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AN ANALYSIS OF THE LABOR-INTENSIVE CONTINUOUS RICE PRODUCTION SYSTEM IN PERU

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AN ANALYSIS OF THE LABOR-INTENSIVE CONTINUOUS RICE PRODUCTION SYSTEM AT IRRI[1]

ABSTRACT

A thrice-weekly rice planting and harvesting system on 250-m^2 plot is evaluated. The system is compared with conventional production systems in the Philippines and elsewhere in terms of production, land use, labor use, labor distribution, water requirement, capital use, and economics of the system.

The continuous rice production system (rice garden) efficiently utilizes about twice as much as labor, uses land fully throughout the year, and produces three times the output of conventional two-crop rice production systems. With the return to labor and capital accounted at their opportunity cost, the system provides a return to land twice that of the conventional system.

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AN ANALYSIS OF THE LABOR-INTENSIVE CONTINUOUS RICE PRODUCTION SYSTEM AT IRRI

Different systems of rice production may utilize different ratios of labor and capital because of diverse land endowments and varying institutional conditions. The energy use of systems may also differ. The development of small-scale machinery, short-growth-duration photoperiod-insensitive rice varieties and efficient water management techniques may make it possible to organize highly efficient small-scale production units around the concept of frequent planting and harvesting. Isolated examples of monthly, weekly, and daily planting and harvesting of rice exist in the Philippines. Such systems are reputed to have substantial advantages over conventional systems of two or three crops per year with regard to equipment utilization and the need for hired labor.

A number of IRRI departments are involved in research on labor-intensive continuous rice production. The Department of Rice Production Training and Research (RPTR) has an ongoing experiment on frequent planting and harvesting started in 1976. The Department of Agricultural Engineering has developed small-scale machines that are relatively efficient on farms of 5 ha or less. Both departments have an interest in the cost and resource utilization aspects of systems that involve frequent planting and harvesting, with special interest in the identification of the potential bottlenecks to intensification that may exist in conventional systems. The Entomology Department is interested in the ecological implications of such systems.

In September 1976, RPTR researchers started a 1-year study of the agronomic and economic feasibility of continuous rice cropping at IRRI. A 1-ha field was divided into 40 plots of 250 m^2. A plot was transplanted every other day, and 1 was harvested on alternate days, 6 days a week. Gains to the system result from 1-day turnaround between each 90-day crop of transplanted IR36, such that 4 crops/year were grown. During 1977, about 23 t/ha were harvested, and 3 men were fully employed with a relatively constant flow of cash income. This compares with partial employment for 1 man and 10 t/ha from the double-crop rice system currently used in many areas of the Philippines.

Thus, the continuous production system promises increased employment and higher production compared with conventional rice production systems. In this paper, we report on a detailed economic study of the 250-m^2 plot system.

Our objective was to evaluate the economic performance of this labor-intensive small-scale system of rice production to explore how farming operations of individual farmers could be adapted to such systems. Several basic conditions of rice production, such as water, cultivation technology, and labor were considered in the analysis of the economic performance of the system.

Specifically, in this paper we:

- determine the costs and returns from producing rice in the system and estimate the returns to labor and capital;
- compare the continuous production system with existing systems to see which are more efficient;
- estimate the forms and amount of capital used by the system; and
- estimate the cost of irrigation needed for highly intensive small-scale production systems.

We used farm budgeting methods based on an intensive first-hand study of the IRRI system as the primary analytical tool. As companion studies, four or five different frequent planting systems were budgeted assuming normal weather and yields. Throughout we assumed that a family or small group of families supplied the labor needed and received the income generated by the system.

LAND USE, PLANNING, AND PREPARATION FOR THE EXPERIMENT

The experimental continuous rice production system at IRRI is popularly called the *rice garden* because of the small, garden-like fields within the 1-ha experiment.

Soils and crop weather

The chemical properties of the paddy soil in the rice garden are shown in Table 1.

Table 1. Chemical properties of the soil (Maahas clay) in the IRRI continuous rice production experiment, 1976-77.

Property	Av value
pH (1:1 W/V H_2O)	6.8
Electric conductance (m.mhos) (1:1 W/V H_2O)	15.19
Exchangeable cations (m.eq/100 g)	
Na	1.19
K	0.53
Mg	16.45
Ca	23.2
Cation exchange capacity (m.eq/100 g)	42.65
Available P - Bray method (ppm)	5
Organic C (%)	1.6
Total N (%)	0.13
Carbon-Nitrogen ratio	12.37

Daily temperature, solar radiation, and rainfall are plotted in Figure 1. A typhoon at the beginning of the rice garden experiment contributed substantially to the 1976 total rainfall of 2,508 mm. The 1977 total rainfall was lower than the 1966-76 average of 2,085 mm.

The average daily temperature ranged between 23 and 20°C. Total evaporation was closely associated with solar radiation.

In the tropics, solar radiation, especially in the later stages of plant growth is the major climatic factor affecting grain yield. Low rice yields in the tropics have frequently been attributed to low light intensities during the monsoon. Clear skies in April 1977 resulted in a monthly total solar radiation of 13.6 kilocalories. However, this was lower than the 1966-77 average of 16.1 kilocalories, and the total of 23.6 kilocalories for April and May (the ripening period of the dry-season rice) was below the 1966-75 average of 30.8 kilocalories.

Although several typhoons hit southern Luzon in 1976-77, damage to the rice in the continuous production system was minimal because only a few plots were at critical stages of growth when any typhoon struck.

Variety

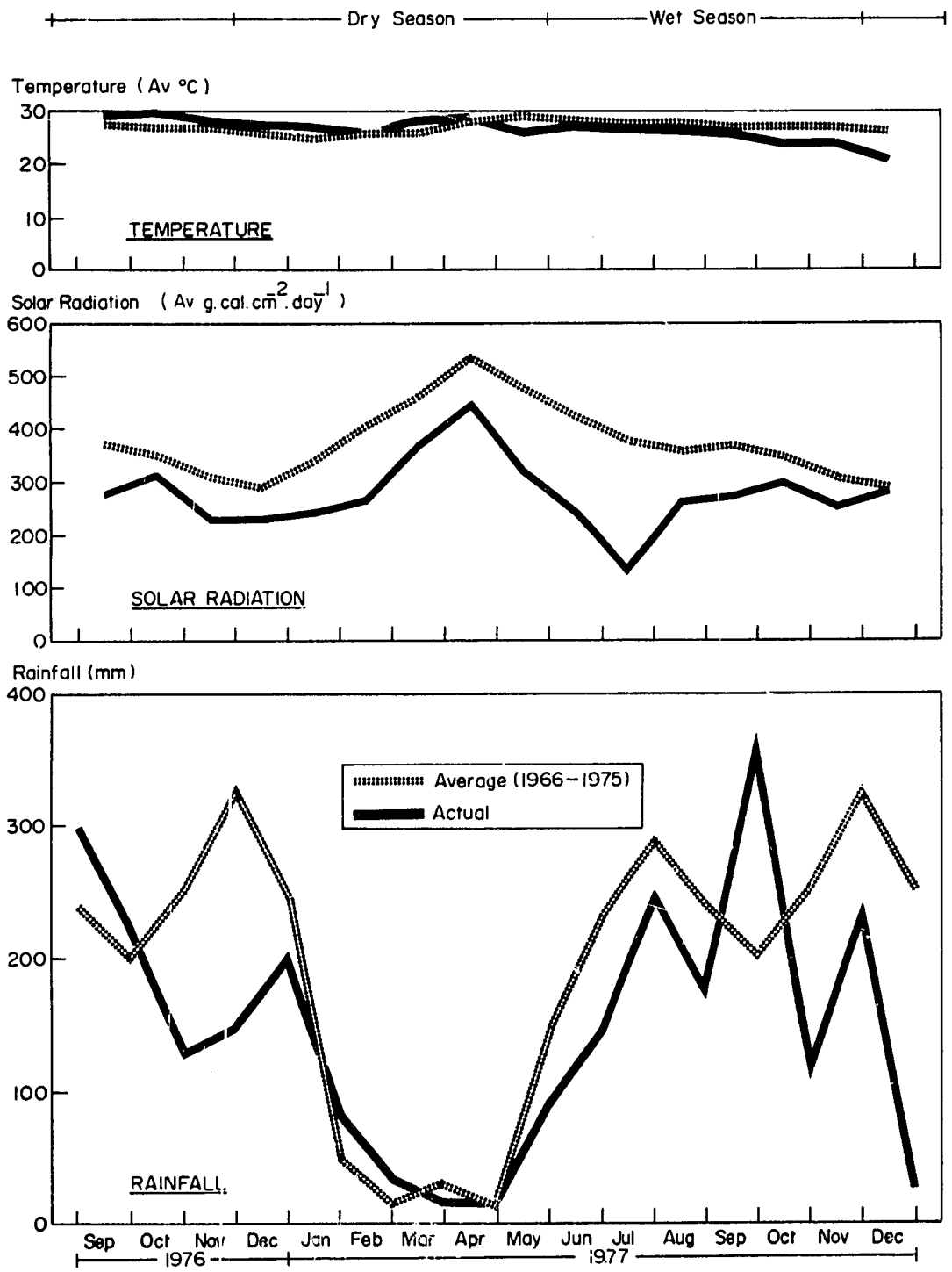
To select the rice variety with the highest yield potential for the rice garden, RPTR studied 10 varieties for factors that affected yield per day -- variety, fertilizer, spacing, and pest management. All varieties or selections except IR36 were discarded because of serious infestations of bacterial blight, leaf streak, virus disease, and brown planthoppers. Based on that evaluation IR36 was grown in the rice garden at 20 x 20 cm spacing with 2 or 3 seedlings per hill.

IR36 matures in 110 days after seeding, grows to a height of 85 cm, and has broad leaves and a spreading type of growth. It produces 14-19 tillers/plant. It is one of the most disease- and insect-resistant rice varieties in Asia. During the 1975 dry season, the IR36 average yield at 3 Bureau of Plant Industry (BPI) experimental stations in the Philippines (Maligaya, Iloilo and Bicol) was 5.8 t/ha with the recommended 90 kg N/ha. During the 1976 wet season at the same stations, IR36 averaged 5.3 t/ha with the recommended 60 kg N/ha.

