PN-AAL-862
ISN 14967

IRRI RESEARCH PAPER SERIES
NUMBER 80 SEPTEMBER 1982

ECONOMIC LIMITATIONS TO INCREASING SHALLOW RAINFED RICE PRODUCTIVITY IN BICOL, PHILIPPINES

A. M. MANDAC, K. P. KALIRAJAN, and J. C. FLINN

The International Rice Research Institute
P.O. Box 933, Manila, Philippines

ECONOMIC LIMITATIONS TO INCREASING SHALLOW RAINFED RICE PRODUCTIVITY IN BICOL, PHILIPPINES[1/]

ABSTRACT

The study area, Camarines Sur, in the Bicol region of the Philippines, has low rice yields (less than 2 t/ha). Farms are small by Philippine standards. Although farmers grow modern varieties, cash inputs are low -- an average of less than 20 kg total nutrients/crop. Whether or not it was profitable to use higher input levels in these rainfed environments was explored using constraints experiments. Yields could be increased more than 1 t/ha by using higher levels of fertilizer and pest management. However, it was usually not profitable to increase input levels to gain production. An analysis of the combined experiments showed site-related characteristics, particularly the incidence of moisture stress and soil CEC, were important determinants of rice yield, over and above the farmer's management of his crop.

[1/] By A. M. Mandac, senior research assistant, K. P. Kalirajan, postdoctoral fellow, and J. C. Flinn, agricultural economist, IRRI.

Submitted to the IRRI Research Paper Series Committee November 1981.

PREVIOUS PAGE BLANK

ECONOMIC LIMITATIONS TO INCREASING SHALLOW RAINFED RICE PRODUCTIVITY IN BICOL, PHILIPPINES

Since its inception 21 years ago, the International Rice Research Institute (IRRI) has sought to develop technology that is attractive to rice farmers and will enable them, subject to appropriate incentives, to increase the yields and cropping intensity of their rice lands. As part of its research program, IRRI examines both biotechnical and sociceconomic factors that limit the productivity of modern rices when grown by farmers.

IRRI's primary research objective in rice production constraints is to identify and measure three groups of factors that limit the performance of modern rices. They are:

- constraints to adoption of new rice technology,
- constraints to effective use of available rice technology, and
- constraints due to biological, physical, institutional, and socioeconomic factors that limit the productivity of available rice technology.

Procedures adopted by and the results of the International Rice Agro-Economic Network are well documented (De Datta et al 1978; IRRI 1977, 1979). The constraints program is one of IRRI's programs concerned with the productivity of modern rice technology in farm environments. Other programs such as the cropping systems program and the rice production training program, are concerned with the continuum from technology design to production programs of rainfed, rice-based cropping systems. Constraints research is a later-stage research process that evaluates the performance of modern technology after it has been adopted (or partly adopted) by farmers.

Constraints research has traditionally studied areas where modern varieties (MV) have been adopted. Frequently they are the irrigated environments which account for about half of the world's rice lands (Table 1). However, constraints researchers are now studying nonirrigated environments in greater detail to complement findings from irrigated sites and because of the increased research focus on rainfed production. In rainfed rice environments, research further focuses on shallow rainfed areas which account for about one quarter of the world's rice lands. Next to water-controlled areas, shallow rainfed areas offer the most promise for rapid increases in rice productivity (Greenland 1981).

Table 1. Current IRRI classification of rice areas according to water regime.[a]

Classification of rice area	Area Million ha	%
Irrigated		
Dry season	8.8	50.6
Wet season	68.1[b]	
Rainfed		
Shallow (0-30 cm)	29.7	22.1
Deep (30-100 cm)	12.8	9.5
Floating (>100 cm)	4.9	3.6
Dryland	19.1	14.2
Total	134.6	100.0

[a] Source: Estimated by Huke (1982) and cited by Greenland (1981). [b] Includes the 8.8 million hectares irrigated in the dry season.

The Philippines has experienced rapid and widespread adoption of MV under shallow rainfed conditions. Ten years after the release of IR8, more than 70% of the country's 1.7 million ha of rainfed rice lands were planted to MV (Table 2), mainly IR36; the current figure is more than 75%. This rapid adoption of MV is significant in production terms and because it is providing the historically poorest group of rice farmers opportunities to increase consumption and farming incomes. MV adoption also increases employment opportunities for agricultural laborers.

Despite widespread adoption of MV in the Philippines, yields in rainfed environments are low. They range from 1.1 to 1.9 t/ha per crop, over all regions (Table 2). Further, the yield disparity between rainfed and irrigated environments has widened since the introduction of modern rices and associated technology. For example, in the Bicol region of southern Luzon, designated by the National Economic Development Authority as an economically depressed region, the yield difference between rainfed and irrigated environments increased 67% between 1964 and 1979. In the Philippines as a whole, the gap doubled over the same period (Table 3). Therefore, it is important to study the causes of the low yields of MV in these rainfed environments.

The rainfed rice growing areas of Camarines Sur in Bicol were chosen for our first concentrated study because:

- farmers already are growing two crops of modern rices a year;
- recommendations are available for rainfed rice production in the region (PCARR 1977);
- Bicol is one of the major rainfed rice growing regions of the Philippines and yields are low -- 1.7 t/ha per crop;
- working in this area would not duplicate rainfed rice research being undertaken by Philippine agencies or other IRRI research programs; and
- the Bicol River Basin Development Authority coordinates the agricultural activities of government agencies in the region. Hence, an institution is in place to extend benefits emerging from the research, should they occur.

The specific objectives of this paper are to:

1. describe farming practices in a typical rainfed rice area of the Bicol region;
2. measure the on-farm yield gap, determine the contribution of managed factors to this gap, and assess the importance of site and managed factors when examining yield variability; and
3. assess, from the farmer's viewpoint, the profitability of increasing inputs above current levels.

Part I of this paper is an overview of rainfed rice farming in Camarines Sur. Part II examines on-farm constraints to higher rice yields in the area.

Table 3. Yield difference between rainfed and irrigated rice, Bicol region and the Philippines, 4 periods.[a]

Period	Yield (t/ha)			Index of yield difference
	Rainfed	Irrigated	Difference	
		Bicol		
1964-66	1.2	1.8	0.6	100
1969-71	1.1	1.9	0.8	133
1974-76	1.5	2.2	0.7	117
1978-79	1.6	2.6	1.0	167
		Philippines		
1964-66	1.2	1.7	0.5	100
1969-71	1.4	1.3	-0.1	-20
1974-76	1.4	2.1	0.7	140
1978-79	1.5	2.5	1.0	200

a/ Calculated from data obtained from the Bureau of Agricultural Economics, Ministry of Agriculture, Philippines.

PART I
RAINFED RICE PRODUCTION

The study was started in three villages of Camarines Sur during the first-crop season of 1980-81. Two data-gathering mechanisms were used:

- farm management record keeping field surveys, and
- yield constraints experiments described by De Datta et al (1978).

Table 2. Hectarage, area planted to modern varieties, and yield of wetland rice in the Philippines, by region, 1976-77.

Region	Total rice-producing area (ha)	Rainfed lowland rice area (ha)	Rainfed area as % of total	Rainfed area planted to MV (%)	Yield (t/ha)
Ilocos	326,725	172,305	53	50	1.5
Cagayan Valley	425,650	161,135	38	60	1.4
Central Luzon	436,465	145,710	33	87	1.9
Southern Tagalog	458,600	142,230	31	72	1.4
Bicol	336,500	158,380	47	89	1.7
Eastern Visayas	180,865	123,080	68	59	1.1
Western Visayas	461,450	338,940	73	84	1.6
Central Visayas	88,800	56,450	64	68	1.4
Northern Mindanao	322,170	112,730	35	86	1.4
Southern Mindanao	382,235	197,075	52	54	1.1
Western Mindanao	146,950	67,010	46	69	1.9
Philippines	3,566,410	1,675,045	47	71	1.5

Source: Barker and Herdt (1979), Bureau of Agricultural Economics (1976-77).

Selection of villages and survey respondents

The role that rainfed rice plays in the rice economy of a region is an important consideration in selecting sites for constraints studies. Almost half (47%) of the rice area in Bicol is wetland rainfed. It was not difficult to identify areas where rainfed rice dominates. Camarines Sur produces almost 30% of the region's rice output. About two-thirds of the Bicol river basin area, which is being developed by the Bicol River Basin Development Authority, is in Camarines Sur. Pending full implementation of irrigation projects, however, a large proportion of the area remains rainfed, producing 37% wetland and 15% dryland rice (Table 4). Ten municipalities, predominantly under wetland rainfed cultivation, account for more than 60% of the province's rainfed rice area (Table 4).

The field site was the municipality of San Fernando, which is north of Naga, the capital of Camarines Sur. Three rainfed villages -- Planza, Beberon, and Lupi -- were chosen for farm surveys and field experiments. Planza is located along the Manila-South highway with households clustered along the main road. By contrast, Beberon and Lupi are adjoining barangays 6 km northwest of San Fernando reached by a rough road serviced by jeepneys plying the Naga City-Lupi route. Households in Beberon and Lupi are more scattered than in Planza because there are extensive upland areas in these villages.

A list of family households in the three survey villages was not available when field work started in May 1980. The first task was to conduct a census of each village. The census was used to divide households into farm families and nonfarm families. The former was subdivided according to tenure status. Eighty-four farmer cooperators (42 owners and 42 tenants) were randomly selected from the 3 villages as the survey sample. Later, however, we found some of the sample tenants owned portions of the land they farmed. These dual forms of land tenure are reflected in several of the following tables.

The 84 farmer cooperators were visited weekly to record information on input use, cultivation practices, and rice output data related to the respondent's largest rice parcel, termed the intensive data parcel (IDP). Many farmers farmed only one parcel of land, hence IDP was synonymous with the rice farm as a whole. Single-visit surveys were made to record farm inventories, farmer prices, yield constraints perceived by farmers, and credit use. Four barangay assistants were enumerators for repeat- and single-visit surveys. They also recorded work undertaken and the moisture status of each sample IDP every 2 days.

Twenty-four constraints experiments (12 in Planza and 6 each in Beberon and Lupi) were established in the 3 villages during the second-crop (October-January 1981-82) season. Half the experiments in each village were located on plateau-upper slopes, and half on lowland plains.

