higher income than either *mertelu* or *mrapat*, it is rarely practiced in the villages. Since cash is limited among the tenants the *sromo*, which has to be paid in advance, is felt to be a burden. Furthermore, the risk is also greater, especially if the crop fails.

Table 7. Returns to tenants[a] (US$) under various tenancy agreements in Central Java, Indonesia, 1971/72.

Type of tenancy arrangement	Revenue[b] 1	Hired labor 2	Inputs 3	Rental 4	Cost to tenants 5 = (2+3+4)	Tenants cash income 6 = (1−5)	Unpaid labor 7	Tenant's income 8 = (6−7)
Maro (half-shares)	16.87	3.46	2.61	c	6.07	10.80	2.60	8.20
Mertelu (one-third shares)	11.24	3.46	2.61	c	6.07	5.17	2.60	2.57
Mrapat (one-fourth shares)	8.43	3.46	d	c	3.46	4.97	2.60	2.37
Sromo:								
(inputs paid by tenants)	16.87	3.46	2.61	3.61	9.68	7.19	2.60	4.59
(inputs paid by owner)	16.87	3.46	0	6.02	9.48	7.39	2.60	4.79
Leasing	33.73	3.46	2.61	12.04	18.11	15.62	2.60	13.02

[a]US$1.00 = Rupiah 410. [b]Assuming a yield of 7 quintals of wet stalked paddy from one *patok* (0.12 ha), harvested under *tebasan*, and sold for $33.73. [c]Rental is not paid under this arrangement. [d]Inputs are paid by landowner.

To complete the picture, the size of income under a leasing arrangement is worth noting here. Tenants get higher income under leasing than under sharecropping (Table 7). That is why they prefer to leasing *mrapat* if money is available.

Bawon **system and market practice.** As a rice producer, the farmer sells rice, not directly to consumers but through marketing institutions. The contact with farmers is through the middleman (*tengkulak*) who collects paddy, either from the farmer's house or from the rice field. A middleman who specializes in collecting paddy from rice fields is called a *penebas*, and the transaction is known as *tebasan*.[4]

In the sample villages, it seems that the role of the *penebas* is quite important. For example, 51 farmers out of the 60 in Nganjat sold part of their harvest. Of that number, 47 sold it through the *tebasan* system for practical considerations. If this phenomenon is analyzed more deeply, the basic reasons become obvious.

In most villages the people still live in a subsistence economy with strong sociocultural ties. Included among these ties are patterns of reciprocity and patron-client relationships, both of which are shown clearly in the harvesting process. Reciprocity says that the farmer has a right to get help in harvesting his crop; on the other hand, he has an obligation to give a reward in the form of *bawon* (harvester's share) to those who help him.

[4] The *tebasan* transaction was reported around 1905–1910. However, emphasis was not on the *time* the payment was made but on the *selling of standing rice the price of which was based on one bau* (= 0.71 ha). It was recorded at the time that *tebasan* occurred in Central Java, especially in Batang, Tegal, Pemalang, Brebes, Semarang, Salatiga, Kendal, Demak, Pati, Banyumas, Magelang, and Temanggung. The transaction also existed in West and East Java. Readers who want to get more information on it may go through the *Adatrechtbundel II (Java en Madoera)* (Martinus Nijhoff's Gravenhage, 1911), pp. 27–28, 128–130, 154–156. See also John Ihalauw, "Mengkaji Penebas", *Cakrawala Majalah Penelitian Social*, 7 (November-December 1974), pp. 225–242.

The farmer is seen as a patron of relatives and close neighbors. He feels that he is fulfilling his obligation as patron by involving them in the harvesting process. Relatives and close neighbors get more than the common share in the villages.[5]

In the transition from subsistence economy to peasant economy, production becomes more commercial, even though traditional practices and social relationships still exist. Farmers are beginning to realize that reciprocity and patron-client relationships in the harvesting process are a burden. The economic disadvantage they suffer is not worth the social prestige they get. But they cannot simply avoid the system because sociocultural ties still have strength in a peasant economy.

The only way to get rid of the burden is to avoid involvement in the harvesting process itself. In *tebasan* the harvesting process is managed by the *penebas*, who can restrict the number of harvesters and who give equal *bawon* to them, without concern for social relationships. Thus, the farmers look at *tebasan* as a good way out of the *bawon* problem.

An uncontrolled number of harvesters bring further losses to the farmer. Such losses can be classified into:

1. Losses during the harvesting process, including stamp-down loss, dropping loss, and leftover loss;
2. Losses from both stealing and handling during transportation from the rice field to the farmer's house where the *bawon* will be distributed; and
3. Losses during *bawon* distribution. They consist of over-sharing (especially for the relatives and neighbors) and handling losses.

With all the losses, it is calculated that the farmer eventually gets an average of only 57.5% of the total yield. Aware of these facts, the farmers try to find a way to minimize the losses. Restricting the number of harvesters is almost impossible because of sociocultural ties. So, they turn to *tebasan* as a solution.

Aside from those reasons, the farmers also regard *tebasan* as a solution to some other problems. Some years ago, the government established a new policy on rice marketing to protect both the producer and the consumer. The *Bulog* (Logistical Board) was instructed to keep the rice price between floor and ceiling level. But the *Bulog* organization did not reach lower than the Regency (Kabupaten) level. The *Bulog* made contracts with local rice mills, which bought paddy from the farmers and sold the rice to the *Bulog*.

The rice mills applied certain standards to the paddy they bought, among them a requirement that barn-dry paddy should have a moisture content of not more than 14%. This means that farmers have to process the wet stalked paddy into barn-dry paddy, with a risk of price reduction if the rice mills say that the paddy is not dry enough. By selling their crop to the *penebas*, the farmers can avoid the problems in processing and the risk of price reduction.

[5] It is common practice for farmers to give as *bawon* half to one-fourth of the rice harvested by relatives, one-fourth to one-sixth of the rice harvested by close neighbors, and one-tenth of the rice harvested by fellow villagers.

The farmers who sell through *tebasan* can also avoid problems in marketing, transportation, storage, and processing.

Finally, *tebasan* is an easy and quick way to get cash. The farmer's need for cash for land preparation, to buy seed and fertilizer, etc usually becomes greater soon after harvest time. In fact the new technology increases capital needs. Even though the farmers can get production credit for all inputs needed, the regulation requiring repayment within 1 month after harvest makes the need for cash even greater. It is worth noting that the application of the *petukan* system adds to its influence to the need for cash, because in that system the land has to be prepared as soon as the harvest is completed.

In a *tebasan* transaction, the price is determined by both the *penebas* and the farmer, taking into consideration the estimated yield, the market price of rice, and the harvesting cost (in the form of *bawon*) that must be paid by the *penebas*. Considering this mode of price determination and the farmer's lack of knowledge about marketing, some people have assumed that only the *penebas* profits from the transaction.

But as the *penebas* and the farmers live in the same or neighboring villages it is hard to understand how *penebas* could continuously exploit the farmers. To evaluate this hypothesis, an example of a *tebasan* transaction during the dry season of 1971 in Klaten is described.

The market price for barn-dry paddy at the time was US$3.68 per quintal. In a *tebasan* at the same time, the price agreed upon was US$33.73 for 0.16 ha of rice field, and the yield was estimated to be 12 quintals of wet stalked paddy.