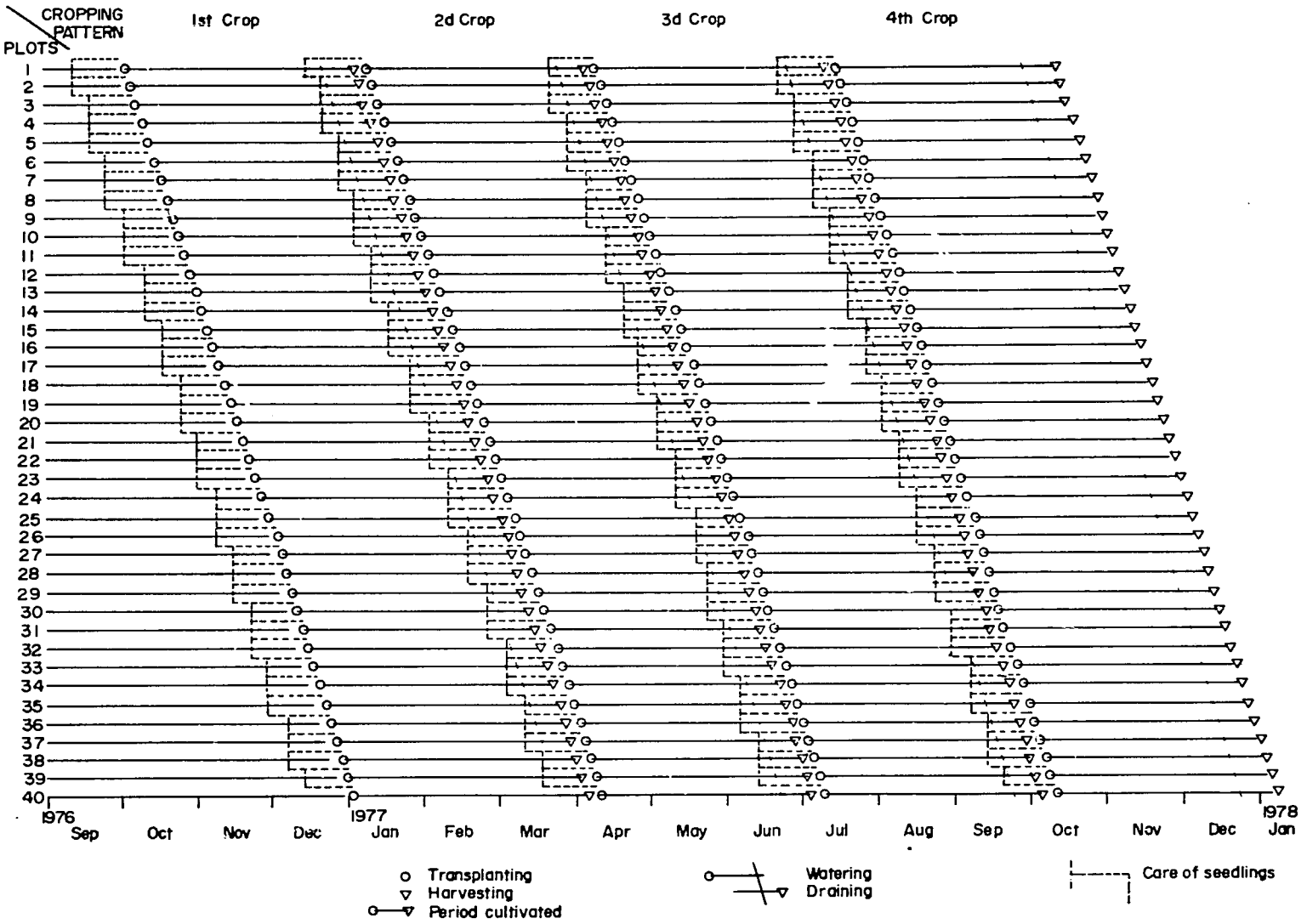
Field preparation and experiment duration

Because IR36 matures about 90 days after transplanting, it is possible to plant a plot 4 times/year if land preparation can be done in 1 or 2 days. With 1 ha planted 4 times/year, the total planted area will be 4 ha (40,000 m^2). Three plantings per week would give 156 plantings/year. To plant 40,000 m^2 exactly 156 times during the year, the 1-ha area would be divided into 256-m^2 plots. But because the IRRI experimental fields were 1,000 m^2, the rice garden was divided into 40 plots of 250 m^2. As a result, the rice garden had 156 plantings and grew 3.9 crops in 1 year. A schematic layout of the

experimental area is shown in Figure 2. Each plot was about 21 x 21 m with about 6,300 hills. An additional 120-m area was used for a seeding nursery, with 1 seeding made each week. Seedlings were 18, 20, and 22 days old on consecutive planting days.



1. Monthly weather at IRRI, September 1976 December 1977.



2. Cropping pattern at the IRRI rice garden.

It would take 373 days to rotate the entire field 4 times; thus, the final 3 plots in the 4th crop were actually harvested in the second year. For convenience, however, our analysis assumed that 4 crops were grown per year.

Figure 3 shows how the experimental area was cropped from September 1976 to January 1977. The experiment was started 1 September 1976 and ended 5 January 1978. At the beginning of the period start-up practices of field measurement, segmentation, and construction of levees and dikes, practices needed to introduce a continuous rice production system into any farm, were required. The first plot was harvested 4 January 1977.

PRODUCTION AND YIELD

Yields of rough rice (14% moisture) are shown in Figure 3. The first and second crops were mainly harvested during the dry season, the third and the fourth during the wet season. Total production for the year was about 23.6 t/ha, an average of 5.9 t/ha or 148 kg/250 m^2.

These yields are not spectacular but compare favorably with yields of conventional systems. For example, during the same 1977 crop year, the yields of IR36 in an IRRI fertilizer-response experiment were 5.2 t/ha in the wet season and 6.1 t/ha in the dry season. Yields of this magnitude are typical of the area.

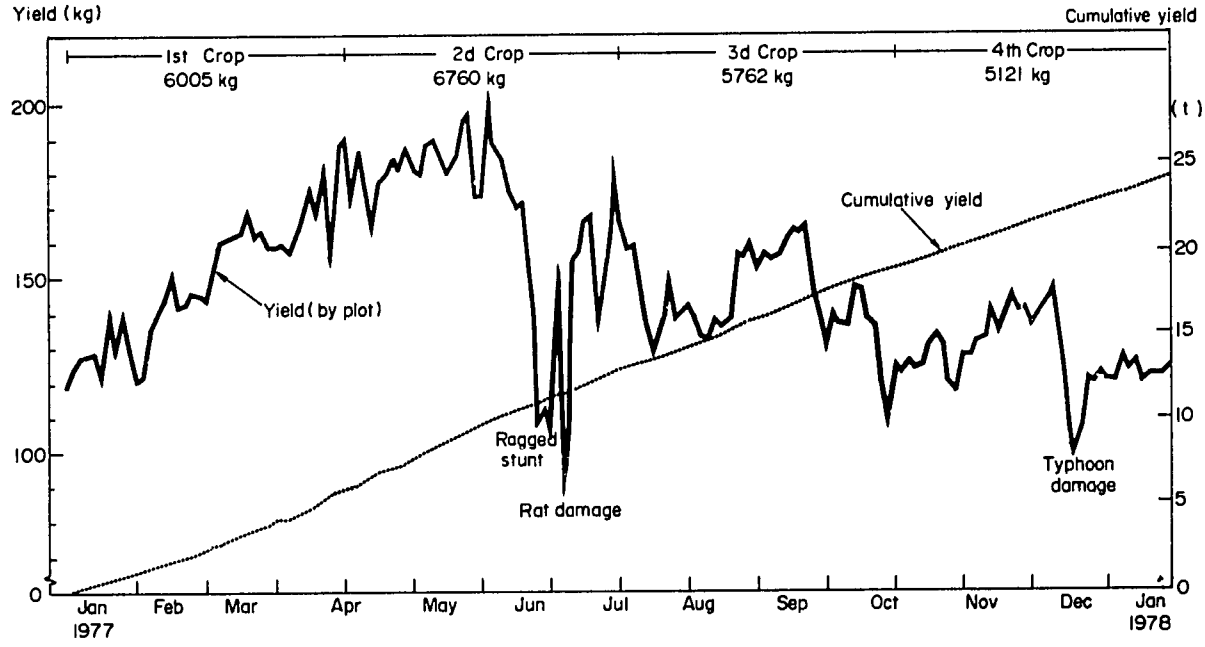
The main production advantage of the continuous rice garden system is that it produces four crops per year from the land so that output per hectare per day is nearly twice that of conventional two-crop systems. The 23.6 t/year from the rice garden works out to 65 kg/ha per day whereas the two crops in the IRRI fertilizer-response experiment gave 31 kg/ha per day.

Yield fluctuations

Figure 3 shows yields per plot over the period. Fertilizer and insecticides were applied to all plots at optimal rates. Water was also well controlled at the optimum depth throughout the test period. Despite careful control over inputs the yield per plot varied considerably. The average of 148 kg/plot had a standard deviation of 23.2 kg, giving a coefficient of variation of more than 16%.

During the 1977 experiment, there was significant damage by diseases, rats, and weather. The first sharp decrease in yield in June resulted from damage by ragged stunt virus. The second decline was attributed to rats that damaged the early maturing rice garden plots, which were practically the only fields with rice at that time. A third yield loss, suffered by plots 25-27 that were then at the flowering stage, was attributed to a typhoon on 14 November.

Ragged stunt and rats suggest a serious problem from the viewpoints of ecology and related science. These problems, however, were eliminated after a few weeks. Rats were controlled by persistent efforts of laborers. Ragged stunt ran its course and disappeared, damaging relatively few plots. That indicates that it is possible for rice farmers to minimize damage caused by crop pests or weather by adopting the continuous rice production system.



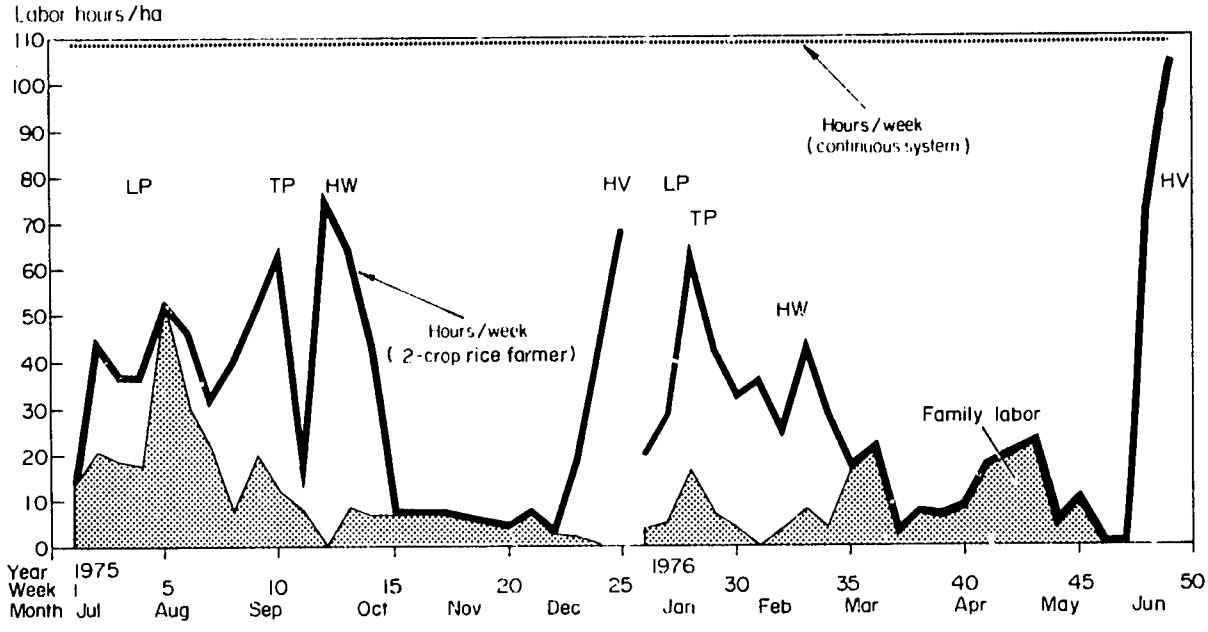
3. Cumulative yield and changes of yield by plot in the IRRI rice garden experiment, 1977.