CHARACTERISTICS OF SURVEY VILLAGES

Climatic conditions

Rainfall. Mean annual rainfall in the province is 1,812 mm (Fig. 1). The wet season usually starts late May and ends late December or early January. Rainfall is usually evenly distributed June through December, providing 7 months of rainfall above 200 mm/month. Farmers usually can plant two rainfed rice crops each year. Rainfall in 1980 was

Table 4. Effective and physical wetland rice area, area double-cropped, and yields, 10 municipalities, Camarines Sur province, Bicol, 1971.[a]

Municipality	Rainfed wetland rice area		Rainfed wetland as % of total rice area	% area double-cropped	Yields[b] (t/ha)	
	Effective	Physical			First crop	Second crop
Libmanan	6,818	4,900	50	39	0.5	0.6
Iriga	4,251	2,615	72	62	1.1	0.9
Canaman	3,646	2,470	89	48	0.6	1.5
Pamplona	3,080	2,212	81	39	0.5	0.7
Nabua	2,795	2,518	52	11	1.2	1.0
Caramoan	2,487	1,548	74	61	0.7	1.2
Buhi	2,231	1,514	52	47	0.6	0.9
San Fernando	2,092	1,214	62	72	0.4	0.7
Bato	1,802	1,608	84	12	0.5	0.4
Calabanga	1,476	1,120	39	32	0.4	1.0
Ten municipalities	30,678	21,719				
Camarines Sur	49,223	34,930	37	41	0.7	1.0

[a] Calculated from 1971 Census of Agriculture Tables. National Census and Statistics Office, NEDA. [b] Note that the yield figures relate to census data for 1971 -- before the general adoption of MV in the area.

1,470 mm, about 340 mm less than the 15-year average (Fig. 1). Lower-than-average rainfall in September and October caused some moisture stress in the second rice crop. Lower-than-normal December rainfall also stressed many crops as they approached maturity. Late December, early January (1981) rainfall, however, was above normal.

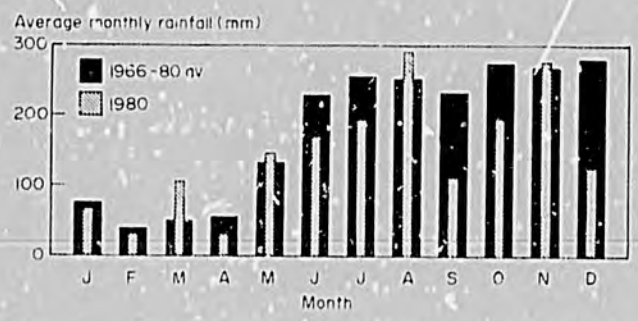

Fig. 1. Average monthly rainfall at Pili, Camarines Sur, Philippines, based on 15 years (1966-80) of rainfall data.

Stability of a two-rainfed-rice cropping pattern is influenced by rainfall variability as well as by wet season duration and total rainfall. One way to examine this point is to plot the quantity of rainfall in terms of crop requirements for given intervals for a sequence of years. The pentad (5-day interval) diagram derived from rainfall records kept by the Bicol Rice and Corn Experiment Station at Pili (about 15 km south of the field site) for 1966-80 is shown in Figure 2. The four rainfall categories shown in the figure correspond roughly to rainfall which, during the 5-day period:

1. was well below the evapotranspiration requirement of a rice crop -- DRY1;
2. met about one-half the requirement -- DRY2;
3. met about three-quarters the requirement -- WET1; and
4. exceeded the requirement -- WET2.

Because the rice is rainfed, the pentad diagram shows climatic variability for rice production both within and over years. For example, rains normally start in May. By June, the major planting period, there is roughly an equal probability that dry (DRY1, DRY2) and wet (WET1, WET2) periods will occur. In July, August, and early September favorable rainfall (WET2, WET3) generally prevails. By late September-October or early November drier periods are more frequent. During this period the first rice crop is harvested and the second crop planted. Dry weather at this time (DRY1, DRY2) will probably depress rice yields if crops are in the late reproductive stage, and may also delay planting of the second crop. Weather conditions are more favorable in late November through early January. However, if the second rice crop is planted late it will mature when moisture stress conditions are increasing.

Typhoons and storms. Figures 3A and 3B show the incidence of tropical storms and typhoons in Bicol. Typhoons and tropical storms frequently occur between July and December. The study area experiences an average of four to five typhoons and two tropical storms each year. Typhoon-prone months

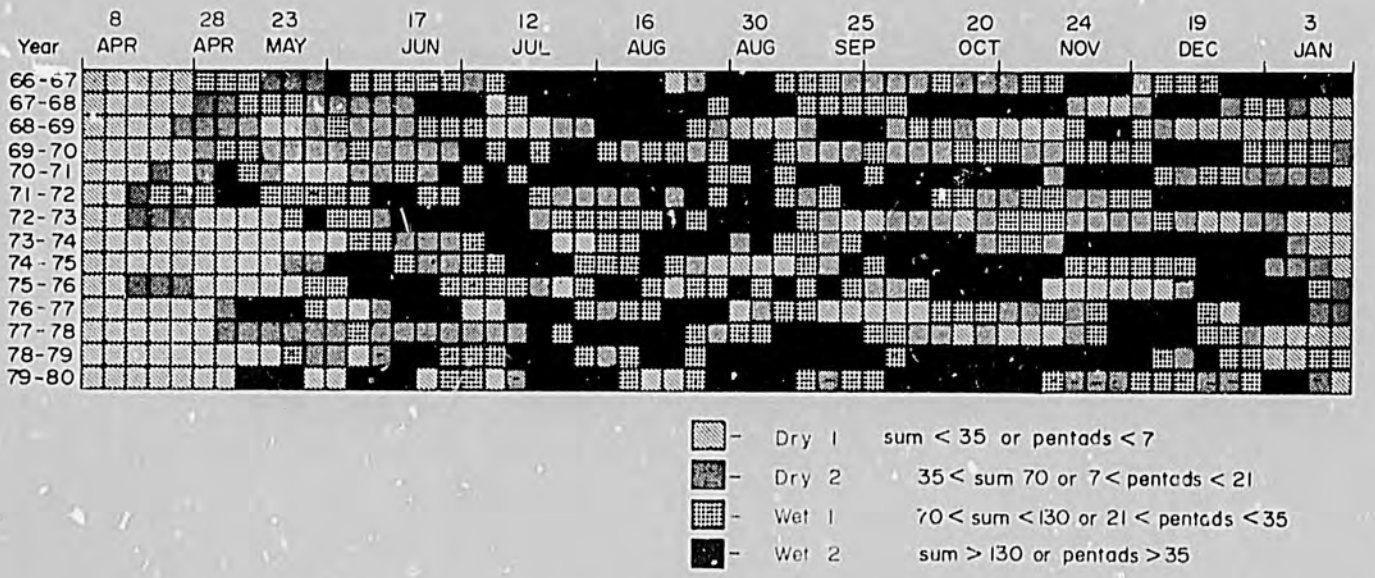

Fig. 2. Pentad diagram for Pili, Camarines Sur, Philippines, 1966-80.

are October and November. This mean expectation is subject to considerable variation. The range is 0-8 typhoons and 0-5 tropical storms per year. Although the 18-year observation period is short when making longer-term inferences, farmers who plant early to harvest in the low-typhoon-incidence months of August and September clearly have a better chance of avoiding crop loss than those who plant later.

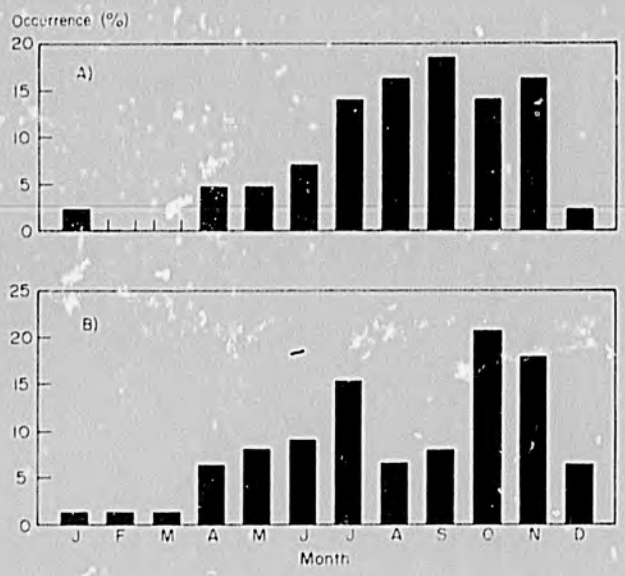

Fig. 3. Percentage of occurrence of tropical storms (A) and typhoons (B) each month in Bicol, Philippines, based on 18 years (1956-73) data.

Land use

Information obtained from barangay officials and the census survey is summarized in Table 5. All rice lands in the villages were rainfed. A few farmers had used pump sets in the past but no longer did so because of the high pumping cost or because their wells had dried up.

Land area and land use. Official land surveys of the towns listed total farm area of the villages as 203 ha for Planza, 187 ha for Beberon, and 137 ha for Lupi. Of the 203 ha in Planza, 80% is planted to rice. Beberon has 40% of its area planted to rice, 30% to coconut, and the rest to sugarcane and other crops. Fifty-eight percent of the area in Lupi is planted to rice and about 40% to coconut. Planza is dominantly a rice village because it is located entirely on rainfed rice lands but substantial portions of Beberon and Lupi are dryland. Demarcation between drylands and wetlands is distinct.

The three barangays had similar total number of households. Households ranged from 143 in Beberon to 154 in Lupi. Beberon had the highest proportion of farm households (87%) and Lupi the lowest (73%). There were more rice farming households in Planza (115) than in Beberon (94) or Lupi (90) which reflects the dominance of rice in the first village compared to the area under upland crops in Beberon and Lupi. As a result, the average operational rice holding is somewhat larger in Planza (1.3 ha/household) than in Beberon or Lupi (0.8-0.9 ha/household).

Table 5. General characteristics of sample villages, San Fernando, Camarines Sur, 1980-81.[a/]

Item	Planza	Beberon	Lupi
Source of irrigation	Rainfed	Rainfed	Rainfed
Total land cultivated (ha)	203.0	187.4	136.8
Estimated rice area (ha)	151.0	75.0	80.8
Estimated coconut area (ha)	10.0	62.0	55.0
Other crop area (ha)	32.0	50.4	26.0
Total no. of farm households	119	124	113
Number of rice farming households	115(100)	94(100)	90(100)
Owner cultivator	53(46)	39(41)	32(36)
Tenant cultivator	38(33)	46(49)	31(34)
Part owner	13(11)	2(2)	13(14)
Others	11(10)	7(7)	14(16)
Nonfarming households	30	19	41
Average operational holding per farm (ha)	1.7	1.5	1.2
Average operational holding for rice (ha)	1.3	0.8	0.9
Number of hand tractors	13	6	9
Number of small threshers	6	2	2
Number of small rice mills	2	2	3

[a/] Figures in parentheses are percentages. Source: Census conducted by IRRI Agricultural Economics Deparment Staff, July 1980.