Assuming a weight reduction of 20% from wet stalked paddy to barn-dry paddy, we calculated the price, in US dollars, paid by the *penebas* for each quintal of barn-dry paddy as follows:

$$100/80 \times 33.73/12 = 3.51.$$

It is clear that the price paid by the *penebas* was lower than the market price. If the farmer had managed the harvesting process himself (with all obligations and losses), he would have received only 57.5% from 12 quintals of wet stalked paddy. If he had sold the paddy in the form of barn-dry paddy at the current market price, he would have gotten a sum calculated as follows:

$$0.575 \times 12 \times .8 \times 3.68 = 20.31$$

He would have gotten US$20.31 from the market, a sum that still includes the various costs (processing, transportation) he would have had to pay before he could sell his paddy. From the *penebas* he received US$33.73 without having to pay those costs. It is clear now why the farmers do not think that selling paddy through *tebasan* involves a loss.

But *tebasan* naturally has a different effect on the farm laborers, especially those involved in the harvesting process. The *penebas* gives less than the common share, and this share is given equally without concern for established social relationships. The common *bawon* in the village is one-tenth of the yield

(relatives and neighbors get more), but a *penebas* usually gives only one-sixteenth of the yield. Besides, a *penebas* can restrict the number of people who harvest the crop. An example from the Regency of Jepara will help clarify this point.

In one rice field of exactly 0.16 ha, 96 harvesters were observed harvesting. At the same time, about 50 m away, rice in a 0.14-ha field was being harvested by only three harvesters. On the first plot the harvest was managed by the owner; on the second, the crop had been sold to a *penebas* who managed the harvesting process.

The position of village officials. The effect of farm size on the position of village officials will be discussed from the socioeconomic and political point of view.

The socioeconomic position. As mentioned earlier, the size of rice fields granted to village officials is about twice that of the farm operated by common villagers. The village officials thus gain certain socioeconomic advantages. Along with their position as officials, the size of their farms establishes them as patrons. As patrons, they allow their clients (relatives and close neighbors) to take part in the harvesting process. The clients receive the *bawon*. The result of the whole process is that the social position of village officials is strengthened.

The bigger rice fields granted to the village officials also provide them with a greater income. With this greater income, they can enlarge their farms through leasing and sharecropping practices. Their better economic position also transforms the village officials into the main informal sources of credit within the village. This process continues as social and economic position reinforce each other.

The political position. Through the performance of their social functions as patrons and the availability of greater amounts of money, village officials gain support on the political stage. This pattern can easily be traced in the election campaign for village head. Aside from the ideological ties at the village level, the formation of various political factions prior to the election is based on the socioeconomic ties mentioned above earlier.

It is quite clear that the socioeconomic and political positions of the village officials are mutually strengthening. As a result, village officials play an important role within the village. Certainly that has implications for the various programs designed for and implemented at the village level. It can be said that without considering carefully the role of village officials, no program or action within the village can be conducted or implemented.

The problem of fragmentation - Orissa, India

T.K. PAL

Evidence shows that fragmentation results in inefficiency in production. Low yield is significantly associated with distance of the fragment from the household, but not with size of fragment or number of fragments per farm. Fragmentation results in problems in proper allocation of water and management of plots.

ONE OF THE PECULIARITIES of land resources in India is that subdivision and fragmentation have been carried to the extreme, creating considerable difficulties in modernizing agriculture. The problem can be traced to the laws of inheritance prevailing in the country. Small plot sizes might have been deliberately created for better water management practices in areas with uneven terrains, but that cannot explain the problem of fragmentation observed almost everywhere in India, except in some states like Punjab, Haryana, and the western part of Uttar Pradesh. In recent years, the rate of growth of agricultural production has been considerably higher in areas where land has been consolidated than in areas without consolidation.

This report seeks to analyze the difficulties associated with fragmentation in the cultivation of high yielding rice varieties in two villages, Kandarpur and Korpada, in the district of Cuttack, Orissa. The two neighboring villages have similar socioeconomic backgrounds and agronomic systems.

Out of an original sample of 57 farms in Kandarpur and 112 farms in Korpada, 15 farms in the first village and 30 farms in the second were randomly selected for this investigation.

In Kandarpur the number of fragments per farm is a little lower and the average size of fragments is very slightly larger than in Korpada (Table 1). The average fragment size in the two villages is quite small — 0.085 ha.

SIZE OF FRAGMENTS AND YIELD

The frequency distribution shows that fragments are concentrated around the smaller sizes (Table 2). That shows that the distributions are skewed to the

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Table 1. Average number and size of fragments per farm in two villages in Orissa, India, 1971/72.

Village	Farmers interviewed (no.)	Fragments (no.)	Total area (ha)	Fragments (no./farm)	Av. size of fragments (ha)
Kandarpur	15	85	7.33	5.67	0.086
Korpada	30	180	15.08	6.00	0.084
Pooled	45	265	22.41	5.89	0.085

Table 2. Frequency distribution of fragments by size in two villages in Orissa, India, 1971/72.

Size of fragments (ha)	Frequency of fragments (%)		
	Kandarpur (85 fragments)	Korpada (180 fragments)	Pooled (265 fragments)
Less than 0.02	5.9	4.0	4.5
0.02 – 0.04	4.7	16.1	12.5
0.04 – 0.06	25.9	18.9	21.1
0.06 – 0.08	14.1	12.8	13.2
0.08 – 0.10	23.5	17.2	19.3
0.10 – 0.12	5.9	6.7	6.4
0.12 – 0.14	3.5	7.8	6.4
0.14 – 0.16	3.5	2.8	3.0
0.16 – 0.18	9.4	8.9	9.1
0.18 – 0.20	1.2	1.7	1.5
0.20 and above	2.4	3.3	3.0

right. Pearsonian coefficients of skewness are obtained by using the relationship:

$$SK_1 = 3\,(\bar{x} - Xm)/s$$

where $\bar{x}$ is the mean, Xm is the median, and s is the standard deviation of the distribution. The values thus obtained for Kandarpur and Korpada separately and after pooling are 0.44, 0.53, and 0.48, respectively.

An attempt was made to find any relation between size of fragments and rice yield. Individual plot yield data were available only for the 1972 wet season. During the wet season, the sample farmers put most of their land in local improved and local varieties. Since the yield is known to be influenced by variety, only those fragments on which the local improved variety CR1014 were cultivated were selected to study the effect of fragment size on yield.

The correlation coefficient between yield and size of fragment in both villages is insignificant (0.23), implying that size of fragments may have no effect on the yield of rice.

LOCATION AND NUMBER OF FRAGMENTS AND YIELD

The distance of fragments from the residence of the cultivators varies widely, but almost one-third of the fragments are located more than 1 km from the residence (Table 3). To determine whether the distance and the number of

Table 3. Distance of fragments from the residence of cultivators in two villages in Orissa, India, 1971/72.

Village	Fragments (%) at given distance from residence				
	Less than 250 m	250–500 m	500 m – 1 km	1 km and above	Av. distance (m)
Kandarpur	8.2	21.2	30.6	40.0	697
Korpada	7.2	32.2	33.3	27.2	602
Pooled	7.5	28.5	32.5	31.3	632

fragments have any effect on rice yield, a chi-square test was carried out after classifying the sample farms in a 2 × 2 × 2 table (Table 4). As the sample sizes were rather small, data from the two villages were pooled. Farms having six or fewer fragments were classified as "few" and farms having more than six fragments as "many." Fragments at an average distance of 600 m or less from the residence were classified as "near" and those at an average of more than 600 m as "far." Farms with an average yield of 2.3 t/ha or less (average yield for the pooled sample) were considered to have "low" yields and farms with average yield higher than 2.3 t/ha have "high."