LABOR USE AND DISTRIBUTION

One of the most important objectives of the continous rice production system is to distribute seasonal peaks in labor and generate employment throughout the year. Rice farming is highly labor-intensive during planting and harvesting. Land preparation and weeding also are labor intensive but do not have the time limits of planting and harvesting. The labor peaks associated with transplanting and harvesting characterize much of the rural labor use in monsoonal Asia.

With irrigation water available throughout the year, many rice farmers have grown either two crops of late maturing or three crops of early maturing rice varieties. However, rural labor is still seasonally underemployed between the peaks of transplanting and harvesting. Oshima (1971) estimated that such underemployment in Southeast Asia is so extensive that the peasant is unemployed as much as one-third of the year even with off-farm work.

Figure 4 shows the weekly labor use by a two-crop rice farmer during 1975-76 in Laguna province, Philippines. The farmer's record was selected from among those of 26 farmers in an IRRI Agricultural Economics Department study. This farmer's land and labor productivity were the highest and most stable among the 26 farmers. He produced 3.7 t/ha during the wet season and 4 t/ha during the dry season. Total labor was 729 hours or 91 days/ha during the wet season, and 80 days/ha during the dry season. Labor productivity was 40.6 kg/day in the 1975 wet season and 49.5 kg/day in the 1976 dry season.



4. Weekly labor input per hectare on a two-crop rice farm, Laguna province (1975–76), and the IRRI continuous rice production system, 1977. LP is land preparation, TP is transplanting, HW is hand weeding, and HV is harvesting.

Figure 4 also shows the fluctuations in farm labor input. Hand weeding during the wet season gave a sharp peak because weed control was done by 2 to 6 workers under the *gama*[2] *arrangement*.

The continuous rice production system with planting, weeding, and harvesting activities staggered over the year disperses the seasonal labor peaks into an equal amount of work each week.

Family labor availability

Rice farm labor is primarily supplied by the cultivator, his family, and hired labor from the village. Transplanting and harvesting are traditionally done by hired labor and labor for crop care is usually provided by the farm operator. In the case of the Laguna farmer (Fig. 4), family workers provided 36% of the total labor inputs during the wet season and 33% of the total labor during the dry season.

The total seasonal labor input per hectare for the Laguna farmer was less than 100 days, which is typical of rice farmers in the Philippines. Barker

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[2] *Gama* is an arrangement in which free labor for certain farm tasks, such as weeding and pulling seedlings, is combined with the right to join harvesting and threshing, and to get a harvesters' share.

and Cordova (1977) found that 62 farmers in 1 area used an average of 106 labor days/ha per crop in 1975, but that 63 farmers in another area used an average of 82 days/ha per crop in 1974. Their survey data showed a significant increase in hired labor input per hectare between 1966 and 1975 in both areas, and a decline in family labor input in Laguna because of the adoption of arrangements like *gama* and of labor-saving technology.

The continuous rice production system provides a constant work opportunity for family labor throughout the year. The level of labor shown for the continuous system in Figure 4 is based on 3 family members working at the rice garden 6 hours/day except Sunday.

Labor input in the rice garden

Work in the IRRI rice garden was done by 3 laborers, each with less than 10 years of experience as rice farmers. In addition, one person served as project adviser, reporter, and data recorder but provided no labor input as a farm worker.

Daily farm activities followed a crop production schedule (Table 2). When a scheduled task fell on a holiday or during bad weather, the activity was done the following day. The 3 laborers had adequate slack time to keep up with all activities even with this degree of rescheduling.

The seedling nursery had three seedbeds. Seeds for three field plots were put in one seedbed once a week. Seedbed land preparation was completed the week previous to sowing. Seedlings were transplanted at 18, 21, and 23 days.

Levees, dikes, and ditches around the plots were repaired before transplanting. Harrowing after plowing was an optional practice that depended on the condition of the plot.

Table 3 shows the farm work schedule followed from initiation of the system until the continuous rice production system was fully operational. For example, workers harvested plots 1-3 in week 18. Other activities in this week included sowing of seedbed for plots 9, 10, and 11; final harrowing for plots 1, 2, and 3; transplanting in plots 40, 1, and 2; and so forth, as shown in the table. In general, in the continuous rice production system, some activities were done on 50% of the total plots (0.5 ha) every week. Full activities were continued until the 54th week. The experiment stopped at the 72nd week after each plot had been planted and harvested 4 times.

Three sets of labor data

It was difficult to determine the exact labor input for each practice on the IRRI rice garden because the time used changed depending on the date and period of the survey, the plots studied, the mental and physical condition of the workers on that day, and the knowledge and judgment of the enumerator observing the farm practices. Labor input data, however,

Table 2. Farm work schedule[a] of the continuous rice production system.

DS	DBT/DT	Activities
-16	-34	(Watering and cleaning of seedbed)
-15	-33	(Plowing seedbed)
-8	-26	(1st harrowing of seedbed)
-2	-20	(2d harrowing of seedbed)
		Soaking seeds
-1	-19	Incubating seeds
		Constructing seedbed
0	-18	Sowing seeds
		Cleaning field - levees, dikes, and ditches
2	-16	(Watering of field)
3	-15	(Plowing field)
4	-14	Constructing or repairing of canal and levees
5	-13	(Applying manure)
9	-9	(Harrowing field)
10	-8	Applying rat baits
		Applying insecticide to seedbed (optional)
17	-1	Watering
		Plowing after application of basal fertilizer
		Harrowing and levelling
		Pulling seedlings - dip roots in Furadan solution
18	0	Marking field
		Transplanting
21	3	Controlling water
22	4	Applying herbicide - 2,4-D
24	6	Applying insecticide - Gamma BHC
25	7	Replanting (optional)
38	20	Hand weeding
43	25	Applying insecticide - Furadan 3G -
		1st topdressing
53	35	2d topdressing
63	45	Applying insecticide - Furadan 3G
78	60	Rat control
93	75	Draining water
108	90	Harvesting
		Hauling, threshing, and winnowing
109	91	Drying (optional)
		Packing

[a] DS = Days after sowing, DBT = Days before transplanting, DT = Days after transplanting. Parentheses indicate preparation practices for introducing the continuous production system to normal field condition. Those practices stopped after start of the system.

Table 3. Plots in which each practice in the continuous rice production system was done during weeks 1-19.

Week	Practices										
	Seedbed making	Land preparation	Transplanting	Weeding	Insecticide	Weeding	1st top-dressing	2d top-dressing	Insecticide	Harvesting	Post-harvesting
1											
2	1 - 3										
3	4 - 6										
4	7 - 9	1									
5	10 - 12	2 - 4	1 - 3	1							
6	13 - 15	5 - 7	4 - 6	2 - 4	1 - 3						
7	16 - 18	8 - 10	7 - 9	5 - 7	4 - 6						
8	19 - 21	11 - 13	10 - 12	8 - 10	7 - 9	1 - 3	1				
9	22 - 24	14 - 16	13 - 15	11 - 13	10 - 12	4 - 6	2 - 4				
10	25 - 27	17 - 19	16 - 18	14 - 16	13 - 15	7 - 9	5 - 7	1 - 3			
11	28 - 30	20 - 22	19 - 21	17 - 19	16 - 18	10 - 12	8 - 10	4 - 6	1 - 2		
12	31 - 33	23 - 25	22 - 24	20 - 22	19 - 21	13 - 15	11 - 13	7 - 9	3 - 5		
13	34 - 36	26 - 28	25 - 27	23 - 25	22 - 24	16 - 18	14 - 16	10 - 12	6 - 8		
14	37 - 39	29 - 31	28 - 30	26 - 28	25 - 27	19 - 21	17 - 19	13 - 16	9 - 11		
15	40 - 2	32 - 34	31 - 33	29 - 31	28 - 30	22 - 24	20 - 22	16 - 18	12 - 14		
16	3 - 5	35 - 37	34 - 36	32 - 34	31 - 33	25 - 27	23 - 25	19 - 21	15 - 17		
17	6 - 8	38 - 40	37 - 39	35 - 37	34 - 36	28 - 30	26 - 28	22 - 24	18 - 20		
18	9 - 11	1 - 3	40 - 2	38 - 40	37 - 39	31 - 33	29 - 31	25 - 27	21 - 23	1 - 3	
19	12 - 14	4 - 6	3 - 5	1 - 3	40 - 2	34 - 36	32 - 34	28 - 30	24 - 26	4 - 6	1 - 2

are fundamental information for evaluating the economy and feasibility of the production system.

Three sets of labor input data were obtained from the experiment. Table 4 shows these sets (RPTR I, II, and DAE I) and an average of the data (DAE II). Table 5 shows the labor inputs on 1,000-m^2 plots, which were started on the same fields after the 250-m^2 plot test stopped; those of 2 groups of rice farmers outside IRRI; and those of Japanese farmers.

RPTR I data were obtained from the first 20 plots grown. During this period the season changed gradually from wet to dry. The data were obtained by an enumerator using a stopwatch. The time worked to produce 1 ha of crop on the 250-m^2 plots was calculated as 751.6 hours or 94 days. That indicates that labor input per hectare for the continuous rice production system was about the same as for rice farmers outside IRRI. The latter are generally nonmechanized and the IRRI experiment was highly mechanized.

The period during which the RPTR I data were gathered was comparatively long and the data on time required for each practice should be accurate. But the survey was conducted at an early point in the experiment and practices involved in phasing the continuous rice production system into a normal farm condition were mixed with the routine production practices (Table 2).

Table 4. Alternative measurements of labor inputs (hours) on the 250-m^2 IRRI rice garden, 1976-77.