Land tenure. Dominant land tenure forms in the study area were owner operators and tenant operators. The proportion of owner operators ranged from 36% in Lupi to 46% in Planza. The proportion of tenant cultivators was also between one-third and one-half. These two groups account for more than 75% of all farm households. There were similar numbers of part owners and tenants-cum-leaseholders in each barangay.

The most common sharing arrangement on tenanted rice farms is two-thirds:one-third. The tenant pays all production costs and chooses his production technology. Rice output is shared 2:1 between the tenant and his landlord after harvesters' shares are deducted. Harvesters' shares ranged from one-ninth to one-eleventh, depending on kinship ties between the harvester, farmer, or landlord.

Rice area per farm. Rice farms in the study site are small by Philippine standards. The modal size was 0.6 ha; only 4 farmers in the sample cultivated more than 2 ha of rice, and 75% of the farms were less than 1 ha (Table 6). The distribution of owned rice lands was positively skewed with a mode of 0.5 ha and a mean of 0.8 ha. The distribution of tenanted land was normal with a mode of 0.7 ha and a mean of 0.8 ha. The smaller modal farm size of owners compared to that of tenants may reflect the relatively easier subdivision of owned land compared to tenanted land. Also, landlords probably prefer to deal with as few tenants as possible.

Table 6. Characteristics of rice holdings of sample farmers, three villages, Camarines Sur, 1980-81.

Tenure	n	Rice holding (ha)			
		Mode	Mean	Low	High
Owner	46	0.50	0.78	0.12	2.45
Tenant	43	0.75	0.80	0.21	1.93
Part owner	14	0.75	1.01	0.28	2.60
All	103	0.60	0.80	0.12	2.60

Dominant cropping patterns. Figure 4 shows dominant cropping patterns observed in the survey villages. Rice was wet-seeded (WSR) from late May whereas transplanting (TPR) started late June. Fifty-three per cent of the first rice crop was wet-seeded. Most of the second crop was planted in November through early December. WSR was dominant, particularly on those fields that grew WSR in the first season. A larger proportion of WSR land (37%) was left fallow in the second season compared to TPR land left fallow (27%).

RICE PRODUCTION IN SURVEY VILLAGES

Adoption of modern varieties

Use of MV is widespread among all tenure groups (Table 7). For the first crop, more than 70% of the farmers planted only IR varieties; IR36 was dominant, followed by IR42 and IR747. Twenty-eight per cent of the farmers planted MV and local varieties such as Malagkit, Benargais, and Javanese rices. Local varieties were grown primarily for home consumption and planted on a small portion of the farm.

All farmers planted at least one IR variety for the second crop. A number of farmers mixed varieties in the same paddy. A reason given for this management strategy was that it reduced the risk of complete failure of the second crop. However, we did not gather sufficient information to test the rationale of this suggestion.

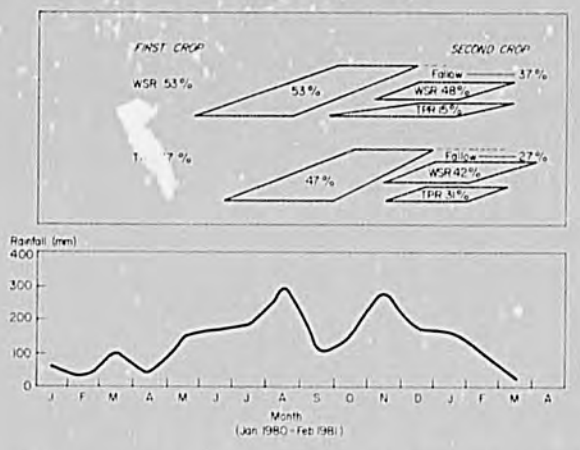

Fig. 4. Dominant cropping patterns observed at Camarines Sur field site, 1980-81.

Adoption of improved practices

Mechanized land preparation. A significantly higher proportion of part owners used tractors for land cultivation than did owners or tenants (Table 8). More time was spent on mechanized land preparation for the second crop (av 4.5 days/ha) than for the first crop (av 2.9 days/ha). Carabao were used on all farms for land preparation -- particularly for harrowing and the final rolling (pagulong) of the field before rice was seeded or transplanted.

Crop establishment. About half the first rice crop was direct-seeded and half transplanted (Table 9). A significantly larger proportion of owners and part owners wet-seeded the first rice crop than did tenants. The method of establishing the second crop did not differ significantly by tenure.

From discussions with farmers it appears the decision to wet-seed or transplant tends to be influenced by three factors:

- water status of the field,
- availability of seedlings when a field was ready for transplanting, and

- farmer's expectation of whether the crop may need to be replanted due to drought or flooding loss.

Farmers who planted earliest -- frequently they were owners -- also tended to direct-seed because of field water status and the risk of crop failure through subsequent drought. For the second crop, establishment method tended to be determined by water status of fields, which varied considerably, even between adjacent fields.

Wet seeding in Bicol has been practiced since prehispanic times. It is not a recent response to labor shortages or higher labor cost. We suspect the decision to wet-seed or transplant in this rainfed environment is principally determined by biophysical, not economic, parameters.

Table 7. Proportion (%) of farmers planting modern and traditional varieties, by tenure group. Camarines Sur, 1980-81.

Crop period and variety	Owner	Tenant	Part owner/ owner-cum-tenant cultivator	All
First crop				
IR only	71	73	70	71
IR and traditional	27	27	30	28
Traditional only	2	0	0	1
Second crop				
IR only	91	74	79	81
IR and traditional	9	26	21	19
Traditional only	0	0	0	0

Table 8. Percentage of sample farmers adopting mechanized land preparation and use level, by tenure category, Camarines Sur, 1980-81.[a/]

	Owner	Tenant	Part owner	All	χ^2
Percentage of adoption					
First crop	41	30	90	50	11.13*
Second crop	35	34	84	42	9.97*
Average level of use by adopters (days per hectare)					
First crop	3.2	2.2	1.8	2.9	-
Second crop	6.0	3.3	3.9	4.5	

[a/]An asterisk (*) means significantly different at the 5% level.

Table 9. Percentage of sample farmers direct-seeding the rice crop, Camarines Sur, 1980-81.[a/]

	Owner	Tenant	Part-owner	All	χ^2
First crop	59	39	50	50	7.68^{**}
Second crop	58	56	74	59	1.47^{ns}

[a/]An asterisk (*) means significantly different at the 5% level, ns means the estimate is not significant.

Table 10. Percentage of farmers adopting agrochemicals and input use of adopters,[a/] by tenure group and crop, Camarines Sur, 1980-81.[a/]

Crop	Owner	Tenant	Part owner	All	χ^2
Adoption					
First crop					
Fertilizer	17	6	10	12	2.11^{ns}
Insecticides	83	70	100	80	4.79^{ns}
Herbicides	93	91	100	93	1.12^{ns}
Second crop					
Fertilizer	3	6	8	5	3.44^{ns}
Insecticide	42	56	75	52	4.16^{ns}
Herbicide	48	50	75	52	2.87^{ns}
Level of use[b/]					
First crop					
Fertilizer	16	29	24	19	
Insecticides	29	24	35	29	
Herbicides	21	25	33	24	
Second crop					
Fertilizer	6	23	11	15	
Insecticides	27	29	22	26	
Herbicides	15	17	17	16	

[a/]ns means not significant at the 5% level. [b/]Fertilizer use levels are in kg N + P_2O_5 + K_2O per hectare; insecticide and herbicide costs are in ₱eso/hectare. US$1=₱7.50.

Agrochemicals. Fertilizer use did not differ between tenure groups (Table 10). On the average, 12% of the sample farmers applied fertilizer to the first crop but only 5% applied to the second. Quantity of fertilizer applied (measured in terms of total nutrients) by users was low. Application averaged 19 kg/ha for the first crop and 15 kg/ha for the second crop. Actual fertilizer use is substantially below the 60-30-0 kg/ha recommended for rainfed conditions in the Philippines (PCARR 1977). Such recommendation is probably derived for more favorable conditions than those existing in rainfed Bicol.

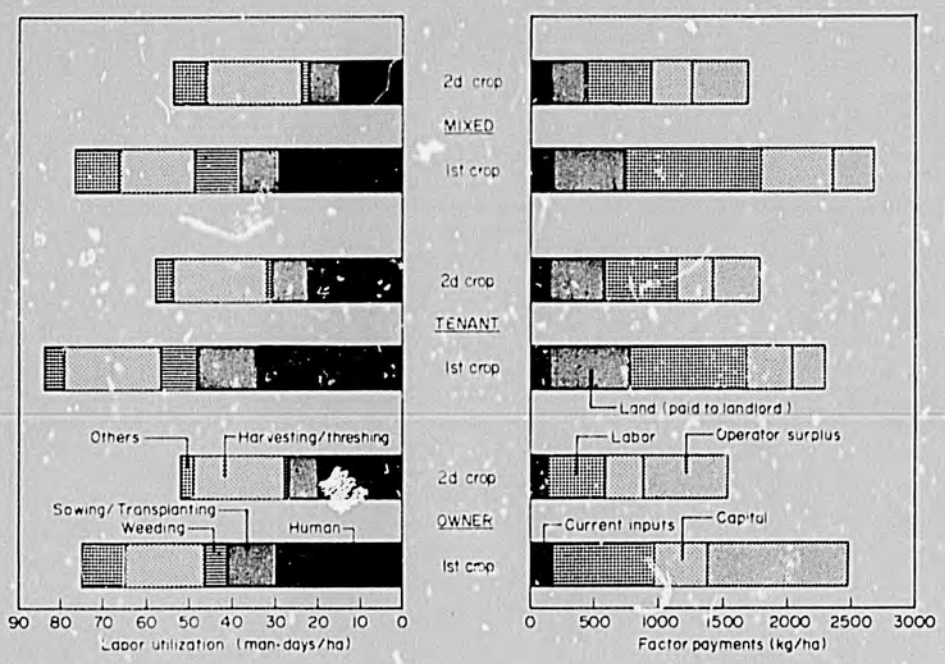

Fig. 5. Labor utilization and cost-return structure by tenure and crop, Camarines Sur, 1980-81.