The chi-square value calculated for Table 4 is 5.0. The table of chi-square with three degrees of freedom is 7.8 at the 5% level. However, two-way chi-square analyses run separately for "yield" against "distance from house" and against "number per farm" give the former a chi-square value of 33.5 and the latter, 1.6 (Table 5). Thus, a highly significant association was noted

Table 4. Number of fragments and yield by distance within number per farm in two villages in Orissa, India, 1971/72.

Yield level	Fragments (no.)			
	Few		Many	
	Near	Far	Near	Far
High	11	4	3	2
Low	6	8	5	6

Table 5. Number of fragments and yield by distance in two villages in Orissa, India, 1971/72.

Yield level	Fragments (no.)			
	Distance from house		No./farm	
	Near	Far	Few	Many
High	14	6	15	5
Low	11	14	14	11

between yield and distance from the house, with the plots farthest from the house giving the lowest yield.

PROBLEMS ASSOCIATED WITH FRAGMENTATION

Farmers selected for the study were asked whether fragmentation poses any problems in successful rice cultivation (Table 6).

The majority of the cultivators (73% in Kandarpur and 80% in Korpada) reported difficulties in proper water management because of the fragmented and scattered nature of their land. The main source of irrigation in the study area is canal water. There are no field channels, and so water flows from plot to plot. The plot farthest from the source receives water last. The farmers have no control over either the time when water is available, or the amount. As everyone recognizes the problem, one would expect that it would be quite simple for the farmers to cooperate in laying out field channels. Unfortunately, although everybody agrees on the need for field channels, no one is prepared to give up any land for them. Charity, here, does not begin at home.

Closely linked with the water management problem is the problem of fertilizing with fragmentation. The importance of the problem is realized by a large proportion of farmers in Korpada (80%), but is felt less acutely by their counterparts in Kandarpur (27%). Because irrigation water flows from one plot to another, chemical fertilizers applied, particularly as topdressing, will be partly or completely washed away. A similar problem is likely to be encountered with insecticides applied in granular form.

Another difficulty in such a situation is the considerable waste of time in carrying fertilizers to widely separated plots. The activity is likely to push up the cost of labor in applying fertilizer. The first two problems create difficulty with rice cultivation, whether the variety is traditional or high yielding. The problem associated with insect, pest, and disease control is greater with high yielding rice varieties, for they require more plant-protection inputs and are more susceptible to diseases and insects.

Table 6. Problems associated with fragmentation experienced by farmers in two villages in Orissa, India, 1971/72.

Nature of problem	Farmers reporting (%)	
	Kandapur[a]	Korpada[b]
Water management	73.3	80.0
Manuring	26.7	80.0
Spraying	33.3	66.7
Harvesting	33.3	3.3
Supervision	13.3	10.0
Plowing	26.7	20.0
Land wastage	6.7	6.7

[a]15 farmers reporting. [b]30 farmers reporting.

Spraying for plant protection may not be very effective if the plot sprayed is surrounded by plots of other farmers who have not sprayed. With wide scattering of fragments the difficulty is increased. Sixty-seven percent of farmers interviewed in Korpada and 33% in Kandarpur reported that fragmentation has created some complications in providing plant protection through spraying.

Most of the high yielding rice varieties mature earlier than the local rice. With delayed harvesting, shattering of grains is greater with high yielding rice. Since the adoption of high yielding varieties of rice is not universal, it is not uncommon to find a plot with high yielding rice ready for harvesting, surrounded by other plots with local rice that has not yet completed the vegetative growth phase. As the separating bund between two plots is very narrow (about 30 cm), carrying the harvested crop to the threshing floor might necessitate trampling across the others' fields, an eventuality which is certain to be resisted. About 33% of the cultivators reported this problem in Kandarpur, but only 3 in Korpada.

Cultivation of high yielding rice varieties demands a lot of supervision from the farmer. He has to watch over crop growth, decide if his rice land requires weeding, and take immediate action against diseases and insect attacks. Supervision becomes difficult if his land is scattered over a wide area. Curiously, very few farmers in both villages reported any difficulty in this matter. One is inclined to believe that the farmers of this area have a poor understanding of the management requirements for growing high yielding rice.

A somewhat large proportion of cultivators (27% in Kandarpur and 20% in Korpada) reported that small fragments create some difficulty in plowing for land preparation. A small percentage of them also reported that fragmentation has resulted in land wastage.

In summary, there is clear evidence that fragmentation results in inefficiency in production. Size of fragment is not critical; however, the scattering of fragments results in problems in proper allocation of water and proper management of plots. Recognition of the need for consolidation is slowly developing among the cultivators in the study area. The State Government should actively consider passing a land consolidation act, as has been done in a few other States.

Impact of the systems of land tenure, credit and water control - Nueva Ecija, Philippines

ROMEO T. HERRERA

Land tenure, credit, and water control are closely linked problems of long standing in Gapan, Nueva Ecija. All three factors have limited the capacity of Gapan farmers to make effective use of the new rice technology and achieve higher yields. To make the current land reform program work, institutions that can deliver credit and water to farmers in a more efficient and equitable manner are needed. After the declaration of Martial Law in September 1972, the government stepped up efforts to implement land reform, extend credit, and improve irrigation, but it is too early to comment on the success of these programs.

THREE BASIC ISSUES confront farmers in Gapan, Nueva Ecija: the system of land tenure and share tenancy, the system of credit, and water control. Other production problems, such as lack of adequate inputs, insects and diseases, are closely related to those basic issues. Natural occurrences such as typhoons, floods, and drought are not considered here, although obviously they affect production.

The three basic issues are considered as to origin and development, associated problems, and possible avenues for improvement.

HISTORICAL PERSPECTIVE

A description of farming in Central Luzon (where Gapan is located) is incompletz if it does not mention the system of land tenure or landownership and crop sharing. The impact of that system was never demonstrated so dramatically as in the late 1940's and early 1950's when peasants in the region took up arms and openly defied government forces, primarily on the issue of land and ultimately on the sharing of benefits derived from it.[1] In the province of Nueva

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[1] F. Lachica, *Huk: Philippine Agrarian Society in Revolt* (Manila, Solidaridad Publishing House, 1971).

Ecija in 1948, 75% of the palay (rice) farmers were tenants, while in Pampanga and Bulacan (sister provinces of Nueva Ecija) the percentages were 88 and 66, respectively.[2]

The unequal distribution of agricultural land in this region stems from a long process of colonization. For centuries, the central plain of Luzon has been under a feudal system of landownership, in which a single person (or family) owns vast areas of agricultural land (sometimes thousands of hectares), leaving the rest of the population landless and therefore dependent on his kind patronage.

Historically, the region has had three basic types of large landholdings: the *encomienda* in the early part of the Spanish conquest, followed by the *caciques*, and finally by the present-day *hacienda*. *Small landowners*, however, are now by far the largest landowning class. The Department of Agrarian Reform reports that 83% of all landowners having rice- and corn-tenanted land own more than 7 ha each.[3] The four systems may be defined as follows:

Encomienda — a system of landownership devised by the Spanish crown as an incentive and reward to deserving Spaniards who participated in the conquest of the Philippines. This system was feudalistic in that those who tilled the land were essentially vassals who owed everything to their landlords.

Caciques — landed, hence influential, natives who were appointed by the Spanish governor to oversee a certain area, a barrio, or a municipality, with powers to collect taxes and perform minimal administrative functions. Their power and influence enabled them to secure their positions and increase their holdings. They were later known as *ilustrados* and became the forerunners of our present-day landlords and politicians.