Operation	RPTR I Sep-Dec 1976 (hours/250 m^2)	RPTR II Apr-May 1977 (hours/250 m^2)	DAE I Nov-Dec 1977 (hours/250 m^2)	DAE II Average (hours/250 m^2)	DAE II Average (hours/ha)
Land preparation	3.62	7.82		5.55	222.0
Seedbed	1.37	1.85		1.62	64.8
Transplanting	3.35	6.66		5.01	200.4
Fertilizing	1.18	0.59		0.55[a]	22.0
Insect control	0.45	0.44		0.45	18.0
Weed control	0.33	4.65		2.50	100.0
Irrigation	0.40	2.20		1.30	52.0
Harvesting	8.09	10.05	9.12	10.03	401.2
Miscellaneous	-	7.43[b]		3.72[c]	148.8
Total	18.79	41.69	9.12	30.73	1,229.2

[a] Excludes time required for applying manure to the first crop. [b] Because these data were obtained from diaries of the workers, this entry appears to be the *balancing* entry between the 8-hour day the workers worked and the time needed to do the job. [c] Includes such practices as rat and bird control, cleaning dikes, measurement of fertilizer and chemicals, disposing of straw after threshing, and others.

Table 5. Labor inputs (hours/ha) on the 1,000-m^2 continuous rice production system, of 2 groups of Laguna farmers, and of Japanese rice farmers.

Operation	IRRI 1000 m^2	Laguna farmers[a] Wet 1975	Laguna farmers[a] Dry 1976	Laguna farmers[b] Wet 1975	Laguna farmers[b] Dry 1976	Japanese farmers[c] 1970	Japanese farmers[c] 1975
Land preparation	112.5	239.0	69.5	105.6	80.0	114.0	92.0
Seedbed	87.3	21.5	26.0			81.0	71.0
Transplanting	245.5	68.0	84.0	101.6	83.2	234.0	125.0
Fertilizing	11.1	4.0	4.0	21.6	24.0	66.0	48.0
Insect control	7.5	8.0	16.0			30.0	27.0
Weed control	82.8	164.0	152.0	236.8	108.8	130.0	84.0
Irrigation	65.0	15.0	26.0	50.4	53.6	108.0	99.0
Harvesting	308.0	128.0	164.0	278.4	195.2	415.0	269.0
Miscellaneous	138.0	81.2	100.2	24.8	24.0	-	-
Total	1,057.7	728.7	641.7	819.2	568.8	1,178.0	815.0

[a] Rice constraints survey, Agricultural Economics Department, IRRI.
[b] Hayami et al 1976. [c] Ministry of Agriculture and Forestry 1976.

A first harrowing and manure application should be considered as preparation practices for the new system. In addition, hand weeding and replanting time were somewhat underestimated compared with that obtained from typical rice farmers outside IRRI. Because all 40 plots were not actually in production during the RPTR I survey, it is likely that the routines were not fully stable. In this data set harvesting hours were obtained from 4-15 January 1977 because rice was not ready for harvest during the survey period.

RPTR II data were based on a daily record kept by each worker. All practices observed during the period were recorded. The total labor input on one 250-m^2 plot was 41.69 hours. This is equivalent to 1,667 hours or 208.5 day/ha, which is twice that of a rice farmer outside IRRI. A disadvantage is that the records were kept by laborers hired to work a normal 8-hour day, which may have resulted in an upward bias.

Weeding and transplanting appear to be disproportionately high in RPTR II compared with RPTR I. Our observation was that the workers tended to repair dikes, weed, and transplant after all other tasks had been completed and when there was time left in the day. Also, it was sometimes hard to separate weeding from other activities, hence weeding and miscellaneous hours were high.

Miscellaneous practices were reported at 7.43 hours/plot, or about 297 hours/ha. At IRRI it took 30 minutes to get machines, equipment, fertilizer, and chemicals to the field. This was included in miscellaneous time in the RPTR II data. Time not spent on specific tasks, which was obtained from diaries, was also included in the miscellaneous category.

DAE I data, obtained by the senior author from 1 to 21 December 1977 were almost similar to RPTR II data. A slight difference was noted in variations in yields and distance of harvested plot from threshing place.

The DAE I survey, however, was conducted during the final stage of the 250-m^2 plot experiment and only harvesting practices on plots 27-36 could be timed. During the balance of the time the workers were establishing the 1,000-m^2 experiment (Table 5).

Average labor input data

DAE II data were computed by averaging the other three data sets, with two considerations:

1. First harrowing and manure application, practices needed only for introducing the continuous rice production system into a conventional rice farm, should be distinguished from regular or routine practices when the economic performance of the continuous rice production system is analyzed.

2. The time required for winnowing, drying, and cleaning varies with weather and yield. In the RPTR II data, considerable time was spent in cleaning rice because no winnowing was done. DAE I data show fewer hours of cleaning because DAE I rice had been winnowed carefully.

Winnowing and cleaning were not reported separately in RPTR II data, so DAE II data were obtained by allocating the total time used for two operations in the appropriate proportions.

As a result of these adjustments and the averaging, total labor input was 30.73 hours/250 m^2 or 1,229.2 hours or 154 days/ha, which is about 1.7 times that of a typical rice farmer outside IRRI and about the same as that used by rice farmers in Japan (Table 5).

Cost of labor

At the rice garden, 3 laborers had actual work hours of about 7.5/day. Each worked about 300 days a year and total work hours was roughly 6,750 or 1,688/ha per crop. This is almost equal to the 1,667.6 hours shown for RPTR II, which means that RPTR II reflects the total labor input. However, if each activity required for the production system were timed accurately, total labor actually required might be reduced to the level of DAE II. Thus, DAE II data may reflect labor *used*, and RPTR II reflects labor *available*.

Imputed labor costs per hectare are summarized in Table 6. According to RPTR II, each laborer worked the equivalent of 277 full (8 hours) days in a year (Table 7). Assuming that the laborers actually worked 300 days in a year, working hours available per day would be 7.4. On the other hand, DAE II data indicated the laborers used only 5.44 hours/day for 300 days. Imputed cost of family labor was estimated at ₱8.41 to ₱8.85 per (8 hours) day per worker.

WATER REQUIREMENTS AND IRRIGATION COST

Year-round irrigation is a necessity for the rice garden system. No farmer can start such a venture without a very reliable water supply. A farmer-controlled pump provides such a reliability. Because water for the IRRI rice garden experiment was supplied from the station system, no valid records were available to indicate water requirements. Thus, to determine how big a pump and what hours of operation would be required to adequately supply water to a rice garden, we used a water-balance model.

Principles of plant-water relationships for rice

The life cycle of the rice plant includes seedling, vegetative, reproductive, and ripening stages. The amount of water required by the plant varies by stages and irrigation is normally regulated accordingly. Table 8 gives the water control and depths used. A large amount of water is required throughout the reproductive stage and any water deficiency during that stage can decrease yield. Water supply was stopped on the 75th day after transplanting.

The rice garden water was distributed to the plots by the workers. An occasional water shortage was observed in March and April because of competition with other experimental fields.

Table 6. Imputed labor costs per hectare based on two data sets for the IRRI continuous rice production system.

Operation	Rate/day[a] (₱)	RPTR II Hours/ha per crop	RPTR II Cost (₱)	DAE II Hours/ha per crop	DAE II Cost (₱)
Land preparation					
Plowing and harrowing	13.00	165.6	269.1	111.6	181.35
Levee maintenance	11.00	147.2	202.4	110.4	151.80
Seeds and seedbedding	5.00	74.0	46.25	64.8	40.50
Transplanting	8.40	266.4	279.72	200.4	210.42
Fertilizing	10.00	23.6	29.50	22.0	27.50
Insect control	10.00	17.6	22.0	18.0	22.50
Weed control	8.00	186.0	186.0	100.0	100.00
Irrigation	5.00	88.0	55.0	52.0	32.50
Harvesting					
Cutting, threshing, and others	11.00	302.0	415.25	332.0	456.50
Hauling and drying	5.00	100.0	62.4	69.2	43.25
Miscellaneous	5.00	297.2	185.75	148.8	93.0
Total		1,667.6	1,753.47	1,229.2	1,359.32

[a] Source of data for imputing labor costs is Kikuchi et al 1977. Costs are computed on the basis of an 8-hour day. Exchange rate was ₱7.35 = US$1.

Table 7. Total labor input and imputed labor cost at the IRRI rice garden.

Item	RPTR II		DAE II	
Labor hours (days)				
Per hectare	1,662.7	(208)	1,224.5	(153)
Per year	6,650.8	(831)	4,898.0	(612)
Per worker	2,216.9	(277)	1,632.7	(204)
Imputed labor cost (₱)				
Per hectare	1,747.35		1,353.45	
Per year	6,989.38		5,413.78	
Per worker	2,329.79		1,804.59	
Per day	8.41		8.85	

[a] Exchange rate was ₱7.35 = US$1.00.

Table 8. Stages of growth of the rice plant and water control.[a]

Stages of growth		Period (days)		Water control	Range of water depth[b] (mm/day)
Seedling	1. Nursery stage	21		Shallow	0 - 30
Vegetative	2. Rootage	10	65	Medium	60 - 150
	3. Early tillering stage				
	4. Peak tillering stage	20			
	5. Maximum tiller stage				
Reproductive	6. Young spikelet development stage	35			
	7. Bootage or blooming stage				
Ripening	8. Milk ripe stage	10		Shallow	30 - 80
	9. Dough stage				
	10. Yellow ripe stage	15		Drain	0
	11. Full ripe stage				

[a] Sources: Matsuo 1961, IRRI 1970. [b] Based on observations at the IRRI Rice Garden.

Water balance model and computation

Actual water requirements in a paddy differ greatly according to the plot selected, soil characteristics, crop-growing weather, and irrigation method. Because of the difficulty in calculating daily or weekly water use in the 40 rice garden plots over the 4 crops, water requirement was not measured directly. Instead, a water-balance model was used to estimate water requirements by plot (Flinn 1971).

The water requirement at the end of any time period (WD_t) is estimated by subtracting the amount of water lost by evapotranspiration (ET_t) and seepage and percolation (SP_t), and adding the amount of effective rainfall (RF_t) and irrigation (IR_t) since the previous period to the water depth at the end of the previous period (WD_{t-1}):

$$WD_t = WD_{t-1} + RF_t + IR_t - ET_t - SP_t$$

When the calculated water depth exceeds the effective bund height, actual water depth is set equal to the bund height.

The model was operated with daily data for each variable. Daily rainfall (RF) and evaporation (EV) data were available at IRRI. Daily values of ET were computed according to the equation

$$ET = a + b\ (EV)$$

Daily values of SP were computed as a trigonometric function.

Model operations were possible once RF, EV, SP, and the initial WD were specified. IR_t varied with WD_t. Daily values of WD_t were estimated for a plot. The model indicated that the plot would be irrigated when WD_t fell below the normal depth of 3 to 6 cm. Actually, however, water was not supplied to the plots immediately when WD_t fell below the height because there was a 3-7 day time lag. This time lag was considered in computing the model. Finally, a maximum effective bund height of 15 cm was assumed.

Water requirement

The daily irrigation water requirements were estimated for each plot throughout the cropping period using the model. The amount of water supplied to each plot varied depending on crop stage and weather. The minimum was about 40 m^3 and the maximum about 190 m^3 (Table 9).