Insecticides and herbicides are more widely used by farmers than is fertilizer. They are more frequently applied to the first crop than the second crop (Table 10). One foliar spray, costing an average of ₱26-29/ha, was commonly used for insect control. This implies an application rate of less than 0.2 kg active ingredient (a.i.), well below the recommended 0.8 kg a.i./ha. The most common herbicide used was liquid 2,4-D. Butachlor is becoming more widely used in the study area.

Labor input

Although more owners and part owners used power tillers for land preparation and wet-seeded their crop than did tenants, there was no significant variation in the pattern of labor use among the three tenurial classes (Fig. 5). Labor use for the first transplanted rice crop was 103 days/ha. Significantly less labor (55 days/ha) was used for a wet-seeded crop (Table 11). Family members provided more than half of the labor used to grow the crop.

Three operations (land preparation, transplanting, and harvesting and threshing) accounted for more than 80% of labor use. Minimal quantities of labor were used for crop maintenance. Substantially more labor was used to prepare land for the direct-seeded (47 days/ha) than for the transplanted crop (37 days/ha), however, significantly more labor was used to transplant than direct-seed the crop. It also took longer to harvest the direct-seeded crop than the transplanted crop.

Table 11. Comparison of labor inputs per hectare for direct-seeded vs transplanted rice of sample farmers in three villages, Camarines Sur, first crop, 1980-81.

Activity	Direct seeded		Transplanted		Difference[a]
	Man-days	%	Man-days	%	
Land preparation[b]					
Human	25.7	47	38.0	37	12.3*
Machine	1.4		0.8		-0.6
Animal	19.3		28.2		8.9*
Sowing/transplanting	1.5	3	22.8	22	21.3*
Weeding	4.4	8	9.6	9	5.2
Harvesting and threshing	16.3	30	24.4	24	8.1*
Fertilizer and chemical application	0.6	1	1.1	1	0.5*
Others[c]	6.0	11	7.5	7	1.5
Total	54.5	100	103.4	100	48.9*
Family	32.4	59	53.7	52	21.30*
Hired	22.1	41	49.7	48	27.60*

[a] An asterisk (*) means significantly different at the 5% level or better. [b] Includes clearing and repairing dikes. [c] Includes cleaning and hauling operations.

A similar pattern of labor use emerges for the second crop (Table 12). Labor inputs tend to be lower for the second crop than for the first crop. The direct-seeded crop needed 43 days/ha and the transplanted crop needed 79 days/ha, mainly because transplanting is considerably more labor intensive than direct seeding.

Table 12. Comparison of labor inputs per hectare for direct-seeded vs transplanted rice of sample farmers in three villages, Camarines Sur, second crop, 1980-81.

Activity	Direct seeded		Transplanted		Difference[a]
	Man-days	%	Man-days	%	
Land preparation[b]					
Human	17.1	40	24.5	31	7.4
Machine	2.4		1.9		-0.5
Animal	12.8		18.3		5.5
Sowing/transplanting	1.3	3	20.8	26	19.5*
Weeding	1.0	2	0.5	1	-0.5
Harvesting and threshing	20.4	47	26.6	33	6.2*
Fertilizer and chemical application	0.7	2	0.8	1	0.1
Others[c]	2.6	6	6.5	8	3.9
Total	43.1	100	79.9	100	36.6*
Family	22.2	52	40.4	51	18.2*
Hired	20.9	48	39.3	49	18.4*

[a] An asterisk (*) means significantly different at the 5% level or better. [b] Includes clearing and repairing dikes. [c] Includes cleaning and hauling operations.

Table 13. Mean rice yields by tenure, method of crop establishment, and crop, Camarines Sur, 1980-81.[a]

Method of crop establishment	Yield (t/ha)			All
	Owner	Tenant	Part owner	
First crop				
Wet seeded	2.3	2.0	2.5	2.2
Transplanted	2.8	2.5	2.9	2.6
Difference	0.5*	0.5*	0.4ns	0.4*
Second crop				
Wet seeded	1.4	1.5	1.6	1.5
Transplanted	2.0	2.2	2.0	2.1
Difference	0.6*	0.7*	0.4ns	0.6*

[a] An asterisk (*) means significantly different at the 5% level or better; ns = not significant.

Rice yields

Mean rice yields did not differ by tenure group in either season, but they differed by crop establishment method (Table 13). For the first crop, average yield obtained by tenant cultivators was 2.3 t/ha, compared to 2.5 and 2.7 t/ha obtained by owner cultivators and owner-cum-tenant cultivators. In general, second-crop yields, averaging 1.6 t/ha, were significantly lower than first-crop yields.

Mean rice yields differed by crop establishment under owned and tenanted areas. For owners, the mean yield differences between direct-seeded and transplanted rice were 0.5 t/ha for the first crop and 0.6 t/ha for the second crop. Similar yield differences were obtained under share-tenanted farms. The following economic analysis examines the production systems for owners and tenants, the two dominant forms of tenure, and direct-seeded and transplanted rice crops.

Is the crop establishment method the real reason for the significant difference in yields between WSR and TPR? An analysis of field water status (we categorized fields with less than 20 stress days as low stress fields, and those with more than 20 stress days as high-stress fields) versus crop establishment method showed direct seeding was most frequently used on fields with higher moisture stress levels (Table 14). Moisture stress, as opposed to crop establishment method, accounted for the significant yield difference between WSR and TPR, as will be confirmed in later analysis.

Table 14. Proportion of farmers wet-seeding their rice crop and the water status of the field, first and second crops, Camarines Sur, 1980-81.

Crop	% of crop wet-seeded		χ^2[b]
	Low stress	High stress[a]	
First crop	42	78	7.07**
Second crop	48	84	23.77**

[a] Low-moisture stress sites had less than 20 days of stress, high-stress sites had more than 20 days of stress. [b] Two asterisks (**) means significantly different at the 1% level.

Credit practices

Rainfed areas in Bicol are currently excluded from the Masagana 99 credit program. More than half the owners and 37% of the tenants interviewed claimed they did not borrow money for farming (Table 15). Most frequent borrowing sources were friends and relatives and banks. Effective interest rates averaged 71%/year from the former source and 13%/year from the latter.

Tenants and part owners most frequently borrowed money from friends and relatives, but at higher interest rates (108-116% a year). The difference

between owner and tenant rates suggests owners are given preferential rates over their tenant counterparts, perhaps because landowners have higher status in the community.

For all farmers, average credit level was ₱762/ha. Yet, average cash outlay per hectare for the 2 rice crops was ₱300/ha. This suggests that most of the loans reported were not being used for rice or, for that matter, for agricultural purposes.

ECONOMIC ANALYSIS OF RICE PRODUCTION SYSTEMS

We evaluated economic performance of direct-seeded and transplanted rice by comparing the input and output values for an owner and for a tenant operator. The results are shown in Tables 16 and 17, and summarized in Figure 5. The tables show how output per hectare was distributed among various factors used in growing the rice crop and show the

Table 15. Credit, source, and interest rates, by tenure group, three villages, Camarines Sur, 1980-81.

Credit source	Owner cultivator			Tenant cultivator			Owner-cum-tenant cultivator		
	%	Amount borrowed[a] (₱/ha per year)	Interest (%/year)	%	Amount borrowed[a] (₱/ha per year)	Interest (%/year)	%	Amount borrowed[a] (₱/ha per year)	Interest (%/year)
Friends and relatives	35	532	71	40	552	108	50	429	116
Landlord	0	0	-	7	221	119	21	445	133
Middleman	2	2000	43	0	0	-	0	0	-
Institutional (Banks)	7	5333	13	7	2736	12	8	580	12
Others	2	3670	12	9	809	125	21	4000	42
Did not borrow	54	0	-	37	0	-	0	0	-
All	100	736	56	100	500		100	1208	96
(n)		(46)			(43)			(14)	

[a] US$1 = ₱7.50.

Table 16. Cost-return structure of wet-seeded vs transplanted rice, by tenure, three villages, Camarines Sur, first crop, 1980-81.

	Factor payments[a] (kg/ha)		Factor shares (% of output)	
	Owner cultivator	Tenant cultivator	Owner cultivator	Tenant cultivator
Wet-seeded rice				
Output rough rice	2259	2038	100	100
Factor payments:				
Current inputs	146	162	6	8
Land (paid to landlord)	-	598	-	29
Capital[b]	392	377	17	18
Labor: Total	647	704	29	35
Hired	356	463	16	23
Family	291	241	13	12
Operator surplus	1074	197	48	10
(Sample size)	(24)	(13)		
Transplanted rice				
Output rough rice	2768	2465	100	100
Factor payments:				
Current inputs	183	114	7	5
Land (paid to landlord)	-	724	-	29
Capital[b]	399	361	14	15
Labor: Total	1053	1059	38	43
Hired	577	641	21	26
Family	476	418	17	17
Operator surplus	1133	207	41	8
(Sample size)	(17)	(20)		

[a] Measured in rice equivalents. [b] Sum of paid or imputed rentals or carabao, tractor, and other machines.
US$1 = ₱7.50

Table 17. Cost-return structure of wet-seeded vs transplanted rice, by tenure, three villages, Camarines Sur, second crop, 1980-81.

	Factor payments[a] (kg/ha)		Factor shares (% of output)	
	Owner cultivator	Tenant cultivator	Owner cultivator	Tenant cultivator
Wet-seeded rice				
Output rough rice	1354	1457	100	100
Factor payments:				
Current inputs	121	145	9	10
Land (paid to landlord)	-	355	-	24
Capital[b]	266	298	20	20
Labor: Total	363	494	27	34
Hired	356	463	26	32
Family	7	31	1	2
Operator surplus	604	165	44	10
(Sample size)	(29)	(18)		
Transplanted rice				
Output rough rice	2007	2182	100	100
Factor payments:				
Current inputs	132	105	7	5
Land (paid to landlord)	-	558	-	26
Capital[b]	333	259	17	12
Labor: Total	711	650	35	30
Hired	384	457	19	21
Family	327	193	16	9
Operator surplus	831	610	41	27
(Sample size)	(11)	(14)		

[a] Measured in rice equivalents. [b] Sum of paid or imputed rentals of carabao, tractor, and other machines. US$1 = ₱7.50.

farm operator's surplus (net profits) after costs have been paid. Despite higher labor use for TPR, net profits were similar for the first crop and greater for the second crop compared to WSR. Even if transplanted first-crop profits were not higher, the farm operator benefited from increased farm-family labor return.