Hacienda — a large agricultural estate engaged in some commercial venture, owned either individually or by a corporation.

Small landowners — a group of landowners with only a few hectares of land. Many in this group are owner-operators who cultivate the land themselves, but others have a few tenants.

In both the *haciendas* and smaller holdings, ownership does not necessarily imply a knowledge of farming. There are many absentee owners, and frequently the management of the farming enterprise becomes the responsibility of the tenant. That is particularly true in rice production, where most of the operating units comprise 2 to 3 ha. Large rice holdings under single management are rare, suggesting that this type of organization is not economically viable. The large estates frequently employ an overseer or *katiwala*, whose main responsibility is to collect the share rent rather than to manage production of the rice crop. On the large estates, exploitation does not always end at the

[2] P. Salgado, *Social Philosophy in the Philippine Context* (Quezon City, 1972), p. 110.

[3] M. Mangahas, "Economic Aspects of Agrarian Reform Under the New Society," *The Philippine Review of Business and Economics* 11 (December, 1974), p. 2.

rice paddies; it extends to the landlord's house where the son or daughter of a share-tenant may work as household help with minimal compensation.

Meanwhile, because of a vicious "debt cycle" whereby a share-tenant, through subtle manipulations, is kept indebted to his landlord, it is not uncommon to find farmers still paying the debt incurred by their grandfathers decades ago. In the process, their own debt accumulates and is passed on to their children and to theirs.

The logical net effect of the systems was the emergence of a poor and dependent but nevertheless highly politicized peasantry — a potent force in any sociopolitical upheaval.

With this background it is easier to understand the present state of Gapan farmers and their struggle for a "a little more food in their stomach, a little more clothing on their backs, and a little more shelter over their heads", to quote the late President Ramon Magsaysay.

SYSTEM OF LAND TENURE

The four general Philippine types or systems of land tenure observed in Mahipon, Malimba, and San Nicolas in Gapan are share-tenancy, leasehold, pure ownership, and a combination of any of the first three types (Table 1). Currently, a rapid shift is occurring from share-tenancy to leasehold (ultimately intended to be full ownership) under the land reform program.

Share-tenancy. Under share-tenancy, a landless farmer tills land owned by a landlord. He theoretically gets 50% of the harvest in return for his labor and use of work animals and implements, after the cash cost of production has been subtracted from the gross yield. The system is generally considered unjust, since the landlord, who merely waits for the harvest, gets as much as (if not more than) the farmer who does all the work and improves the land. The farmer's contribution includes the use of his work animals and farm equipment, not to mention expenses for food of hired laborers.

Table 1. Tenure of farmers surveyed in three villages of Gapan, Nueva Ecija, Philippines, mid-1960's and 1971/72.

Tenure class	Respondents (%)			
	Mahipon	Malimba	San Nicolas	Total
		Mid-1960's		
Share-tenant	72	89	82	80
Lessee	3	3	2	3
Owner-operator	25	8	16	17
Combination	0	0	0	0
		1971		
Share-tenant	26	59	56	46
Lessee	45	23	24	31
Owner-operator	25	9	16	17
Combination	4	9	4	6

Share-tenancy, in effect, sentences the tenant and his family to lifelong deprivation, both physically and psychologically. The tenant is squeezed between two grindstones — from above by the unjust sharing system and from below by the unproductive soil. His situation is aggravated by insufficient knowledge of better farming methods and lack of adequate inputs.

Leasehold. Although not entirely new, the leasehold system of land tenure became popular only after the approval of the Land Reform Code (RA 3844 as amended by RA 6389) and its subsequent implementation in 1964. Unlike share-tenancy, leasehold requires a fixed rental for cultivated land, an amount not exceeding 25% of the normal yield of that land. Likewise, the lessee is given full freedom and responsibility to make decisions on farm operations. Under this system, he has the chance to improve his condition, but bears all the risk of reduced income during years of poor harvest.

The government encourages farmers to adopt this system. In fact, lessees are promised government assistance, especially credit and other special programs such as cooperatives.

Pure ownership. There are three kinds of pure owners: owner-operators, who cultivate their land themselves; pure landlords, who employ either tenants or hired laborers to work for them; and a combination type, who till a part of their holding and sharecrop or lease out a part of it.

Owner-operators usually own smaller holdings than pure landlords. They are progressive, normally (for obvious reasons) leading other farmers in adopting new farming methods. They likewise enjoy higher social status, are more articulate and more highly educated, and almost always assume leadership roles in their respective communities. They also provide credit to their neighbors, accumulating huge profits in the process. In short, they are the embodiment of the farmers' lifelong dream — independent, progressive, and active citizens.

The pure landlords are the remnants of the feudalistic figures created by the Spaniards — the *encomendero* and his native counterpart, the *cacique*. They usually own large areas of land (mostly through inheritance), from tens to hundreds and, sometimes, thousands of hectares. Unlike owner-operators, pure landlords seem to be more cautious in recommending new practices to their tenants. In fact, some share-tenants reported that their landlords discourage them from following the recommended methods of farming, primarily because the methods are expensive.

Of course, they enjoy a very high socioeconomic status, not only in their barrio or municipality but even in their province or perhaps in the region. Like the owner-operators, they are also articulate and well educated, and monopolize leadership positions at the municipal and provincial levels (some advance to the national level). They engage in such big-time enterprises as rice milling and storage, transport, gasoline retailing, banking, and politics.

The third type of pure owners, those who cultivate a part of their holdings while at the same time sharecropping or leasing out a part, is characterized by

the entrepreneurial spirit. They are ready to try new methods of doing things, setting an example for their tenants. They use farm machinery extensively and hire out such machinery to small farmers, thus getting additional income. They differ little from pure landlords in other respects, although they tend to concentrate on farming rather than on other types of business.

Combination. Those operating under the combination type of land tenure are transitional farmers, in the process of progressing from share-tenancy to leasehold and from leasehold to pure ownership. They still retain some degree of loyalty to and dependence on their landlords as they begin to make their own decisions. The arrangement puts them in a safe position: they are eligible for government assistance (credit), but they can also borrow from their landlords when government support fails to materialize.

CREDIT SYSTEMS

The three sources of credit in Nueva Ecija are government cooperatives, commercial banks, and private individuals. In Gapan, the Agricultural Credit Administration (ACA) and Farmers' Cooperative Marketing Association (FACOMA) have been more active than the banks (Table 2). In many other areas, the reverse is true.

Government cooperatives. The government has a long history of credit assistance to farmers in this country. The assistance is usually channeled through agencies under the Office of the President. One such agency was the Agricultural Credit and Cooperative Financing Administration (ACCFA), created in the early 1950's to provide credit to farmers and initiate the organization of marketing cooperatives, later known as FACOMAS. The ACCFA

Table 2. Amount and sources of production credit in three villages in Gapan, Nueva Ecija, Philippines, 1971/72.

	Mahipon	Malimba	San Nicolas
		Borrowed cash	
Borrowers (%)	51	70	40
Average amount borrowed ($/ha)	26	23	36
Source (%)			
ACA[a]	—	35	36
FACOMA[b]	35	—	—
Landlord	30	48	32
Others	35	17	32
		Borrowed in kind	
Borrowers (%)	19	18	7
Average amount borrowed ($/ha)	9	12	18
Source (%)			
Landlord	85	75	50
Others	—	—	50

[a]ACA = Agricultural Credit Administration. [b]FACOMA = Farmers Cooperative Marketing Association.

failed after losing millions of pesos in unpaid loans. Nor did the FACOMAS perform well. Only a handful are still functioning.