The water supplied to the rice garden throughout the year was about 15,000 m^3. It is generally agreed that assuming a relatively small amount of seepage and percolation, about 8,500 m^3 to 12,000 m^3 of water/ha is required for a rice crop (Tanaka 1971).

Using the water balance model, we estimated the maximum daily amount of supplementary water for 11 April 1977 at 256 m^3. This quantity could be supplied by a 10-cm centrifugal pump of 500-liter-per-minute capacity driven by a 10-hp motor, from a well 30 m deep. Such a pump would have taken about 8.7 hours to irrigate the rice garden on that day.

Lorenzo Jose, a Filipino farmer operating a highly intensive rice garden (*see* following sections), used a 3-hp electric pump coupled to a 5-cm outlet pipe for his 1.5-ha farm. The pump had a 200-500 liter-per-minute-capacity and provided sufficient year-round irrigation for his farm divided into 107 plots of 140 m^2 size. One major canal, about 50 cm wide, and 2 small distribution canals longitudinally traversed his semirectangular farm. This pump, however, may be too small for an IRRI rice garden of 250-m^2 plots.

Table 9. Required amounts of irrigation water calculated using the water balance model (m^3/250 m^2) by plot at the IRRI rice garden.

Plot	1st crop	2d crop	3d crop	4th crop	Total
Seedbed					128.2
1	71.0	131.7	145.4	44.3	392.4
2	63.3	133.1	141.2	40.7	378.3
3	60.9	134.5	133.9	39.0*	368.3
4	62.4	149.6	134.1	39.0*	385.1
5	58.6	150.6	129.4	53.9	392.5
6	62.4	150.9	120.7	54.3	388.3
7	58.1	150.4	114.9	52.5	375.9
8	52.3	153.2	109.5	57.6	372.6
9	50.3	155.4	101.5	59.9	367.1
10	50.1	163.5	96.7	55.4	365.7
11	45.6	165.7	92.3	55.3	358.9
12	55.8	164.8	85.5	52.2	358.3
13	57.2	164.7	79.4	49.9	351.2
14	59.1	169.3	76.3	47.4	352.1
15	62.5	174.1	74.2	50.3	361.1
16	60.9	174.0	71.3	41.3	347.5
17	53.2	178.0	68.7	39.0*	338.9
18	49.3	180.9	64.1	41.1	335.4
19	50.8	179.8	71.7	52.0	354.3
20	52.0	183.9	68.3	54.1	358.3
21	57.0	186.7	62.9	50.4	357.0
22	60.5	188.4	63.1	44.1	356.1
23	63.3	191.2	65.7	43.9	364.1
24	66.9	192.6	61.7	43.7	364.9
25	70.8	193.4	57.9	43.6	365.7
26	72.7	193.9 **	53.6	43.4	363.6
27	81.4	189.4	48.5	46.2	365.5
28	82.2	184.0	47.6	46.0	359.8
29	106.0	181.7	49.7	48.6	386.0
30	105.2	184.2	48.3	50.7	388.4
31	102.4	177.1	51.8	50.3	381.6
32	101.5	173.9	46.9	49.7	372.0
33	103.2	169.1	46.6	53.5	372.4
34	113.0	166.6	47.1	57.6	384.3
35	116.9	166.7	46.2	65.4	395.2
36	118.0	161.7	48.3	64.7	392.7
37	119.4	155.6	47.1	67.8	389.9
38	118.5	154.8	41.8	67.5	382.6
39	123.4	154.4	48.3	66.4	392.5
40	129.5	148.8	46.0	67.8	392.1
Total	3,047.6	6,722.3	3,008.2	2,050.5	14,956.8

*Minimum amount of irrigated water, ** Maximum amount of irrigated water.

Irrigation cost

The cost of pumped water is a combination of operating and overhead costs. Because a pumping set is made up of three units, cost calculation should include costs of motor or engine and pump, well construction and connections, and pump housing.

In a study of pump costs using 10 farmers in Tarlac province, the average capital investment to purchase and set up a 10-cm centrifugal pump unit was almost ₱7,000 (Table 10). The average depth of wells was 13 m and average length of tube was 9.6 m.

Data on hourly fuel and grease consumption of the 10-cm centrifugal pumps were obtained in the 10-farmer study and in an earlier, larger study (Table 11). To supply irrigation water for the rice garden (15,000 m^3) would require about 506 hours of pumping, 845 liters of fuel, and 6.58 liters of grease. The total cost of oil and grease for operating the pump would be about ₱1,393/year.

To calculate average irrigation cost per plot we assumed that water was distributed to each plot and irrigation required about 3.16 pumping hours/plot. According to the labor input data of DAE II, workers put in about 1.3 hours/plot for watering and draining. This was about 40% of the 3.16 pump working hours. Half of the 2.76 labor hours reported for levee making was added to the above labor hours as supplemental irrigation tasks.

The wage rate reported by Hayami et al (1976) was ₱5.00/day or ₱0.63/hour for irrigation. Using this rate, irrigation labor cost was ₱1.69/plot, or ₱67.60/ha. Rice was planted 4 times a year, so the total irrigation labor cost was equivalent to about ₱270/year.

The annual cost of farm machines such as pump sets is determined by service life. In our study, 2 different lengths of service life (10 and 15 years) were considered. In addition, interest at 12% was charged for each year of use (*see* Table 12). As a result, irrigation costs to supply 10 m^3 of water/ha at the IRRI rice garden were calculated to be between ₱1.66 and ₱2.38 (Table 12).

Table 13 shows the comparative costs for rice farmers outside IRRI who paid an irrigation fee to the National Irrigation Administration (NIA).

CAPITAL AND INPUTS UTILIZATION

Purchased inputs were applied at a fairly high rate at the rice garden, as shown in Table 14. The basal application was broadcasted and incorporated, and ammonium sulfate was topdressed on paddy water. Nitrogen was applied 1 day before transplanting (basal fertilizer), 25 days after transplanting (first topdressing), and 6 to 7 days before panicle initiation (second topdressing).

Table 15 indicates how commercial fertilizers were applied to the rice garden by crop season. Total cost of fertilizer was ₱2,552/year, excluding labor cost. About 5 t of chicken manure/ha at a cost equivalent to ₱500

was broadcasted just before the first crop was planted. However, only commercial fertilizer was considered in our analysis.

Rice garden seedlings were dipped in a Furadan solution just before transplanting for protection against whorl maggots and early infestation by stem borers. The later applications of Furadan (0.5 and 1.0 kg/ha) were aimed at controlling green leafhoppers and late infestation by whorl maggots and stem borers.

Table 10. Average capital cost of the 10-cm centrifugal pump in Tarlac province.

Item	Cost (₱)	(%)
Pump and engine set	6,240	90
Well construction	330	5
Housing and canal	360	5
Total	6,930	100

Data from Department of Irrigation and Water Management, IRRI.

Table 11. Fuel and grease consumption per hour of a 10-cm centrifugal pump.

Item	Fuel	Grease
Liters per hour	1.67	0.013
With 1971 price[a]		
Price per liter (₱)	0.18	1.50
Cost per hour (₱)	0.30	0.02
With 1977 price[b]		
Price per liter (₱)	1.6	6.35
Cost per hour (₱)	2.67	0.08

[a] Source: Reyes 1972. [b] Data from Department of Rice Production Training and Research, IRRI.

Table 12. Irrigation cost and efficiency of producing 4 crops of rice on 1 ha of land by the continuous cropping method at IRRI.

Item	Service life (years)			
	10		15	
	Interest rate (%)		Interest rate (%)	
	0	12	0	12
Depreciation cost (₱)	1,050	1,890	817	1,657
Fuel and oil cost (₱)	1,393	1,393	1,393	1,393
Imputed labor cost (₱)	270	270	270	270
Irrigation cost (₱)	2,713	3,553	2,480	3,320
Amounts of irrigated water (m^3/year)	14,975	14,975	14,975	14,975
Yield (kg)	23,648	23,648	23,648	23,648
Efficiency:				
₱/10 m^3/ha	1.81	2.38	1.66	2.22
₱/50 kg/ha[a]	5.74	7.51	5.24	7.02

[a] A cavan is 50 kg net weight (moisture content 14%).

Table 13. Irrigation cost and efficiency for 2-crop rice farmers outside IRRI.

Item	1975 wet season	1976 dry season	Whole year
Yield (kg)[a]	4,240	3,590	7,830
Irrigation fee (₱)	110	165	275
Labor cost (₱) per			
labor input (days)	9.1	8.2	17.03
imputed labor cost[b]	45.5	41.0	86.05
Irrigation cost (₱)	155.5	206.0	361.5
Efficiency:			
(₱/50 kg per ha)	1.83	2.87	2.31

[a] Hayami et al 1976. These are average yields of 3 small rice farmers (cultivating less than 2 ha) in Laguna province. [b] Imputed by ₱5/ha.

Table 14. Inputs (seeds, fertilizer, and chemicals) and costs for the IRRI rice garden.

Item	a.i.[a/] (%)	Amount (kg/ha)	Amount (kg/250 m^2)	Price (kg/bag)	Price (₱/bag)	Price (₱/kg)	Costs (₱/250 m^2)	Costs (₱/ha)	Remarks
Seeds		20	0.5			1.30	0.65	26.00	
Fertilizer									
Basal:									
Urea	46.0	174	4.35	50	83	1.66	7.22	288.80	(80 kg N/ha)
		130	3.25				5.4	216.00	(60 kg N/ha)
Solophos	18.0	333	8.3	50	40	0.80	6.66	266.40	(60 kg P_2O_5/ha)
		167	4.17				3.33	133.20	(30 kg P_2O_5/ha)
Topdressed:[b/]									
First	21.00	143	3.58	50	53	1.06	3.79	151.60	(30 kg N/ha)
		190	4.75				5.04	201.60	(40 kg N/ha)
Second	21.00	143	3.58				3.79	151.60	(30 kg N/ha)
Herbicide									
2,4-D	3.2	25	0.63	25	63	2.52	1.59	63.60	(0.8 kg/ha)
Insecticides									
Furadan 3G	3.0	16.7	0.42	16.7	97	5.81	2.44	97.60	(0.5 kg/ha)
Gamma BHC 6G	6.0	25.0	0.63	25.0	65	2.60	1.64	65.60	(1.5 kg/ha)
Furadan 3G	3.0	16.7	0.42	16.7	97	5.81	2.44	97.60	(0.5 kg/ha)
Furadan 3G	3.0	33.4	0.84	16.7	97	5.81	4.88	195.20	(1.0 kg/ha)
Rat bait									
Tomorin							2.25	10.00	(1.0 kg/ha)
Milled rice								80.00	(40.0 kg/ha)
Total									
1st crop							32.70	1,319.60	
2d crop							30.69	1,227.60	
3d crop							34.02	1,360.80	
4th crop							29.66	1,186.40	

[a/]Active ingredient. [b/]Ammonium sulfate.