The cost-return structure, measured in terms of factor shares, indicates the share to capital is low. It did not differ between either crop establishment method. Operator surplus ranged from 41 to 48% of the total output for owner cultivators and from 8 to 27% for tenant cultivators. Operator's surplus includes a return to management and to land investment. For a tenant operator, surplus is the management return.

Economic advantages of TPR compared to WSR are more evident when income shares to various factors of rice production are calculated. The value added from a two-crop rice pattern, and its distribution among various earners for the two planting methods are compared in Table 18. An income of ₱4,700/year from transplanted rice was almost ₱1,300 higher than for direct-seeded rice. Operator's surplus increased absolutely for both owner cultivator and tenants. Farmers' increased income resulted from more intensive use of farm family labor and hired labor with transplanted rice. Transplanting may be the preferable practice in view of the labor employment problem and society welfare. However, the trade-off of early crop establishment by direct seeding, which increases the probability of a higher-yielding second rice crop, must be considered. These issues will be examined in more detail.

PART II
RICE YIELD CONSTRAINTS

Twenty-four constraints experiments were established in the 3 survey barangays. Twelve were on plateaus and upper slopes (high-elevation sites), and 12 were on valley bottom plains (low-elevation sites). This division was chosen because we hypothesized that, all other things being equal, rice yields are lower on the upper than on the lower aspects of the toposequence because of their less adequate water regimes (Bolcon and Zandstra 1980).

Complete factorial treatments in fertilizer, insect, and weed management formed the basis of the experiment. Lower input levels were the farmer's current practices. Higher levels were the researcher's practice. Researcher's input levels

Table 18. Comparison of income per hectare per year and its share among earners by crop establishment and tenure, three villages, Camarines Sur, 1980-81.

	Owner cultivators		Tenant cultivators	
	₱/ha	%	₱/ha	%
Wet-seeded rice				
Value added[a/]	3559	100	3403	100
Earners:				
Landlord	-		1027	30
Farmer	2953	83	1688	50
Capital[b/]	698	20	719	21
Labor	458	13	463	14
Operator surplus	1797	50	506	15
Hired laborer	606	17	688	20
Transplanted rice				
Value added[a/]	4772	100	4701	100
Earners:				
Landlord	-		1365	29
Farmer	3744	78	2072	44
Capital	785	16	699	15
Labor	854	18	674	14
Operator surplus	2105	44	699	15
Hired laborer	1026	22	1197	25

[a/] Output value less current input costs. US$1=₱7.50.
[b/] Includes return to hired capital.

Table 19. Test levels and farmer's levels of inputs and practices used in constraints experiments, Camarines Sur, second crop, 1980.

Input levels	Fertilizer[a/] (kg/ha) N	P_2O_5	K_2O	Zn	Insect control[b/] F	G	Weed control[c/] F	G
Complete factorial								
Farmers'	0	0	0	0	0.5	0	0.6	0
High	45	30	0	10	2	1	0	1
Additional treatments								
9	15	30	0	10	2	1	0	1
10	30	30	0	10	2	1	0	1
11	60	30	0	10	2	1	0	1
12	60	30	30	20	2	1	0	1

[a/] Nitrogen was applied in 2 equal split doses: basal, and 5-7 days before panicle initiation. P_2O_5 and Zn were incorporated during the last harrowing. [b/] Farmers insect control consisted of 1 foliar application (F) equivalent to 0.08 kg a.i./ha at 28 days after seeding (DS) or days after transplanting (DT). High level involved 1 granular application of carbofuran at 0.5 kg a.i./ha applied at 5 DT/DS and 2 applications of azimphonethyl at 0.75 kg a.i./ha at 55 and 70 DT/DS. F = foliar; G = granular. [c/] High level of weed control consisted of 1 application of butachlor at 1.25 kg a.i./ha at applied 4-6 DT/DS. Farmers' level involved 1 spray of 2,4-D equivalent to 0.13 kg a.i./ha applied 25 days after establishment. F = foliar, G = granular.

were those judged realistic from a farmer's viewpoint. They were not maximum yield inputs (Table 19). The researcher's fertilizer treatment included nitrogen (45 kg/ha), phosphorus (30 kg P_2O_5/ha), and zinc sulfate (10 kg/ha). Researchers anticipated that phosphorus or zinc, in addition to nitrogen, might be deficient in the area. The researcher's insect and weed management strategies were those recommended elsewhere for rainfed rice and cost ₱400 and ₱105 per ha, respectively. The eight factorial treatments were augmented with four treatments to allow a response surface in nitrogen to be fitted over the sites.

Mean levels of selected soil parameters for the low- and high-elevation sites are in Table 20. Low-elevation sites had significantly higher clay content, and associated higher levels of exchangeable potassium, and cation exchange capacity (CEC). The CEC, however, is low for Philippine rice soils (a general figure is 30-40 meq/100 g, De Datta, IRRI [pers. comm.]), indicating a low inherent fertility status at the research site. Available phosphorus (Olsen) had a mean value of 6.4 ppm. Available phosphorus in more than 80% of the experimental sites was below the critical 10 ppm value. Therefore, it was likely that rice would respond to phosphorus as well as to nitrogen at this site.

Table 20. Mean value of site variables for constraint experiment located on low- and high-elevation landscape positions, rainfed constraint experiment, Bicol, 1980-81.

Site variable	Low elevation	High elevation	Difference[a/]
Soil characteristics			
Particle size analysis			
Clay (%)	65.1	43.3	21.8*
Silt (%)	26.0	30.7	4.7*
Sand (%)	8.9	26.0	17.1*
pH	5.5	5.5	0^{ns}
Total N (%)	0.2	0.2	0^{ns}
Organic matter (%)	2.8	2.5	0.3^{ns}
Available P (Olsen) (ppm)	8.3	4.5	3.8^{ns}
Exchangeable K (meq/100g)	0.2	0.1	0.1*
Available Zn (K+P) (ppm)	0.8	1.0	0.2^{ns}
CEC (meq/100g)	22.9	14.7	8.2*
Water stress			
Early (days)	12.2	15.3	3.1^{ns}
Late (days)	7.9	11.5	3.6^{ns}
Total (days)	20.1	26.8	6.7^{ns}
n	12	12	

[a/] Differences in means are based on calculated student t tests. An asterisk (*) means significantly different at the 5% level, ns means not significant.

Mean incidence of moisture stress, calculated as suggested by Wickham (1971), over the course of the experiments, measured in terms of stress days, was greater on the high-elevation sites than on low-elevation sites. However, because of high within-group variability, mean incidence of stress days did not differ significantly between the two landscape positions ($\chi^2 = 2.74^{ns}$).

Yields and site groupings

The mean farmer's yield over the 24 sites was 1.6 t/ha. Mean researcher's yield was 2.8 t/ha. The mean researcher's yields were 2.9 t/ha for the low-elevation sites and 2.7 t/ha for the high-elevation sites. Farmer's yields were 1.7 and 1.6 t/ha for those 2 sites. Farmer's and researcher's yields, however, did not differ significantly by elevation (Table 21). This criterion, therefore, was not a satisfactory basis for differentiating sites based on responses to management factors.

Table 21. Analysis of variance of rice constraints experiments, by landscape position and treatment, Bicol, 1980-81.

	df	MS	F
Total	191		
Sites	23	4.36	32.92**
High vs low (HL)	1	.13	1.01^{ns}
Among high (H)	11	1.94	14.63**
Among low (L)	11	7.17	54.12**
Treatments (T)	7	3.90	29.45**
Error	161	.13	
HLxT	7	.51	
HxT	77	.15	
LxT	77	.08	

CV = 16.7%

A scattergram of yields against stress days showed that clustering sites on a stress day basis might be more productive. Sites with 20 days of stress or less were designated low-stress sites. Those with 21 or more cumulative days of stress were designated high-stress sites. Validity of this grouping by stress days was confirmed by an analysis of variance (ANOVA) of the pooled data which showed that mean yields were significantly different between the two sets of sites (Table 22). Bartlett's test for homogeneity of variance ($\chi^2 = 4.54^{ns}$) implies that the groupings were valid for a pooled ANOVA (Cochran and Cox 1960).

Yield gaps by sites

The mean yield of the farmer's treatment, at 2.1 t/ha for the low-stress sites, was significantly higher than the 1.3 t/ha estimated for the high-stress sites (Table 23). Researcher's yields were also significantly higher on the low-stress sites (3.2 t/ha) than on the high-stress sites (2.5 t/ha). Thus, both farmer's and researcher's yields were shifted upward by about the same amount on both sets of sites (Fig. 6). As a result, the yield gap for the 2 groups of sites (1.1 and 1.2 t/ha) did not differ significantly. Therefore, the yield gap of the pooled data, 1.2 t/ha, provides a reasonable estimate of the yield gap for the rainfed rice crop at the research site in the second season, 1980-81.

Table 22. Analysis of variance of rice constraints experiment, by moisture stress incidence and treatment, Bicol, 1980-81.

	df	MS	F
Sites	23	4.36	32.92**
Low vs high stress (LH)	1	27.78	180.12**
Within low (L)	9	5.62	35.20**
Within high (H)	13	1.69	15.08**
Treatments	7	3.90	29.46**
Insect control (I)	1	5.46	41.23**
Fertilizer (F)	1	20.71	156.44**
Weed control (W)	1	.86	6.52*
IxF	1	.02	$<1^{ns}$
IxW	1	.07	$<1^{ns}$
FxW	1	.05	$<1^{ns}$
IxFxW	1	.13	1.01^{ns}
Error[a/]	161	.13	
LMxT	7	.15	
LxT	63	.16	
HxT	91	.11	
Total	191		

[a/] Barlett's test for homogeneity of variance, $\chi^2 = 4.54^{ns}$.

Table 23. Mean yields of farmers' and researchers' practice and the resulting yield gap, low-stress and high-stress sites, and pooled data rainfed rice constraints experiments, Bicol, 1980-81.[a/]

	No.	Estimated yield (t/ha)		Yield gap (t/ha)
		Farmer	Researcher	
Pooled sites	24	1.59	2.77	1.18
Low-stress sites	10	2.08	3.18	1.10
High-stress sites	14	1.25	2.48	1.23
Difference (L-M)		.83**	.70*	$.13^{ns}$

[a/] An asterisk (*) means significantly different at the 5% level; ** at 1% ** means significantly different at the 1% level, ns means not significant.