In the early 1960's, the ACCFA was scrapped altogether and its functions were taken over by a new agency, the ACA. The ACA served as the credit arm of the Philippine Land Reform Program implemented in 1964. Unlike the ACCFA, which virtually became a "milking cow" of many sectors, the ACA, despite its extremely limited resources, seems to be performing above par in terms of recovering loans. Its success may be explained by the fact that leaseholders and pure owners — those qualified to borrow — are afraid of losing their credit line and, therefore, pay their loans. Leaseholders may be more concerned with maintaining their credit line because they cannot revert to borrowing from their former landlords, having "burned their bridges behind them" when they shifted from share-tenancy to leasehold. Pure owners want to keep their credit line because they are not willing to pay high interest rates on loans obtained from private moneylenders.

Compared with private loans to small farmers, government loans carry minimal interest: 8% basic interest plus 4% as a service fee to the local cooperative which processes the loans, or a total of 12% per annum. Farmers' cooperatives can also get loans from the government thru the ACA at an interest rate of not more than 8% per annum.

Commercial banks. With the development of the Rural Banks system, commercial banks have assumed a more important role in rural credit in recent years. The Rural Bank lends at 12% interest. Its loans are rediscounted at a nominal rate of interest with the Central Bank, and agricultural loans are guaranteed by the government up to 75%. Because of the attractiveness of this type of loan, the limited funds available, and the difficulty of dealing with many small tenant farmers, the banks have tended to loan to rural business interests — rice millers, those in the transport business, etc. — in short, the landowning class. Recently the government, through the Masagana 99 program, attempted to rectify this inequity by providing more credit funds and placing sanctions on banks that do not lend to small farmers.

Private lenders. The private sector is the main source of credit for farmers, especially share-tenants. Over centuries of interaction, Central Luzon residents have been able to develop sophisticated and varied credit arrangements. Notable among these credit systems are *takipan, talindua, terciahan, takalanan,* and other variations. Salgado describes the first three of these credit systems as follows:

> *Takipan*. This form of credit under which the landowners loan the *aparcero* two cavans (1 cavan = sack of 44 kg) and collect four cavans. Under this form of borrowing, the *aparcero* thus pays 100% interest on what he borrows, but usually the price of palay is higher when the advance is made than when it is returned. This practice is now prevalent in Central Luzon (Nueva Ecija and Bulacan).
>
> *Talindua.* Under this form of credit, the *aparcero* pays three cavans for

only two cavans borrowed. In this case, the *aparcero* pays interest on what he borrowed, at an apparent rate of 50% (per crop, although the rice price may be a little lower at harvest than at planting time).

Terciahan. This is a form of credit in which a loan of three cavans of palay is paid back with four cavans. Thus, the *aparcero* pays 33-1/3% interest."[4]

The *takalanan* type of credit is similar to *talindua* (50% interest more or less), but here the leader specifies how much of the loan is repayable in palay. For instance, if the prevailing market price of one cavan is ₱30.00 ($5.00), the lender will give only ₱15.00 to the borrower, to be repaid with one cavan of palay after harvest.

A more detailed presentation of interest rates paid is in Table 3.

WATER CONTROL

The Peñaranda River Irrigation System (PRIS) constructed in the early 1930's started operating in 1932. Since then, Gapan farmers have been using water from this source, except in two rainfed barrios, Mahipon (one of the three sample barrios) and Kapalangan.

The PRIS is government owned and managed by the National Irrigation Administration (NIA). The irrigation fee originally imposed in 1932 was only ₱6.00/ha per year. At the time, there was only one cropping season in a calendar year. In 1937, the fee was increased to ₱12.00/ha per year. Double-cropping became very popular in 1960, and by 1966 many farmers were already planting twice a year. In 1966, after 29 years, the NIA increased the fee to ₱25.00/ha in the wet season and ₱35.00/ha in the dry season.

Also in 1966, farmers in Malimba (one of the three sample barrios) formed the Malimba Irrigators Association and appointed Jose Guinto as its first president (Mr. Guinto has continuously served as president up to the time of the survey). Similar organizations were established in other barrios of Gapan.

The year 1966 was significant for Gapan farmer-irrigators. First, the ₱25.00-₱35.00/ha irrigation fee was announced. Second, the Malimba Irrigators Association was formed. Third, the increase in irrigation fee led farmers to protest at Malacañang. Their action resulted in the reduction of the irrigation fee to ₱12.00/ha per season, on the condition that the farmers themselves would clean the canals near their paddies.

Impact on MV adoption and yield. As of August 1969, 5 years after Gapan was declared a land reform area, the number of share-tenants was still substantial: 45% of 2,232 farmers. Leaseholders were 48% while owner-operators constituted only 7% of the total.[5]

While "landowners and owner-operators were the only persons to acquire

[4] Salgado, *op. cit.*, p. 115. (parenthetical statement is that of the author).

[5] R. Barker, G. Dozina, Jr., and L. Fu-Shan, "The Changing Pattern of Rice Production in Gapan, Nueva Ecija, 1965 to 1970," IRRI seminar paper, Dec. 11, 1971. (mimeo.)

Table 3. Interest rates and repayment arrangements for loans made in three barrios of Gapan, Nueva Ecija, Philippines, 1971/72 wet season.

Rate and arrangement	Farmers (no.) reporting			
	Mahipon	Malimba	San Nicolas	Total
		Cash loans		
Interest payable at per annum rate				
12%	26	12	7	45
8%	1	4	4	9
50%	1	2	—	3
10%[a]	—	1	—	1
43%	—	1	—	1
30%	—	1	—	1
Interest payable at per harvest rate				
20%	—	2	1	3
15%	—	2	—	2
5%	—	2	—	2
10%	—	—	1	1
6%	—	—	1	1
Others[b]	—	1	—	1
No interest	4	2	3	9
		Loans in kind (no.)		
Interest payable at per annum rate				
50%	—	—	1	1
40%	—	—	1	1
Interest payable at per harvest rate				
P1.00/cavan or 3%	1	—	—	1
1 cavan/10 cavans or 10%	1	—	—	1
5%	—	—	1	1
No interest	9	14	3	26
		Combination loans (no.)		
No interest				
Repayable 1/3 in palay, 2/3 in cash	—	1	—	1
Repayable 1/3 in cash, 2/3 in kind	—	1	—	1
Landlord buys palay	—	1	—	1
No response	29	19	32	80
Farmers (no.) interviewed	72	66	55	193

[a]1/2 no interest, 1/2 20% interest; [b]1/3 no interest, 2/3 low interest.

IR8 seed in Gapan in 1966,"* it did not take long before share-tenants and leaseholders became users of the seeds. By 1971, almost 100% of the 193 farmers interviewed in the three barrios of Gapan were MV (modern varieties) adopters. Of this number, 46 and 32% were tenants and leaseholders, respectively. Considering the influence of landlords on the decision-making patterns

* R. E. Huke and J. Duncan, "Spatial Aspects of HYV Diffusion", Seminar on Economics of Rice Production in the Philippines, IRRI Dec. 11-13, 1969, p. 2-7. (unpublished)

of share-tenants, and the inherent desirable characteristics of the new seeds, not to mention some sociocultural traits common among Filipinos like *gaya-gaya* (the tendency to imitate "blindly" anything seen or heard), *pakiksama* (smooth interpersonal relations) and *utang na loob* (debt of gratitude), the rapid diffusion and adoption of MV even among share-tenants are easily understood. Tenure arrangement, therefore, is not a significant factor in MV adoption. As Huke and Duncan said, "In Gapan at least, the process of adopting new rice varieties is not encouraged by the transformation from share-tenancy to leasehold."[7]

In terms of yield, no meaningful difference exists among the three major tenurial groups of owner-operators, leaseholders, and share-tenants. What then is the rationale for the tenant farmers' desire to shift from tenancy to leasehold, if not to owner-operatorship? One logical answer is the farmers' lifetime aspiration to be free from the landlord, to "be our own boss" as some of them would say. Thus, while the change of tenure may not necessarily result in increased yield, it could increase income (getting a bigger share of the produce) and, more importantly perhaps, help the farmers attain a certain degree of freedom and social status in the community.