Table 15. Fertilizer use, cost, and application costs by crop in the IRRI rice garden, 1977.

Item	Amount per 250-m^2 plot per cropping					Total/ha per year
	1st crop	2d crop	3d crop	4th crop	Total	
Cost of fertilizer (₱)						
Urea, basal[a]	5.40	7.22	7.22	5.40	25.24	1009.60
Solophos, basal[b]	6.66	0	3.33	3.33	13.32	582.80
Ammonium sulfate, 1st TD[c]	5.04	3.79	3.79	5.04	17.66	706.40
Ammonium sulfate, 2d TD[d]	0	3.79	3.79	0	7.58	303.20
Labor used for application (hours)						
RPTR II	0.42	0.44	0.59	0.42	1.87	74.80
DAE II	0.38	0.42	0.55	0.38	1.73	69.20
Imputed labor cost for application (₱)						
RPTR II	0.53	0.55	0.74	0.53	2.35	93.50
DAE II	0.48	0.53	0.69	0.48	2.18	86.50
Total cost (₱)						
RPTR II	17.63	15.35	18.87	14.30	66.15	2645.50
DAE II	17.58	15.33	18.82	14.25	65.98	2638.50

[a] Rates were 60, 80, 80, and 60 kg N/ha for successive crops. [b] Rates were 60, 0, 30, and 30 kg P/ha for successive crops. [c] Rates were 40, 30, 30, and 40 kg N/ha for successive crops. [d] Rates were 0, 30, 30, and 0 kg N/ha for successive crops.

At IRRI rats were controlled by electric fences, poison baits (tomorin), and dusting rat burrows with cyanogas. IRRI also supplied neighboring farms with poison baits. The cost of the electric fence was excluded from the economic analysis because rat fences are not common outside IRRI and are not likely to be needed or used elsewhere.

Farm machinery and equipment

To operate a rice garden system, a farmer would likely want to own a power tiller, a thresher, a paddy cleaner, and possibly a dryer, in addition to an irrigation pump and some other smaller equipment. A list of farm machinery and equipment used in the IRRI rice garden is in Table 16. Irrigation was assumed to be from a 10-cm centrifugal pump.

Land preparation

Land preparation on one 250-m^2 plot was usually performed in 1 day by 1 worker. Total time of labor input for land preparation was between 222 (DAE II) and 313 hours (RPTR II)/ha. This was more than twice as much as in the conventional 2-crop system that used a carabao (Barker and Abarientos 1974). The labor requirement for land preparation was estimated by Barker as 160 hours/ha with 1 carabao and 116 hours/ha with a 6-hp tiller and a carabao.

The idea that small plot size leads to greater labor intensity in the rice garden is reinforced by a comparison of the land preparation time in 250- and 1,000-m^2 rice garden plots. The labor input/ha for plowing and harrowing the 250-m^2 plots was 1.5 times that for 1,000-m^2 plots (87 hours vs 58 hours/ha). Moreover, the labor requirement for levee making on the small plots was 3 times that for the large plots (110 hours vs 36 hours/ha).

Harvesting, threshing, and drying

Harvesting and threshing constitute a major portion of the total time used in rice production -- 24-33% of the total time in the systems examined. An average yield of 148 kg on 250 m^2 would require 2.5 to 4.6 hours/plot if workers used traditional threshing methods, but an average of 1.7 to 2.2 threshing hours if a 5-hp minithresher was used.

Wet rice harvested in sunny weather was usually sun dried. During frequent rain showers grain was usually dried to 14% moisture content with 2 small IRRI batch dryers. Drying cost was estimated at about ₱0.05/kg. Because the dryer had a capacity of 1 t/batch (more than what is produced in the rice garden plots in a week) we arbitrarily assumed that the dryer was used cooperatively with other rice farmers.

An oscillating IRRI prototype grain cleaner with a 2 t/hour grain-cleaning capacity was used for cleaning the grain during the wet season. Cleaning was included in the costs of the rice garden.

Costs of capital items

The costs of the set of capital items used in the rice garden are shown in Table 17. Straight line depreciation, a constant proportion of original cost for repairs, and a return to capital of 12%/year were assumed (Cabanilla and Herdt 1976). Truck cost (a truck was used at IRRI because the buildings were far from the rice garden) was excluded from the economic analysis.

The costs of fuel and oil for the power tiller and small thresher used were derived from consumption and capacity data for the equipment used in the rice garden. Fuel consumption and costs of each farm machine are summarized in Table 18. Hours of machine operation were derived from RPTR II and DAE II. Grease costs were excluded because exact data were not available. The total costs of fuel consumption per year were estimated at ₱2,450 by RPTR II and ₱1,568 by DAE II.

Table 19 shows the hours of machine operation per hectare per year based on the two labor input data sets. Total work hours for the power tiller was 348 to 578 hours/year. Use of thresher was estimated at 139 to 176 hours hours/year; that of the cleaner was 34 to 63 hours/year.

ECONOMIC EVALUATION

The data discussed in the preceding sections provide most of the information needed for an economic analysis of the rice garden. The cost of land, which is the most difficult input to value because it is closely related to productivity, was not discussed, however.

In the long run, land receives the residual earnings after other factors have been paid their market rate. Thus, land used for a rice garden would have a higher value than ordinary double-cropped land. There is no good way, however, to determine what that market rent would be. If the rice garden idea were to spread widely, market rents would rise significantly. But if only one farmer in an area used the system, rents would probably increase only modestly.

Table 16. Farm machinery and equipment used at the IRRI rice garden.

Machinery/equipment	Details	
Power tiller	Purchase date:	28 Sep 1976
	Body type :	Durasteel Industries, Inc. power tiller Briggs and Stratton 5 hp, 4 cycle
	Price :	₱3,500
Thresher	Purchase date:	2 Feb 1977
	Body type :	Mini-axial flow thresher with 5 hp Briggs and Stratton engine. Original design by IRRI, made by JCCE Industries
	Price :	₱3,500
Rice cleaner	Purchase date:	11 Mar 1977
	Body type :	Grain cleaner equipped with 3 hp Briggs and Stratton engine
	Price :	₱2,400
Sprayer	Purchase date:	28 Jan 1976
	Body type :	Knapsack sprayer (18 liters)
	Price :	₱690

Table 17. Annual cost (₱) of farm machinery and equipment (5 years for machinery, 3 for equipment, and 10 for pump).

Item	Purchase price	Repair and maintenance	Depreciation[b]		Repair + depreciation		Interest rate (%)	Imputed return to capital
			Standard life	Extended life	Standard life	Extended life		
Machinery								
Power tiller	3,500	175	700	350	875	525	12	420
Thresher	3,500	175	700	350	875	525	12	420
Rice cleaner	2,400	120	480	240	600	360	12	288
Pump set (4")[c]	7,000	350	700	467	1,050	817	12	840
Equipment								
Sprayer	690		230		230			
Shovels (3)	105		35		35			
Buckets (3)	45				45			
Leveler	15				15			
Wooden marker	30				30			
Others[d]	100				100			
Total	17,385	820			3,855	2,227	-	1,968

[a] Estimated at 5% of the value of machinery and car. [b] Straight-line depreciation. Extended life indicates alternative annual cost based on 10 years for machinery, 5 for equipment, and 15 for pump set. [c] *See* section on irrigation. [d] Bamboo basket for winnowing, seat mat for winnowing, jute sacks for packing, knife for harvesting, knife for weeding at dike, etc.

Table 18. Fuel consumption by farm machinery used at the 250-m^2 IRRI rice garden.

Item	Source of data[a]	Practice (hours/250 m^2)	Gasoline and grease used[b] (liters/hour per 250 m^2)	Gasoline and grease price (₱/liter per 250 m^2)	Cost of fuel and oil consumption (₱/250 m^2)	(₱/ha)	(₱/ha per year)
Power tiller							
Plowing	A	1.18	1.89	1.6	3.57	142.8	571.2
	B	0.84	1.89	1.6	2.54	101.6	406.4
Harrowing	A	2.43	1.89	1.6	7.35	294.0	1,176.0
	B	1.34	1.89	1.6	4.05	162.0	648.0
Thresher[c]							
Threshing	A	1.10	1.89	1.6	3.33	133.2	532.8
	B	0.87	1.89	1.6	2.63	105.2	420.8
Rice cleaner[d]							
Cleaning	A	0.79	1.68	1.6	2.12	84.8	169.6
	B	0.43	1.68	1.6	1.16	46.4	92.8
Irrigation pump							
Watering		3.16	1.67	1.6	8.45	338.0	1,351.5
- Grease -			0.013	6.35	0.26	10.3	41.3

[a] A = RPTR II, B = DAE II. [b] Based on *Fuel Consumption Figures* by Briggs and Straton, Inc. In this figure, fuel consumption (liters/hour) by hp under the conditions of full and normal load is indicated. [c] Threshing is a cooperative practice by two workers. Hence, working hours of the thresher is half the total labor hours. [d] At the rice garden, in good weather the harvested palay was winnowed by two workers. In the wet season, a rice cleaner was used.

Table 19. Machine operation hours[a/] per hectare per year in 250-m^2 IRRI rice garden.

Machinery	RPTR II (hours)		DAE II (hours)	
Power tiller				
Plowing	188.8		134.4	
Harrowing	388.8		214.4	
Total	577.6	(72)	348.8	(44)
Thresher				
Threshing	176.0	(22)	139.2	(17)
Rice cleaner				
Cleaning	63.2	(8)	34.4	(4)
Irrigation pump				
Watering	506.0	(63)	506.0	(63)
Dryer[b/]				
Drying	400.0	(50)	400.0	(50)

[a/] Figures in parentheses are days, obtained by dividing hours by 8.
[b/] Workers harvested 40 plots 4 times in a year. Assumed one-half is devoted to drying of palay which is equal to 80 days at 5 hours/day.

Imputed land rent

One method of imputing the value of land is to evaluate it at the leaseholder's rate. By Philippine law (Republic Act 3844), the lease rentals for rice land should not be more than the equivalent of 25% of the average normal harvest during the 3 years before the establishment of the leasehold relationship. At the rice garden 23,648 kg rice was produced in a year. Assuming that this is the average normal harvest, the maximum lease rentals for the rice garden would be ₱5,912 (assuming a price of ₱1.00/kg).

Another method is to value the rice garden land at rates similar to those of double-cropped land on farms in Laguna province. The common rental in the province is 660 kg (15 cavans)/ha for dry-season cropping and 528 kg (12 cavans)/ha for the wet season. Using these rates and assuming the rice garden produces 2 wet-season and 2 dry-season crops per year gives a rental of ₱2,376, which is about 10% of the output of the rice garden. This alternative is a much more likely land rental rate. But even with this procedure the rent would still differ depending on the productivity of a particular region. For example, rents of 440 kg/ha in the wet season and 528/ha in the dry season are common in Central Luzon.