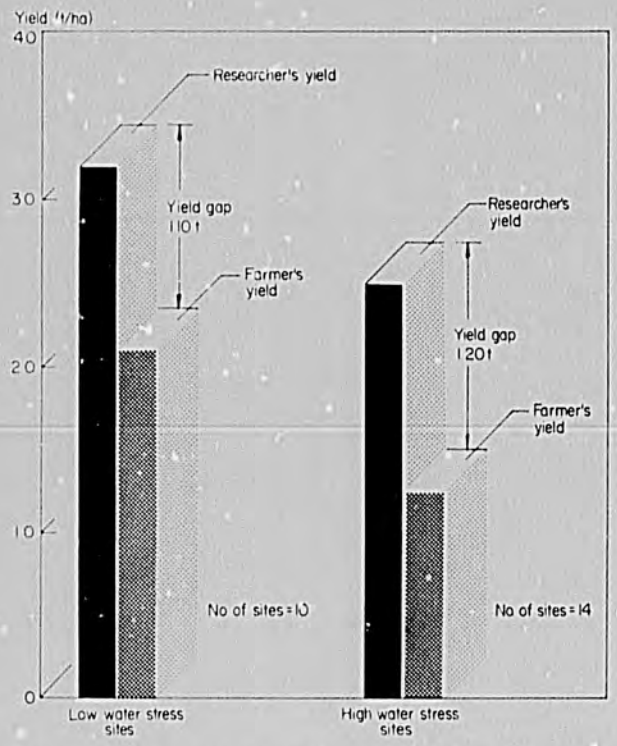

Fig. 6. Relative contribution of fertilizer, insect control, and weed control to rice yield improvement on farmers' fields under low and moderate moisture stress conditions, Bicol, Philippines, 1980.

Contribution of test factors to the yield gap

Because higher order interactions were not significant (see the ANOVA in Table 23) the yield gap can be directly attributed to the three test factors as demonstrated by De Datta et al (1978, p. 47).

Fertilizer. The mean contribution of fertilizer to the yield gap was 0.6 t/ha for the low-stress sites and 0.7 t/ha for the high-stress sites (Table 24). These values were not significantly different. Therefore, the mean contribution of fertilizer over all sites (0.6 t/ha) provides a reasonable estimate of the contribution of fertilizer to the yield gap.

Insect control. Insect control contributed 0.3 t/ha to the yield gap. Contribution of this factor was similar between the low-stress sites and the high-stress sites (Table 24).

Weed control. The mean contribution of weed control to the yield gap was 0.1 t/ha for the low-stress sites and 0.2 t/ha for the high-stress sites (Table 24). The 0.1 t/ha difference between the two groups of sites was not significant. The mean contribution of weed control over all sites was 0.1 t/ha. Results imply that the researcher's and farmer's weed control practices were equally effective. In irrigated rice yield constraints analysis reported by IRRI (1977, 1979) the inference was that both the researcher and the farmer had similar and adequate levels of weed control. Our results were similar on fields with little early moisture stress. However, both the farmer's and our weed control appeared to be inadequate on fields subjected to severe early moisture stress.

Table 24. Contribution of test factors to the yield gap, low- and high-stress sites, and pooled data, rainfed rice constraints experiments, Bicol, 1980-81.

Test factor	Estimated yield (t/ha)		Contribution of test factor
	Farmer	Researcher	
Fertilizer			
Pooled sites	1.86	2.51	.65
Low stress	2.35	2.91	.56
High stress	1.52	2.22	.70
Difference (L-H)	.83**	.69*	.14^{ns}
Insect control			
Pooled sites	2.01	2.35	.34
Low stress	2.46	2.79	.33
High stress	1.69	2.03	.34
Difference (L-H)	.77**	.76**	.01^{ns}
Weed control			
Pooled sites	2.11	2.24	.13
Low stress	2.59	2.66	.07
High stress	1.77	1.94	.17
Difference (L-H)	.82**	.72**	.10^{ns}

Table 25. Summary of test factor contribution to the rice yield gap, by moisture status and grouped data, rainfed rice constraints experiment, Bicol, 1980-81.

Factor	Low-stress site		High-stress site		Pooled site	
	t/ha	%	t/ha	%	t/ha	%
n	10		14		24	
Fertilizer	.55	51	.70	57	.64	55
Insect control	.33	30	.34	28	.34	29
Weed control	.07	7	.17	14	.13	11
Residual	.14	12	.02	1	.07	5
Yield gap	1.10	100	1.23	100	1.18	100

Test factors: summary. The mean yield gap estimated for the rainfed rice constraints experiments in Bicol was 1.2 t/ha. Fertilizer contributed most to this gap. It accounted for 55% of the yield gap over all sites (Table 25). Insect control was second, contributing, on the average, 0.2 t/ha or

29% to the yield gap. Weed control contributed the smallest proportion to the yield gap -- 0.1 t/ha or 11% of the 1.2 t/ha yield gap (Fig. 7).

Because contributions of the three test factors did not differ significantly between high-stress and low-stress sites, estimates from the 24 sites pooled were used for the budget analysis of the rice yield constraints trials.

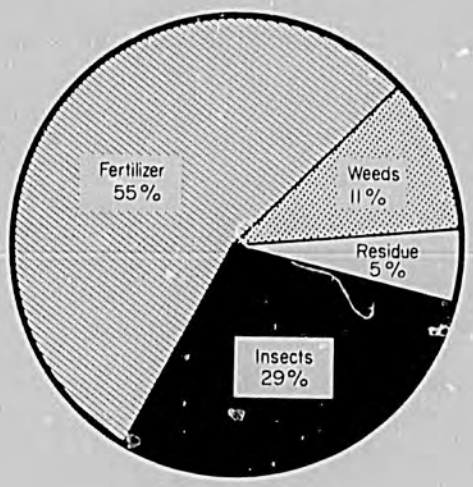

Fig. 7. Contribution of test factors to yield gap, rainfed rice yield constraints experiments, Bicol, Philippines, 1980-81.

ECONOMIC ANALYSIS OF CONSTRAINTS TRIALS

The constraints experiments show that it is possible to raise average rice yields of rainfed fields more than 1 t/ha in the study area. This can be achieved with the use of more fertilizer, insecticides, and herbicides. The issue, however, is whether it is profitable, from the farmer's viewpoint, to increase input use to achieve this higher yield. The budget analysis of the constraints experiments which addresses this issue considered three situations for an owner and a tenant operator:

- farmer-effective prices prevailing in Bicol in 1980,
- instances when farmers received the official price for palay, and
- 1981 fertilizer and rice prices.

Profitability of practices: 1980 farmer's prices

The profitability of a change in input use will depend on whether incremental benefits exceed or fall short of incremental costs of proposed technology. Incremental costs of the researcher's fertilizer, insect, and weed control practices beyond the farmer's are summarized in Table 26. The cost of 45-30-0-10 fertilizer was ₱520/ha.[2/] It is the dominant added cost compared to insect control (₱385/ha) and weed control (₱85/ha). The added cost of the researcher's package above the farmer's current practice was about ₱1,000/ha, which, if available, is within the ₱1,350/ha ceiling of the Masagana 99 program.

Incremental benefits of the researcher's technology, and the incremental benefit-cost (B-C) ratios of components of the technology, and for the technology as a whole, are reported in Table 27. Output retained by the cultivator was less than the gross increase in output because harvester's and owner's shares were first deducted to derive residual net yields. The value of the farmer-effective yield was based on a farmer-effective price of ₱1,000/t for rough rice, the typical price received by farmers in the study area for the second crop, 1980-81.

Table 26. Estimated cost of farmers' and researchers' fertilizer, insect, and management strategies, rainfed rice yield constraints experiments, Bicol, second crop, 1980-81.[a/]

	Estimated cost (₱/ha)			
	Fertilizer	Insect	Weeds	Package (₱/ha)
Farmer's level (F)	0	15	20	35
Researcher's level (R)	520	400	105	1025
Incremental cost of practice (R-F)	520	385	85	990

[a/] The test and farmer's levels of inputs in quantity terms are listed in Table 19. Interest charges, which vary from 14% through formal sources to more than 100% through informal sources of credit are not included, neither are transport and other procurement charges. Thus, the above figures are conservative estimates of the farmer-effective cost of the technology. US$ = ₱7.50.

The incremental B-C ratios for a tenant operator, for each test factor, and for the package as a whole were all less than 1 (Table 27). It would not be profitable, therefore, for tenants to adopt the researcher's practice, given prices and tenurial arrangements then prevailing in the study area. The incremental B-C ratios for an owner exceeded 1 for fertilizer and weed management practices. A rule of thumb often applied, however, is that incremental B-C ratio needs to exceed 2 to make a change in technology attractive to low-resource farmers. Thus, it is doubtful if either of these practices would have been attractive to a typical owner operator on the rainfed site in Bicol.

In summary, the researchers were able to increase farmer's yield a little more than 1 t/ha -- costing about ₱1,000/ha. At the existing prices, added returns and added costs were similar. From a profit viewpoint, the test technology was not superior to the farmer's.

[2/] US$1 = ₱7.50.

Table 27. Estimated net benefits and marginal benefit cost ratios of researcher's practices and the technology package for owner and tenant-operator farmer effective prices, rainfed rice constraints experiment, Bicol, second crop, 1980-81.

	Fertilizer	Insect	Weeds	Package[a]
Yield increment[b] (t/ha)	.64	.34	.13	1.18
Harvester's share[c] (t)	.07	.04	.01	.13
Net yield:				
Owner (t/ha)	.57	.30	.12	1.05
Tenant[d] (t/ha)	.38	.20	.08	.70
Value of net yield[e] (₱/ha)				
Owner	570	300	120	1050
Tenant	380	200	80	700
Incremental cost[f]	520	385	85	900
Incremental B-C ratio				
Owner	1.10	.78	1.41	1.17
Tenant	.73	.52	.94	.78

[a] Difference between all best factors at the researcher's level and all best factors at the farmer's level. [b] See Table 24. The sum of the yields of the test factors is less than for the package as a whole because of the .07/t residual. [c] Harvester's share is 1/9 of threshed crop. [d] Tenant pays landlord 1/3 of yield after harvester's share is deducted. [e] Effective price of rough rice in research site was ₱1.00/ton. US$1 = ₱7.50. [f] See Table 25. The operator pays all input costs. Labor costs to apply the added input not included.

Table 28. Estimated net benefits and marginal benefit cost ratios of test factors assuming farmers received official price for rough rice, rainfed rice constraints experiments, Bicol, second crop, 1980-81.