The importance of credit to small-time farmers, especially share-tenants and new leaseholders, cannot be overemphasized. Credit seems to be the lifeblood of small rice farmers. Locked in the so-called "debt cycle," they need constant transfusion of capital to keep their farm operation going. Devoid of savings, they have to get financial assistance from any available source, regardless of the rate of interest imposed.

The need for credit is clearly shown by the increasing number of actual borrowers and users of credit when available. Likewise, an increasing number of farmers think that lack of credit is a constraint to getting higher yields.

While the need for credit is increasing, the rate of interest on loans is decreasing. This observation, reported by 55% of the borrowers, might be due to the increasing popularity of banks and government loaning agencies, which charge lower interest than do private moneylenders.

Earlier studies have shown that the adoption of MV is closely associated with the availability of irrigation. Thus, farmers whose land is irrigated tend to adopt MV sooner than those with rainfed farms. This is logical, considering the risks involved. Huke and Duncan reported that "in areas without irrigation water, the extra investment in fertilizers, pesticides and herbicides is often wasted if rainfall is inadequate or poorly timed."[8]

In terms of yield, the irrigated farms perform better than rainfed farms; the two groups differ by about a ton on the average. But even among irrigated farms, yields vary. Those nearer the main canal have better yields than those farther from it.

[7] *Ibid.*, p. 2-30.

[8] *Ibid.*, p. 2-27.

The importance of irrigation and credit to rice farming in general is further manifested by the following data. When asked if their farming can still be improved, 99% of 193 respondents replied in the affirmative. When further asked how they can improve their farming, 28% suggested the improvement of their water supply system, while 23% cited the provision of sufficient capital or credit.

PROBLEMS AND SOLUTIONS

As was previously suggested, the problems of land tenure, credit, and water are closely linked. The government is making an effort to change the traditional landlord-tenant system, but lack of small-farmer credit from institutional sources and inadequate irrigation facilities tend to prolong the traditional dependence on the landlord. Frequently, even after the tenant has nominally achieved leasehold status, his relationship with the landlord remains basically unchanged.

Of the three villages surveyed, Mahipon faces the most difficult problem. It is a rainfed barrio, and most farmers there indicated that they could not use more credit effectively, even if it were readily available at low interest rates. Without irrigation water, modern rice technology can have only a very limited role. However, the presence until recently of an extremely capable extension worker has permitted Mahipon farmers to make as much progress in rice production as farmers in some of the more favorably situated neighboring villages.

Compared to San Nicolas, Malimba is poorly irrigated and has problems of too much water in the wet season and too little in the dry season. It illustrates the situation of a village that is not located close to the main water turnout. Farmers nearer the water source put illegal checks in the laterals and take more water than they can effectively use. The new barrio irrigation association in Malimba can do little to correct the practice, since the administrative boundaries of the barrio do not coincide with the physical boundaries of the water distribution system. An irrigation association organized according to major laterals or sublaterals would seem to make more sense.

To summarize, for Gapan farmers institutional issues are as important as, if not more important than, technical issues in achieving increased rice production. To make the current land reform program work, institutions or organizations that can deliver credit and water to farmers in a more efficient and more equitable fashion are needed. If these organizations are to be viable, some means must be established not only for delivering the services but also for collecting repayments of loan and fees for services. Creating a viable institutional structure of this type is not accomplished overnight; it is a task that takes years or decades.

New government programs. Shortly after the completion of the Gapan survey, martial law was declared in the Philippines in September 1972, and land reform was proclaimed as the "cornerstone" of the new government

program. Efforts to implement land reform, extend credit, and improve the irrigation system have been intensified throughout the Philippines and, in particular, in major rice-growing communities such as Gapan. Through the land reform program the government has begun issuing certificates of land transfer to the farmers. Credit is being provided to the farmers through the Rural Banks, the Philippine National Bank, and the Masagana 99 Program. The National Irrigation Administration has hastened the completion of the Upper Pampanga River Project, which is designed to provide more irrigation water and improve the water-delivery system.

All these programs promise a more prosperous and productive future for the Gapan farmer, and should enhance his capacity to make effective use of modern rice technology. But the long-term viability of these programs and, hence, the degree to which Gapan farmers will really benefit from them will depend on the creation of successful farm-level organizations. At this time, it is still too early to comment on the success of the new government programs.

Effect of government rice policy on choice of crop and variety - Punjab province, Pakistan

HAIDER ALI CHAUDHARI and ABDUR RASHID

The government policy is currently geared to the increased production of fine rice intended largely for export. Due to pronounced adverse effects of pests, it has been necessary to encourage the production of fine rice through a price support double that for the coarse modern varieties. What is needed is a fine variety with some of the characteristics found in modern varieties: fertilizer responsiveness, resistance to pests, and early maturity to permit the timely sowing of the wheat crop that follows.

ANY STUDY of the new rice technology in the Punjab Province of Pakistan must consider the effect of government policy on such aspects of rice production as crop choice, cropping pattern, and cropping intensity. Before the breakdown of relations with the eastern wing of the country, the emphasis of government policy was clearly on increased production of rice, primarily to meet the expanding demand in that wing. Since the major potential for increase in rice production was in the growing of coarse, imported modern varieties (IR8 and Mehran 69, a local selection of IRRI cross IR6, which has not been officially named by IRRI), the government promoted production of those varieties. Now, with the considerable decrease in local demand for coarse rice, the emphasis has been laid on expanding production of fine rice grown largely for export. To increase the production of fine rice, the government is undertaking some economic measures, which will be discussed in the following sections.

PRICE POLICY

The most effective instrument for regulating the production of different rice varieties in the Punjab Province is the formula of differential procurement prices. Table 1 shows the increasing gap between the prices of coarse and fine

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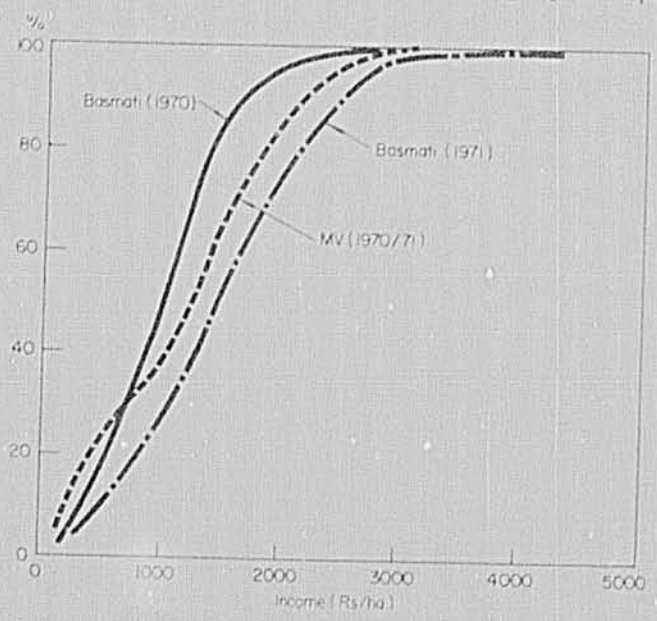
Table 1. The government procurement price[a] for fine and coarse varieties of milled rice in the Punjab Province, Pakistan, 1966/72. Source: Food Department, Government of the Punjab.