Costs and returns analysis

Tables 20 and 21 summarize the costs and returns of the continuous rice production system for the two sets of labor data, two levels of returns to land, and two machinery durability assumptions. Table 20 shows the details of costs for four selected cases. Table 21 shows various measures of income for all eight cases. Both tables use the following income definitions:

- Net farm income is the total income earned from the capital and labor used in the farming operation. It is the income that would be earned if a family owned the capital and supplied all the labor but rented the land at the two rates shown. Net farm income differs for the two sets of labor data with identical land rent and machinery life because the labor data were used to determine costs of fuel and oil as well as imputed labor costs.

- Labor return is net farm income minus return to capital, calculated at 12%/year. The return per day was computed on the basis of 8-hour days. Return to capital was computed as net farm income minus the opportunity cost of labor. Opportunity cost is calculated as shown in Table 6.

Table 21 illustrates the sensitivity of the results to the amount of labor used and the assumptions made about fixed costs. Because of the extremely large difference between the lower and higher land rent assumptions, the system looks attractive at the likely land rental rate of ₱2,376 and unattractive at the extremely high rental rate. As indicated above, it is highly unlikely that the high rate would occur.

At the likely land rental rate, there is a range in labor returns from ₱7.14/worker per day to ₱13.05/worker per day, with the highest return occurring with the long machinery life and the low labor input. Returns to capital similarly range from 5.2 to 26.1%/year. We believe the first line of Table 21 represents the best reflection of income from the system. This most likely case uses the DAE II labor data and the short machinery life with the lower land rent.

Comparative analysis of economic performance

The case that had high returns and short machinery life (with labor of DAE II) was used to compare the economic performance of the IRRI rice garden with other intensive rice farming systems. Results are summarized in Table 22 with four other situations: Lorenzo P. Jose's daily planting and harvesting system, an intensive share tenant farmer in Laguna province, an average of 7 rice farmers in the same province, and the costs and returns of Japanese rice farmers in 1975.

L. P. Jose had a threefold objective in adopting the daily planting and harvesting rice production system on his farm in Pampanga province: to maximize use of farm family labor, increase rice production through intensified land use, and derive a higher farm income per given unit of land. He divided 1.5 ha into 107 plots and had 6 workers do daily practices year-round. Three were hired laborers. Each worker engaged in farm

Table 20. Costs and returns (₱/year) of the rice garden system for alternative labor input data, land rent, and machinery life.

Item	Standard machinery life Likely land rent		Extended machinery life High land rent	
	RPTR II[a]	DAE II[b]	RPTR II[a]	DAE II[b]
Gross returns (at ₱1/kg)	23,648	23,648	23,648	23,648
Variable costs				
Seed	104	104	104	104
Fertilizer	2,552	2,552	2,552	2,552
Herbicide	254	254	254	254
Insecticide	2,184	2,184	2,184	2,184
Tiller fuel, oil	1,747	1,054	1,747	1,054
Thresher fuel, oil	533	421	533	421
Cleaner fuel, oil	170	93	170	93
Pump fuel, oil	1,393	1,393	1,393	1,393
Drying costs	578	578	578	578
Gross margin	14,133	15,015	14,133	15,015
Fixed costs				
Imputed land rent	2,375	2,376	5,912	5,912
Power tiller	875	875	525	525
Thresher	875	875	525	525
Cleaner	600	600	360	360
Pump, engine	1,050	1,050	817	817
Equipment	455	455	455	455
Net farm income	7,902	8,784	5,539	6,421
Imputed value of labor	6,989	5,414	6,989	5,414
Return to capital	913	3,370	-1,450	1,007
Imputed interest on capital	1,968	1,968	1,968	1,968
Return to labor, management	5,934	6,816	3,571	4,453
Labor return/worker per year	1,978	2,272	1,190	1,484
Labor return/worker per day	7.14	11.13	4.30	7.28

[a] This data set showed 277 8-hour days for 3 workers or 831 days. Returns/worker per day computed for 8-hour days. [b] This data set showed 204 8-hour days for 3 workers or 612 days.

Table 21. Net income, returns to labor and capital at two labor input levels, two land rental rates, and two durability assumptions on capital equipment, 250-m^2 IRRI rice garden.

Labor input (8-hour days)	Imputed land cost (₱/ha per year)	Machinery life[a]	Net farm income	Labor return[b] ₱/worker per year	Labor return[b] ₱/day	Return to mgt. capital[c] ₱/yr	Return to mgt. capital[c] %[d]
612	2376	5-10	8784	2272	11.13	3370	19.3
612	2376	10-15	9957	2663	13.05	4543	26.1
612	5912	5-10	5248	1093	5.36	-166	-
612	5912	10-15	6421	1484	7.28	1007	5.7
831	2376	5-10	7902	1978	7.14	913	5.2
831	2376	10-15	9075	2369	8.55	2086	11.9
831	5912	5-10	4366	799	2.88	-2623	-
831	5912	10-15	5539	1190	4.30	-1450	-

[a]The first figure shows the life of the tiller, thresher, and cleaner; the second shows the life of the pump set. [b]Assuming a return to capital of 12%/year. [c]Assuming a return to labor equal to its opportunity cost (Table 6). [d]Return per year as a % of value of capital.

practices for a total of 3,650 physical stress hours or about 10 hours/day. Small-scale highly specialized equipment such as hand winnower, complex cropper, and rotary mulcher were used instead of large machinery. Irrigation and water delivery were maintained at a level sufficient to continuously flood the rice farm.

Since early 1966, Jose has shown that 1.5 ha can produce 43.2 t of rice or 28.8 t/ha, which is equivalent to the combined production of 18 ha of land cultivated by an average Filipino farmer.

Table 23 shows the results of a cost-returns analysis estimated by Ranit and Drilon (1977) for Jose. To compare their evaluation with the IRRI rice garden analysis, the results were recalculated because imputed land rent and capital costs were excluded in their analysis. According to the alternative result, the total value-added ratio was almost the same as that for the IRRI rice garden. This shows that the ratio of current inputs to total return is high in a continuous rice production system. The ratio of net farm income to total production was relatively lower than for the IRRI rice garden (Table 22) because the number of hired workers engaged in farm practices in the two cases differed. Factor share analysis shows that the share of labor was high and those of land and capital were low for Jose's farm. The intensive Laguna rice farmer chosen for comparison was a share tenant. The total value added on his farm was 86% of the total output value. Labor's share of value added was 31% and the residual to family factors was 21%. The ratio of family income to total value added was small. The major reason for the low family income was the large rental under the share arrangement, which amounted to 48% of value added.

Table 22. Costs and returns of alternative intensive rice production systems.

Item	IRRI 250-m^2 CRPS	Lorenzo Jose CRPS[a]	Intensive Laguna farmer[b]	7 Laguna farmers[b]	Japanese rice farmers[c]
Production (kg)	23,648	28,800	7,634	6,455	5,250
Gross returns (₱/ha per year)	23,648	28,800	7,634	6,455	33,814[d]
Hired labor	0	8,161	1,572	1,207	512
Other variable cost	8,633	9,442	1,093	1,045	4,241
Gross margin (₱/ha per year)	15,015	11,197	4,969	4,203	29,061
Land cost	2,376	2,200	3,181	1,659	4,981
Capital costs	3,855	1,333	198	218	4,055
Net farm income (₱/ha per year)	8,784	7,664	1,590	2,326	20,025
Imputed value of family labor	5,414	8,161[e]	441[e]	807[e]	8,509
Return to capital, mgt. (₱/ha per year)	3,370	-497	1,149	1,519	11,516
12% imputed interest on capital	1,968	1,333	[f]	585	4,055
Return to family labor (₱/ha per year)	6,816	6,331	1,590	1,741	15,970
Family labor return/workday	11.13	8.67	26.94	20.48	166.35
Shares (%)					
Net farm income/gross returns	37	27	21	36	59
Value added (VA)/ gross returns	63	67	86	84	87
Labor's share in VA	36	84	31	35	31
Land's share in VA	16	11	48	31	17
Residual share in VA	48	5	21	34	52

[a] See Table 23. [b] See Table 24. [c] Source: Ministry of Agriculture and Forestry 1976. [d] ₱1 = Yen 40. [e] Imputed at the prevailing wage, by task. [f] Rental of capital items included in capital costs.

Table 23. Costs and returns of Lorenzo P. Jose's rice farm.

Item	Ranit and Drilon's data 1.5 ha	Ranit and Drilon's data 1 ha	Alternative (1 ha)
Production (kg/year)	43,200	28,800	28,800
Gross returns (₱)	43,200	28,800	28,800
Variable costs (₱)			
Seed	200	133	133
Fertilizer	2,332	1,555	1,555
Chemicals	3,639	2,426	2,426
Electricity	4,992	3,328	3,328
Fuel, oil	3,000	2,000	2,000
Transportation	1,800	1,200	0[a]
Hired labor	12,242	8,161	8,161[b]
Gross margin (₱)			11,197
Land cost, imputed	0	0	2,200[c]
Loan interest	720	480	480
Other capital cost, imputed			853[d]
Net farm income (₱)	14,275	9,517	7,664
Imputed value of family labor	12,242	8,161	8,161[b]
Return to capital, mgt. (₱)			-497
Imputed interest on capital (12%)			1,333
Return to family labor (₱)			6,331
Days of family labor used	1,095	730	730
Family labor return (₱/workday)			8.67
Shares (%)			
Net farm income as % of gross return			27
Value added as % of gross return			67
Share of labor in value added			84
Share of land in value added			11
Residual share in value added			5

[a] Cost was excluded to make it comparable with IRRI rice garden calculations. [b] Three workers each worked 10-13 hours/day. They received wages plus food and lodging valued at ₱11.18/worker per day. The same rate was imputed to family labor contribution from 3 family workers. [c] 500 kg/ha for 2 wet-season crops, 600 kg/ha for 2 dry-season crops. [d] Annual capital cost of the pump set (depreciation and repairs) was estimated at ₱1,466 based on Reyes 1972. In addition, the farm was equipped with hand winnower, complex cropper, rotary mulcher, infrared lamp dryer, etc. This estimate was derived by assuming total capital cost of ₱2,000 for the 1.5 ha, then deducting the interest paid on the loan.

The average data for 7 rice farmers in Laguna were derived from records of rice farm operations kept for the 1975-76 crop years (Hayami 1976). The farmers produced 6.4 t/ha per year, hired a substantial amount of labor, used about 12% of the current inputs of the IRRI rice garden, and had

substantially lower capital costs. Total family labor used in addition to hired labor was 85 days/ha per year, compared to 612 days for the rice garden (Table 24). Total return to family labor was ₱1,741 and daily return was ₱20.48. In the rice garden return per man per year was ₱2,272.