	Fertilizer	Insect	Weeds	Package[a]
Net yield[b] (t/ha)	.57	.30	.12	1.05
Owner	.57	.30	.12	1.05
Tenant	.38	.20	.08	.70
Value of net yield[c] (t/ha)				
Owner	827	435	174	1523
Tenant	551	290	116	1050
Incremental cost[d]	520	385	85	900
Incremental B-C ratio				
Owner	1.59	1.13	2.05	1.69
Tenant	1.06	.75	1.36	1.13

[a] Difference between all best factors at the researcher's level and all best factors at the farmer's level. [b] See Table 27. [c] Assuming farmers received the NFA official price of ₱1,450/t. US$1 = ₱7.50. [d] See Table 26.

Profitability of practices: 1980 official prices

The official price of rice in late 1980 was ₱1,450/t, if purchased by the National Food Authority (NFA). Farmers in the study area do not have ready access to NFA warehouses so they sell their rice to palay buyers at about ₱1,000/t or 70% of the official price. The B-C ratios were recalculated on the assumption that farmers sold direct to NFA at official prices (Table 28).

Higher rice prices increased net benefits by 30%. However, other than for the researcher's weed management practice, the incremental B-C ratios were still less than 2 for an owner operator. This implies that even if farmers received the official price for rice, there may not be a strong incentive to increase fertilizer or insect inputs. Further, although the incremental B-C ratio of the weed management practice exceeds 2, the added yield is small -- less than 0.1 t/ha -- which probably would be inadequate to convince farmers that this practice was technically superior to their own.

Profitability of practices: 1981 prices

In early 1981, the government announced the official price of rough rice would be ₱1,550/t and fertilizer subsidy would be reduced and eventually eliminated over the next 2-3 years. This implies a 33% increase in fertilizer costs at current prices. Cost of urea in Naga has increased from ₱96/50-kg bag in late 1980 to ₱126 in August 1981. The profitability of the researcher's technology was recalculated for an estimated 25% increase in fertilizer price and 2 sets of rice prices: the NFA official price, and 70% of the NFA guaranteed price (Table 29).

If farmers received the announced NFA price for their rice, the researcher's technology would still probably not be attractive to farmers (Table 29) because of minimum B-C ratios of less than 2, and because incremental yield due to weed control is not impressive. Of course, the technology is less attractive at 70% of the NFA price, which probably represents a more realistic 1981 farmer-effective price for rice in the study area.

The budget analysis demonstrates that lack of profitability is one reason farmers do not use higher input levels on rainfed rice in Bicol given currently available technology. Anticipated shifts in rice and input prices suggest those economic constraints will remain -- and probably become more restrictive. Therefore, attempts to increase on-farm yields in Bicol should focus on developing more productive, cost-effective technology. IRRI's Agronomy Department has established trials in the region to develop such technology.

ACCOUNTING FOR YIELD VARIABILITY BETWEEN CONSTRAINTS SITES

Response analysis of constraints experiments

Combining the 12 treatments from the constraints experiments (the 8 factorial treatments and the additional 4 treatments) with the site-related

factors provides an opportunity to relate the variability between individual sites to managed and site-determined factors. Production functions in the following variables were estimated:

$$Y = f\ (N, I, W, CEC, SD, N.SD, SH, VD) \qquad (1)$$

where

- Y is yield, in kg/ha;
- N is nitrogen input, in kg/ha;
- I is expenditure on insecticides, in ₱/ha;
- W is investment in herbicides, in ₱/ha;
- CEC is cation exchange capacity, in meq/100 g;
- SD is moisture stress days during crop growth;
- N•SD is an interaction term between nitrogen and stress;
- SH is the average number of hours of sunshine, per day, in the 45-day period before crop maturity; and
- VD is a variety dummy to allow for the 5 sites where short-season "Speed 70" (IR747) was planted by farmers as opposed to IR36.

Ordinary least squares estimates of three regressions models are reported in Table 30. They differ with respect to the stress variable and the N.stress interaction terms included. In Model 1 the incidence of moisture stress was defined by two parameters: number of stress days before flowering (stress-early) and number of stress days between flowering and physiological maturity of the crop (stress-late). Because these stress parameters had similar coefficients, a pooled stress variable was estimated in Model 2. The interaction term between nitrogen and the pooled stress variable was not significant. Model 3, which is used for subsequent discussion, was estimated without this interaction term.

No significant interactions were observed between applied nitrogen and other variables reported in Model 3, or in other preliminary analysis. These terms act as vertical shifters rather than change the slope of the nitrogen response function. The rice crop showed little response to applied nitrogen. Maximum yield was estimated to occur at 57 kg N/ha which is low for modern rice varieties by most standards (Fig. 8).

Estimated yield increase per peso invested in insecticide was 0.9 kg of rice. When harvester's shares are deducted, the estimated net benefit to an owner was 0.8 kg, or a B-C ratio of about 0.8 (given 1980 prices) which agrees favorably with the incremental B-C ratios calculated in Table 27. In short, it is questionable whether present insect control methods used by farmers or researchers are cost effective. Gross return per peso invested in herbicide was 1.4 kg. Net return (after harvester's shares) was 1.3 kg, which again is the same order of magnitude as the owner-operator benefits calculated in Table 26.

The CEC of each site and percentage of clay were the two soil characteristics most highly associated with between-site yield differences. These two factors were not included in the same analysis

Table 29. Incremental benefit cost (B-C) ratios of researcher's technology over farmer.s prices likely to prevail in 1981, rainfed rice constraints experiment, Bicol, 1980-81.

	Fertilizer	Insects	Weeds	Package[a]
Rice valued at NFA price of ₱1,550/t				
Value of net yield (₱/ha)				
Owner	844	465	186	1628
Tenant	589	310	124	1085
Incremental cost	650	385	85	1120
Incremental B-C ratio				
Owner	1.36	1.21	2.19	1.45
Tenant	.91	.81	1.46	.97
Rice valued at 70% of NFA price, ₱1,085/t				
Value of net yield (₱/ha)				
Owner	618	326	130	1139
Tenant	412	217	87	760
Incremental cost	650	385	85	1120
Incremental B-C ratio				
Owner	.95	.85	1.53	1.02
Tenant	.63	.56	1.02	.68

[a] Difference between treatments with all best factors at the researcher's level and all best factors at the farmer's level. [b] Assuming that fertilizer costs increase by 25%, with no change in the csot of insecticides or herbicides. US$ = ₱7.50.

Table 30. Least squares regression estimates of response function fitted to rainfed rice yield constraints experiments, Bicol, Philippines, 1980-81.[a]

Variable	Model 1	Model 2	Model 3	Marginal R^2
Constant	1105.71	1049.80	992.29	
Nitrogen (kg/ha)	22.07	22.13	24.69	.14
Nitrogen^2 (kg/ha)	- .24	- .22	- .21	.01
Insecticide (₱/ha)	.93	.94	.94	.04
Herbicide (₱/ha)	1.42	1.44	1.44	.01
CEC (meq/ha)	13.02	13.10	12.80	.12
Stress-early (days)	-47.53	-	-	
-late (days)	-41.60	-	-	
-pooled (days)	-	- 44.15	-41.23	.13
N x S-early (N. day)	.23^{ns}	-	-	
N x S-late (N.day)	.03^{ns}	-	-	
N x S-pooled (N.day)	-	.12^{ns}	-	
Sunshine hours per day	5.89	6.01	5.98	.07
Variety dummy (0,1)	-414.37	-410.97	-413.66	.04
R^2	.56	.56	.56	
$\bar{R}^2$	.54	.54	.54	
F ratio	30.67	32.40	36.43	
Standard error of Y (kg/ha)	587.27	585.27	584.77	

[a] A dash (-) means that the variable is not included in that model. All coefficients, other than those marked ns (not significant), are significantly different at the 5% level or better. US$1 = ₱7.50.

because of their higher intercorrelation (r = 0.86). CEC, the cheaper variable to estimate in IRRI's Analytical Services Laboratory, was retained in the analysis and used in subsequent work.

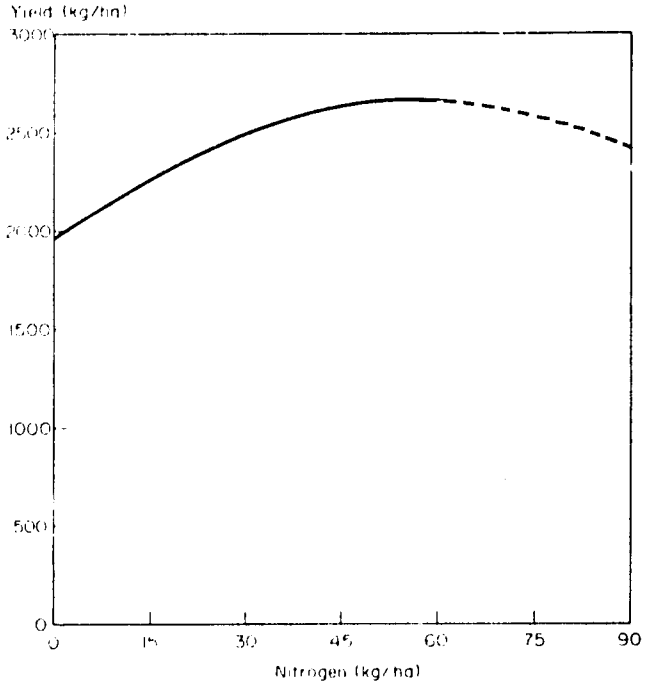

Fig. 8. Response of rainfed rice in Camarines Sur, Bicol, Philippines, to applied nitrogen. Source: Table 30 response function model. All inputs (other than fertilizer N) were held at their mean levels.

Using the range of stress days recorded (mean of 24, with a high of 46), each day of moisture stress was calculated to reduce yields by 41 kg/ha. Sites with more sunshine hours -- which was used as a proxy for irradiation -- during crop maturity had higher yields. The variety dummy implies that the yield of the earlier-maturing IR747 (an unreleased cross of TKM6 and TKM6/TN1, widely grown in the Philippines) averaged 414 kg/ha lower than later-maturing IR36.

Although all variables in Model 3 are significant at 5% probability, partial regression coefficients do not provide an opportunity to interpret the relative importance of each variable when accounting for yield differences in and between sites. The marginal R^2, the right hand column of Table 30, provides such an estimate. The marginal R^2 for the linear term in N (0.14) shows that N describes 25% of the explained variability. Stress index (marginal R^2 of 0.13) explains a further 23% of the variability in the unadjusted R^2. The CEC is the third most important variable (21%) explaining yield differences. Nitrogen inputs, CEC, and field moisture status, therefore, were important determinants of within-site and between-site rice yield variability at the Bicol site.