Year	Basmati (Rs/t)	IR8/IR6 (Rs/t)
1966	750	469
1967	830	509
1968	1018	509
1969	938	509
1970	697	509
1971	1010	509
1972	1125	509

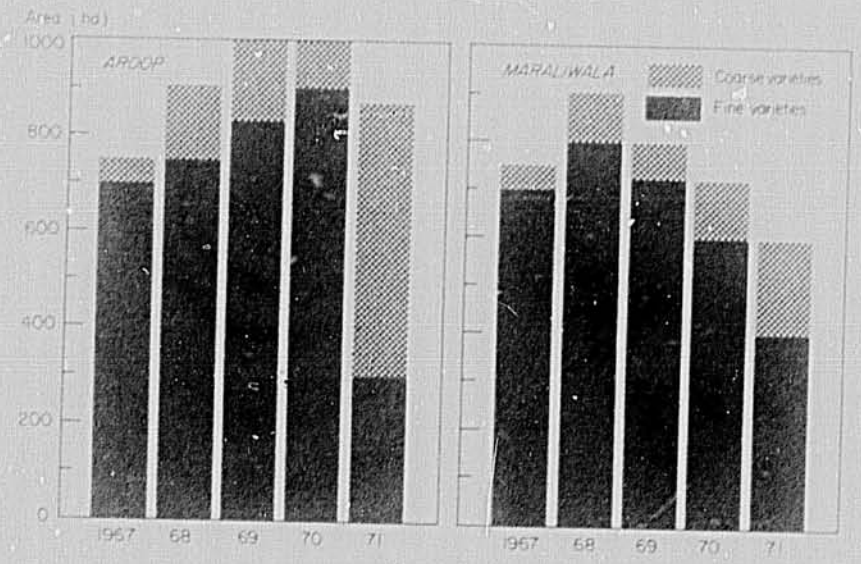
[a]US$1.00 = Rs 9.90.

rice varieties. The steep rise in the prices of Basmati varieties after 1970, while the price trend of modern varieties (MV) remained static, clearly suggests a more favorable production situation for the fine varieties after that year.

To emphasize the difference in profitability, cumulative frequency distributions were drawn. They show the return per hectare for MV and Basmati, based on the yields reported by farmers in 1971 and the profits that could be expected using 1970 and 1971 prices (Fig. 1). Since the price for MV was the same in both years, the cumulative frequency of returns remains unchanged. Basmati was less profitable than MV in 1970 but slightly more profitable in 1971. The



1. Cumulative frequency distribution of income (net of fertilizer cost) for modern varieties and Basmati in the Punjab province, Pakistan, 1970/71



2. Area under fine and coarse varieties of rice in the villages Aroop and Maraliwala, the Punjab province, Pakistan, 1967/71.

trend away from Basmati in 1971 in both study villages suggests that farmers were responding to the low Basmati price in 1970 (Fig. 2).

Following the breakdown of relations with the eastern wing, Pakistan became a producer of surplus rice. Hence, the government's objective is to maximize export earnings. Raising the support price of Basmati in 1971 to encourage higher production of the high-quality rice is completely consistent with that objective, as the analysis in Table 2 reveals. With the 1971 procurement and export prices, the gross return to the government for every ton of Basmati sold is more than four times that for coarse rice such as IR6.

INSECT DAMAGE AND THE PLANT PROTECTION PROGRAM

Another major factor influencing the planting decision in 1971 was the acute vulnerability of the fine varieties to damage from insects, especially stem

Table 2. Approximate procurement and selling price[a] of IR6 and Basmati rice and the gross government profit per hectare, the Punjab Province, Pakistan, 1971. Source: Food Department, Government of the Punjab.

Variety	Yield (t/ha)		Purchase price of milled rice (Rs/t)	Selling price of milled rice (Rs/t)	Government gross profit	
	Unmilled rice	Milled rice			Rs/t	Rs/ha
IR6	3.2	2.1	509	780	271	569
Basmati	2.0	1.3	1010	2200	1190	1547

[a] US$1.00 = Rs 9.90.

Table 3 Area and production[a] of rice by variety in the Punjab Province, Pakistan, 1968/71. Source: "Development Statistics of Punjab, Sind, N.W.F.P. and Baluchistan," Planning and Development Department, Government of the Punjab, 1971.

Variety	1968		1969		1970		1971[b]	
	Area (1000 ha)	Production (1000 t)	Area (1000 ha)	Production (1000 t)	Area (1000 ha)	Production (1000 t)	Area (1000 ha)	Production (1000 t)
Basmati	467	565	486	585	435	405	304	310
IR8/IR6	75	187	97	259	59	269	210	380
Local coarse	287	326	237	331	204	293	134	290
Total	829	1087	820	1175	738	967	648	980

[a]Production is in milled rice. [b]Estimates given by the Department of Agriculture, Government of the Punjab.

borers. There was a 30% loss in total production of fine rice varieties in 1970 due mainly to stem borers. Insect damage plus low prices led to a considerable reduction of the area under Basmati in the following crop year and an increase in the area under MV, principally IR6 (Table 3).

Since rice borer attack on fine rice varieties is the major limitation to increased production of fine rice, the government is undertaking the following important measures:

1. Transfer of a major part (75%) of the pesticide program to the private sector to expand the coverage of the service;
2. Compulsory spraying of rice nurseries and the crop by the Department of Agriculture;
3. Expansion of the pesticides supply through local formulation;
4. Enactment of legislation to stop the early sowing of nurseries; and
5. Extensive aerial spray program — the target crop area to be treated by aerial spraying in 1972 was 240,000 ha, compared with 120,000 ha treated in 1971.

Each of the five stated measures is in itself beset with problems. Pesticides, for example, may be in short supply in some areas and indiscriminately used in others. Nevertheless, this particular problem is receiving the active attention of the government, and all possible efforts are being made to bring it under control.

CROP CHOICE, CROPPING PATTERN, AND CROPPING INTENSITY

Having briefly explained the government policy on price and the pest control program, let us now examine the cropping patterns, crop choice, and cropping intensities in the two study villages as affected by that policy and other factors.

Decision on *kharif* crops.[1] Whether a farmer should grow more rice or other *kharif* (wet season) crops depends on the following factors:

[1]The terms *kharif* and *rabi* are synonymous with wet and dry seasons, respectively.

1. The changes in the government procurement price of rice and its relationship to the prices of other *kharif* crops;
2. The financial position of the farmer, i.e., availability of funds for the purchase of fertilizers and pesticides;
3. The availability of irrigation water;
4. The incidence of pests and diseases;
5. The following *rabi* (dry season) crop, to be grown on the *kharif*-planted area;
6. The availability of marketing facilities and the demand for the particular crop;
7. The type of soil; and
8. The size of holding and the tenancy status.