Contributions of managed factors to high rice yields

Production functions reported in Table 30 provide an alternative means of estimating how the three managed factors contributed to the difference between farmer's and researcher's yields (yield gap). The evaluation is based on the concept of the differential: total yield difference equals the sum of yield changes due to variables in the regression model (Mandac and Herdt 1979).

Mathematically, the differential, dY, is:

$$dY = \frac{\partial Y}{\partial X_1} dX_1 + \ldots \frac{\partial Y}{\partial X_i} dX_i \ldots + \frac{\partial Y}{\partial X_n} dX_n$$

where

$\frac{\partial Y}{\partial X_i}$ is the partial derivative of the production function with respect to input X_i, and

dX_i is the difference in input level X_i between the farmer and the researcher.

Calculations for this analysis are reported in Table 31. The results resemble the yield gap analysis and factor contributions estimated directly from the constraints experiments and reported in Table 25. That is, fertilizer contributed more than 50% to the yield gap, insect control about 30%, and weed control about 10%.

Table 31. Accounting of yield differences between farmer's and researcher's yields via a production function approach, rainfed constraints experiment, Bicol, 1980-81.

Variable	$\frac{\partial Y}{\partial X_i}$ [a]	dX_i [b]	Contribution of factor t/ha [c]	%
N	(24.69-.42N)	45	.68	57
I	.94	385	.36	31
W	1.44	85	.12	11
Residual			.02	1
Yield gap [d]			1.18	100

[a] From Model 3, Table 30; N in the first row equals 45. [b] Difference in N level is 45 kg/ha, for I and W see Table 26. [c] Contribution is calculated as column 2 x column 3. [d] Yield gap estimated from Table 25.

CONCLUSIONS

Shallow rainfed rice yields in Camarines Sur are low -- about 2.4 t/ha for the first crop and 1.6 t/ha for the second crop. We interpret these low yields to result from low soil fertility, low farmer input, and, for the second crop at least,

moisture stress incidence. A set of constraints experiments (second crop) showed yields could be increased 1 t or more if farmers used more fertilizer and insect and weed control. However, a budget analysis of the high-yielding technology showed it is probably not profitable for farmers to increase input use on their second rice crop, given present knowledge. The analysis supports Schultz's hypothesis and Lipton's argument of poor but tolerably efficient farmers. By implication, the cultural practices and low input levels now used by farmers in Bicol are probably the best, given existing rice technology and prevailing economic, weather, and soil conditions in the area.

The researcher's technology was not profitable given current farm prices and yield gains. Technology could be more economically attractive to farmers if rice prices were raised and input prices lowered. Increased government price support for rice and subsidized fertilizer seems unlikely. In the long run, investing in research and infrastructural development to purposefully generate more productive and cost-efficient technology for farmers is a more efficient way of increasing rice supplies and farmer's income (Evenson and Flores 1978). The Agronomy Department has started research in the area to generate high-yielding technology that is attuned to farmer circumstances in the region.

ACKNOWLEDGMENTS

The authors are grateful to the 84 farmers who participated in the project and to our field staff who worked on the surveys and field experiments. Particular thanks are also due R. W. Herdt for comments on a draft of this paper.

REFERENCES CITED

Barker, R., and R. W. Herdt. 1979. Rainfed lowland rice as a research priority -- an economist's view. Pages 3-50 in International Rice Research Institute. Rainfed lowland rice: selected papers from the 1978 international rice research conference. Los Baños, Philippines.

Bolton, F. R., and H. G. Zandstra. 1980. Double cropping rainfed rice in Iloilo Province. Paper presented at a Saturday seminar, July 1980, International Rice Research Institute, Los Baños, Laguna, Philippines.

Bureau of Agricultural Economics. 1976-77. Rice production, area, and yield in the Philippines. (mimeographed report)

Cochran, W. G., and G. M. Cox. 1960. Experimental designs. John Wiley and Sons, New York.

De Datta, S. K., K. A. Gomez, R. W. Herdt, and R. Barker. 1978. A handbook on the methodology for an integrated experiment-survey on rice yield constraints. International Rice Research Institute, Los Baños, Philippines.

Evenson, R. E., and P. M. Flores. 1978. Social returns to rice research. Pages 243-265 in International Rice Research Institute. Economic consequences of the new rice technology. Los Baños, Philippines.

Greenland, D. J. 1981. So what-about the other three. Paper presented at a Thursday seminar, 23 August 1981, International Rice Research Institute, Los Baños, Laguna, Philippines.

Huke, R. E. 1982a. Rice area by type of culture: South, Southeast, and East Asia. International Rice Research Institute, Los Baños, Laguna, Philippines.

Huke, R. E. 1982b. Agroclimatic and dry season maps of South, Southeast, and East Asia. International Rice Research Institute, Los Baños, Laguna, Philippines.

IRRI (International Rice Research Institute). 1977. Constraints to high yields on Asian rice farms: an interim report. Los Baños, Philippines.

IRRI (International Rice Research Institute). 1979. Farm-level constraints to high rice yields in Asia: 1974-77. Los Baños, Philippines.

Mandac, A. M., and R. W. Herdt. 1979. Environment and management constraints to high rice yields in Nueva Ecija, Philippines. Paper presented at a Saturday seminar, September 1979, International Rice Research Institute, Los Baños, Laguna, Philippines.

PCARR (Philippine Council for Agriculture and Resources Research). 1977. The Philippines recommends for rice. Los Baños, Philippines.

Wickham, T. H. 1971. Water management in the humid tropics: a farm level analysis. Unpublished Ph D dissertation, Cornell University, New York, USA.

The International Rice Research Institute
P.O. Box 933, Manila, Philippines

Stamp

DFID
Fide
D AED
16 Sep 95

Other papers in this series

ISSN 0115-3862

FOR NUMBERS 1–20, TITLES ARE LISTED ON THE LAST PAGE OF NO. 46 AND PREVIOUS ISSUES

No. 21 Sulfur nutrition of wetland rice

No. 22 Land preparation and crop establishment for rainfed lowland rice

No. 23 Genetic interrelationships of improved rice varieties in Asia

No. 24 Barriers to efficient capital investment in Asian agriculture

No. 25 Barriers to increased rice production in eastern India

No. 26 Rainfed lowland rice as a research priority — an economist's view

No. 27 Rice leaf folder: mass rearing and a proposal for screening for varietal resistance in the greenhouse

No. 28 Measuring the economic benefits of new technologies to small rice farmers

No. 29 An analysis of the labor-intensive continuous rice production system at IRRI

No. 30 Biological constraints to farmers' rice yields in three Philippine provinces

No. 31 Changes in rice harvesting systems in Central Luzon and Laguna

No. 32 Variation in varietal reaction to rice tungro disease: possible causes

No. 33 Determining superior cropping patterns for small farms in a dryland rice environment: test of a methodology

No. 34 Evapotranspiration from rice fields

No. 35 Genetic analysis of traits related to grain characteristics and quality in two crosses of rice

No. 36 Aliwalas to rice garden: a case study of the intensification of rice farming in Camarines Sur, Philippines

No. 37 Denitrification loss of fertilizer nitrogen in paddy soils — its recognition and impact

No. 38 Farm mechanization, employment, and income in Nepal: traditional and mechanized farming in Bara District

No. 39 Study on kresek (wilt) of the rice bacterial blight syndrome

No. 40 Implication of the international rice blast nursery data to the genetics of resistance

No. 41 Weather and climate data for Philippine rice research

No. 42 The effect of the new rice technology in family labor utilization in Laguna

No. 43 The contribution of varietal tolerance for problem soils to yield stability in rice

No. 44 IR42: a rice type for small farmers of South and Southeast Asia

No. 45 Germplasm bank information retrieval system

No. 46 A methodology for determining insect control recommendations

No. 47 Biological nitrogen fixation by epiphytic microorganisms in rice fields

No. 48 Quality characteristics of milled rice grown in different countries

No. 49 Recent developments in research on nitrogen fertilizers for rice

No. 50 Changes in community institutions and income distribution in a West Java village

No. 51 The IRRI computerized mailing list system

No. 52 Differential response of rice varieties to the brown planthopper in international screening tests

No. 53 Resistance of Japanese and IRRI differential rice varieties to pathotypes of *Xanthomonas oryzae* in the Philippines and in Japan

No. 54 Rice production in the Tarai of Kosi zone, Nepal

No. 55 Technological progress and income distribution in a rice village in West Java

No. 56 Rice grain properties and resistance to storage insects: a review

No. 57 Improvement of native rices through induced mutation

No. 58 Impact of a special high-yielding-rice program in Burma

No. 59 Energy requirements for alternative rice production systems in the tropics

No. 60 An illustrated description of a traditional deepwater rice variety of Bangladesh

No. 61 Reactions of differential varieties to the rice gall midge, *Orseolia oryzae*, in Asia. Report of an international collaborative research project

No. 62 A soil moisture-based yield model of wetland rainfed rice

No. 63 Evaluation of double-cropped rainfed wetland rice

No. 64 Trends and strategies for rice insect problems in tropical Asia

No. 65 Landforms in the rice-growing areas of the Cagayan River Basin

No. 66 Soil fertility, fertilizer management, tillage, and mulching effects on rainfed maize grown after rice

No. 67 High-temperature stress in rice

No. 68 Weed-fertilizer interactions in rice

No. 69 The azolla-anabaena complex and its use in rice culture

No. 70 An index to evaluate the effect of water shortage on the yield of wetland rice

No. 71 The development and diffusion of rice varieties in Indonesia

No. 72 Levels of resistance of rice varieties to biotypes of the BPH, *Nilaparvata lugens*, in South and Southeast Asia

No. 73 Growing season analyses for rainfed wetland fields

No. 74 San Bartolome: beyond the green revolution

No. 75 Pathotypes of *Xanthomonas campestris* pv. *oryzae* in Asia

No. 76 Focusing field research on future constraints to rice production

No. 77 An international survey of methods used for evaluation of cooking and eating quality of milled rice

No. 78 Research on algae, blue-green algae, and phototrophic nitrogen fixation at the International Rice Research Institute (1961-81), summarization, problems, and prospects

No. 79 Seed-derived callus culture for selecting salt-tolerant rices