The effect of all those factors may be very briefly summarized as follows:

Whereas the government procurement prices for coarse varieties have remained almost static for the last 6 years, the price of fine rice varieties has risen. Since fine varieties are on the major proportion of the total area under rice, the price incentives should logically have resulted in an increased area under rice. But that has not happened because of the constraint imposed by the heavy losses caused by pests on fine rice varieties. On the other hand, the relative advantages of growing other wet-season crops like fodder and vegetables instead of rice are 1) the short duration of these crops, which enables the farmer to prepare his land effectively for the sowing of the subsequent *rabi* crop, and 2) the ready and increasing demand for fodders and vegetables in the urban centers. Farmers in the villages surrounding such centers can profitably avail themselves of those opportunities. For instance, the proximity of the village Aroop to the town of Gujranwala results in an increased diversion of area from rice to fodders and vegetables (Table 4). In Maraliwala, the area under rice showed an increasing trend up to 1970, after which there was a substantial decrease (Table 5). A major part of the area withdrawn from rice in 1971/72 was diverted to the production of fodder, which can be profitably marketed in Gujranwala town. The relatively poor quality of soil in this village makes vegetable production unprofitable.

Both villages have an ample supply of irrigation water. Hence, the availability of water is not an important factor in the choice of *kharif* crops. The only remaining problem is the economical operation of tube wells. The government has now levied a fixed charge on tube wells in addition to the operating cost. For economical operation, the tube wells should therefore be run at full capacity.

Because of their better financial position, the farmers of Aroop are willing to invest more production resources in the growing of crops for which there is ready market at profitable prices.

The tenancy status has also an important bearing on the choice of a particular crop in a season. On tenant-operated farms, fodders are more likely to be produced for consumption by livestock raised by the tenants. The main crop, such as rice, is shared in kind by the tenant and the landlord. The fodder crops

Table 4. Hectarage under different crops in the village Aroop, the Punjab Province, Pakistan, 1967/68–1971/72.

Crops	Hectare[a]				
	1967/68	1968/69	1969/70	1970/71	1971/72
			Wet season		
Rice (total)	771	893	792	696	587
Fine varieties	677	806	718	617	386
Coarse varieties	94	92	74	79	201
Maize	13	4	n.a.	n.a.	0
Sugarcane	180	62	74	79	31
Cotton	11	10	9	7	9
Vegetables	19	28	37	51	106
Fodders	236	318	397	n.a.	453
Others	3	2	2	2	2
			Dry season		
Wheat	543	662	506	533	576
Barley	5	2	2	1	3
Tobacco	19	22	14	18	13
Wheat and gram	5	4	7	2	5
Fodders	508	463	514	563	508
Vegetables	198	239	357	313	305
Fruits	2	2	2	2	2
Pulses	3	4	1	0	2
Others	7	2	3	1	3

[a]n.a. = data not available.

are not shared, but a price is paid to the landlord at the prevailing village rates. The tenants take the opportunity of growing more fodder crops for raising more cattle, which become a secondary source of income for them. This observation is particularly true for Maraliwala where tenants constitute an important tenurial class.

Table 5. Hectarage under different crops in the village Maraliwala, the Punjab Province, Pakistan, 1967/68–1971/72.

Crops	1967/68	1968/69	1969/70	1970/71	1971/72
			Wet season		
Rice (total)	738	893	925	985	840
Fine varieties	691	749	808	867	279
Coarse varieties	47	144	117	118	561
Maize	10	7	11	10	15
Cotton	12	9	13	11	10
Sugarcane	34	35	39	34	33
Fodders	51	127	119	118	164
			Dry season		
Wheat	937	846	897	928	806
Wheat and gram	34	35	39	34	33
Fodders	156	169	172	170	175
Gram	5	1	2	14	38
Oilseed	18	19	21	47	72
Others	2	4	4	25	n.a.

With regard to size of holding on farms using animal power, as in both of the villages studied, the ratio of fodder to other crops increases as farm size decreases.

The choice between rice varieties. The choice between fine and coarse rice varieties is regulated by the following factors:

1. The relative prices of different varieties,
2. The relative susceptibility of each rice variety to pests and diseases,
3. The relative profitability of the use of fertilizer on MV and pesticides on fine varieties, and
4. The *rabi* crop, to be grown after rice.

The rice farmers in the two villages have to choose between fine varieties (Basmati) and coarse varieties (mainly IR6). Perhaps the most important factors affecting their decision are the incidence of crop pests and diseases and the relative prices.

Fertilizer is subsidized. Nitrogen is sold to the farmer at US$0.113/kg or about half of what most Asian farmers pay. But the government procurement price for the fertilizer-responsive MV is also extremely low, again about half of what most Asian farmers receive (US$0.026/kg of rough rice). Thus, despite the favorable fertilizer price, 4.4 kg rough rice is required to buy 1 kg of nitrogen, while 1 kg of nitrogen might typically yield 10 kg of paddy. If one considers the additional charges for credit and the difficulty that farmers frequently experience in finding fertilizer, the profit margin for fertilizer is not so large as to stimulate a high rate of use. Farmers applied only 30 kg N/ha in Aroop and 37 kg N/ha in Maraliwala. On fairly arid and well-irrigated areas elsewhere in Asia, the rate of application is often two to three times as high. While raising the price of MV would stimulate fertilizer use, it would also encourage a shift toward MV at the expense of Basmati production.

Wheat is the major *rabi* crop following rice in both villages. The area under wheat showed a sudden increase in the *rabi* season 1967/68, encouraged by the introduction of an early maturing modern variety of rice (IR8) in the wet season of 1967. That enabled the farmers to grow wheat in *rabi*. Previously, with late maturing rice varieties, much of the area was either left fallow or planted to crops other than wheat.

The cropping intensity shows an increasing trend (Table 6) in both villages and is a composite effect of a number of factors, including an increase in the number of tractors and tube wells, introduction of early maturing modern varieties of rice and short-duration modern varieties of wheat, an increase in the area under other short-duration crops like fodder and vegetables, and increased availability of fertilizers.

To sum up, the government policy is presently geared to the increased production of fine rice intended largely for export. To achieve this objective the procurement prices of fine varieties are being increased substantially while those of the modern coarse varieties are static and at a very low level, conditions that discourage use of fertilizer. However, the production of fine varieties

Table 6. Cropping intensities in the villages Aroop and Maraliwala, the Punjab Province, Pakistan, 1967/68–1971/72.[a]

Year	Cropping intensity	
	Aroop	Maraliwala
1967–68	175	160
1968–69	192	169
1969–70	192	180
1970–71	180	191
1971–72	184	176

[a]Cropping intensity (%) = $\frac{\text{total cropped area}}{\text{cultivated area}} \times 100$, where cropped area is equal to net cropped area plus area sown more than once. A cropping intensity of 100 is equivalent to a single crop per year, and a cropping intensity of 200 refers to 2 crops per year.

is constrained by the pronounced adverse effects of pests, which in the past have resulted in huge crop losses. To control the problem, the government is undertaking all possible measures to make the plant protection program more effective. The compulsory spraying of nurseries, the increased target acreage for aerial spraying, the transfer of a major part of the pesticide formulation and distribution program to the private sector, and the halting of early sowing of nurseries are some of the important measures undertaken by the government to minimize the losses caused by plant pests and diseases.

Another obstacle in the way toward an increase in area and production of fine varieties is that these varieties mature late and do not permit the timely sowing of the wheat crop that follows. This has so far favored an increase in the area under high yielding and early maturing coarse varieties of rice. However, research resulting in late-sown and short-duration wheat varieties, and early maturing fine rice varieties may tip the scales in favor of expansion of the area under fine varieties as opposed to that under coarse MV. The best possible solution lies in producing a fertilizer-responsive Basmati rice. Research is under way, but changing the plant type without sacrificing the fine quality poses a difficult problem for plant breeders.