The rice garden workers put in nearly five times as much labor time in a year as the family workers in the Laguna farms. Effective daily wage rate of family workers was ₱11 in the rice garden and ₱20 for the Laguna farmers.

Factor shares were relatively equal among labor, land, and capital -- each got about one-third of output in this sample. As shown in Table 24, however, the share of land was low and the share of capital (capital rental paid plus residual profit) was high for large farmers, and vice versa for small farmers in the study.

It is difficult to compare the economic performance of rice farming across countries because economic structure and economic climate differ between countries. Available data suggest that the factor shares in the IRRI rice garden are similar to those of Japanese rice farmers in 1975.

Cash flow and imputed labor cost

The costs and returns analysis showed that the ratio of current intermediate input cost to total return in the continuous rice production system was fairly high compared with other Philippine production systems. The ratio was estimated at 35 to 38%. For the Laguna farmer, it was 10 to 18%.

Figure 5 shows the flow of current inputs cost and imputed labor costs for 4-week periods at the IRRI rice garden. The variable cost curves declined gradually after October 1977 because the experiment with 250-m^2 plots was stopped after each plot was harvested 4 times. If the system had been continued, the line would have been straight. Figure 5 indicates that about 6 months was required after start-up to recover ₱2,500 to ₱3,000 of the current input costs including fuel and oil charge. The expenditure on current input costs over this period was equivalent to about three times the amount Laguna farmers used for double cropping in the 1975-76 crop season. In addition, a farmer would need another ₱4,000 if he were to buy the irrigation pump, power tiller, and thresher.

Lorenzo Jose developed several small farm machines suitable for his daily planting and harvesting system. But as shown previously, he spent about ₱4,000/year or 14% of the total return for seed, fertilizer, and chemicals, and ₱5,300/year or 19% of the total return for electricity, fuel, and oil.

Both the IRRI 250-m^2 system and Jose's system suggest that initial financing is a critical factor in determining whether a farmer can switch from an ordinary system to this kind of production system.

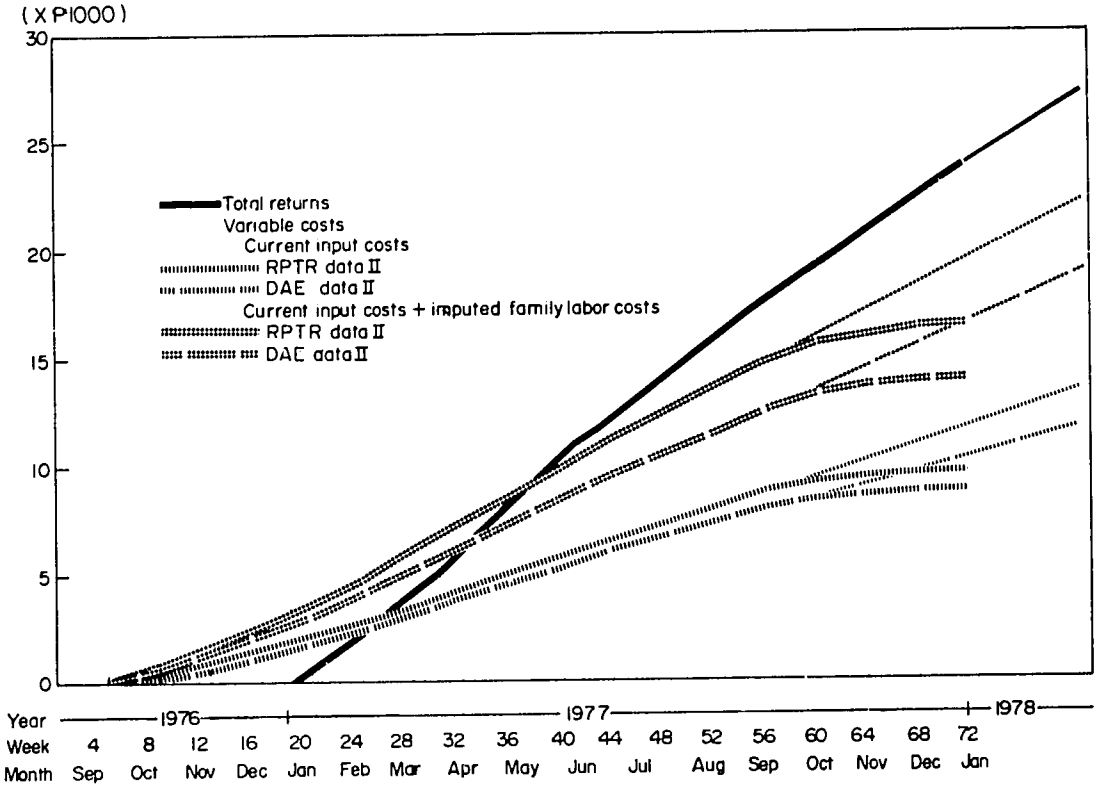
Figure 6 illustrates the break-even point based on the final results of the costs and returns analysis for a 12% return to capital. Break-even points were about 15 t/ha yield for DAE II and about 19.5 t/ha yield for RPTR II when the land rent was excluded. The farm may, therefore, seek to change

the shape of its marginal cost curve or lower its break-even point by increasing productivity to earn higher profit. A change in the productive process, a reconsideration of the most appropriate plot size for optimal machine utilization, a reorganization of layout, or scheduling of farm work may reduce the costs of producing the same product.

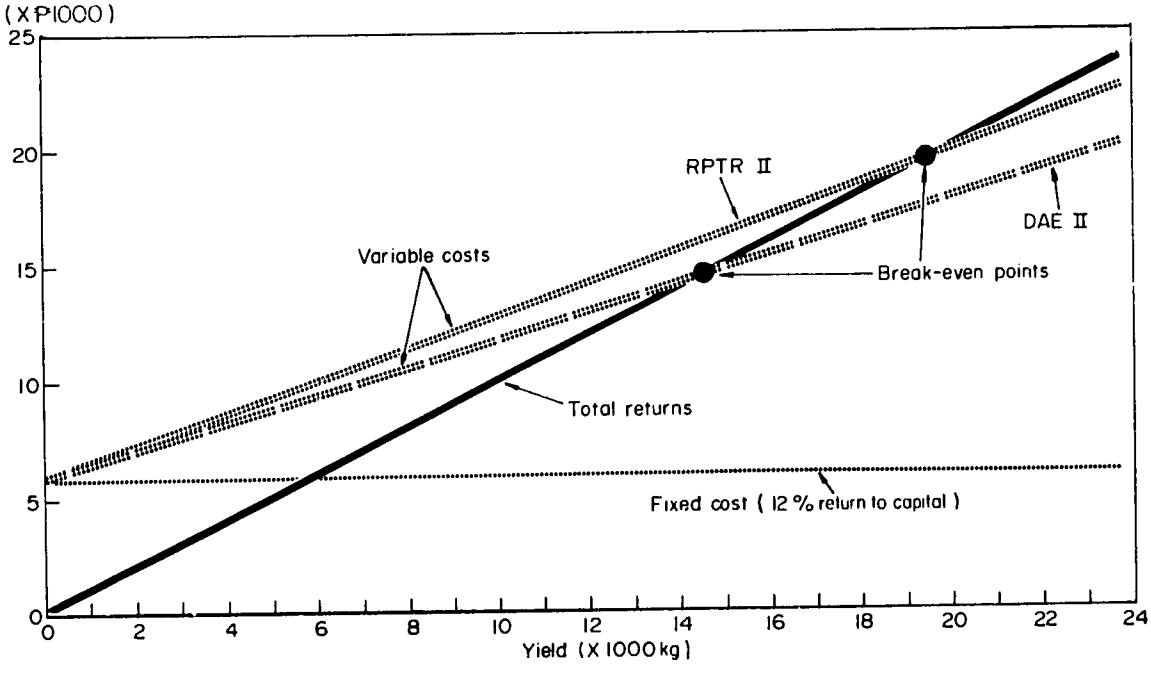
Table 24. Costs and returns of selected rice farmers in Laguna province, 1975-76.

Item	1 farmer RCP data[a]	7 rice farmers, APE data[b]		
		4 larger farmers	3 smaller farmers	All farmers
Production (kg/ha per year)	7,634	6,046	7,766	6,455
Gross returns (₱/ha per year)	7,634	6,046	7,766	6,455
Hired labor	1,572	1,136	1,438	1,207
Other variable costs	1,093	1,076	950	1,045
Gross margin (₱)	4,969	3,834	5,378	4,203
Land rent	3,181	1,145	3,311	1,659
Capital cost	198	231	177	218
Net farm income (₱)	1,590	2,458	1,890	2,326
Imputed value of family labor[c]	435	843	692	807
Return to capital, mgt. (₱)	1,155	1,615	1,198	1,519
Imputed interest on capital (12%)		1,011	2	585
Return to family labor (₱)	1,590[d]	1,447	1,888	1,741
Days of family labor used	59	81	90	85
Family labor return (₱/workday)	26.95	17.86	20.98	20.48
Shares (%)				
Net farm income/gross returns	21	41	24	43
Value added (VA)/gross returns	86	82	88	84
Labor's share in VA	31	40	31	37
Land's share in VA	49	23	49	31
Residual share in VA	20	37	20	32

[a] The most intensive Laguna farmer among a set of 26 interviewed in the rice constraints project of the IRRI Agricultural Economics Department.
[b] Source: Hayami et al 1976. [c] Imputed at task specific wage rates.
[d] Identical to net farm income because all the farmers rented the services of capital equipment.



5. Cash flow and imputed labor costs at the IRRI rice garden.



6. Break-even point of the IRRI rice garden trial.

At IRRI a 1,000-m^2 trial in which rice is planted and harvested once a week was tested by 4 workers. Planting began in October 1977, and the first harvest in January 1978. One complete year of harvesting activity will end in January 1979. The system will then be compared with the 250-m^2 plot system.

SUMMARY AND CONCLUSION

The rice garden system provides dramatic opportunities to increase labor earnings, family income, and productivity of small rice farms. With adequate management, and with levels of inputs per crop comparable with those of many farmers, it can double output and productively triple or quadruple labor input. The continuous system requires good managerial skill and devotion to work, but it is within the capability of many small farmers who have good control over, and access to, water throughout the year. Our analysis was conducted to understand how and at what cost the system could increase employment opportunities and rice production.

The advantages of the continuous rice production system follow:

- Under this system, the farmer can disperse seasonal labor peaks into constant year-round labor use. He generates employment opportunity throughout the year. Labor input data of DAE II show that 3 workers actually worked about 4,898 hours/year or 612 days/year. Assuming that they each worked 300 days, allowing 1-day-a-week holiday, average hours of actual work per day would be about 5.4 hours. Compared with the labor input of about 1,360 hours or 170 days/year on double-crop rice farms in Laguna, this system provides about 3.6 times as much employment opportunity.

  Under the assumption that land rent in the IRRI rice garden would be similar to that of Laguna farmers, farm income (or return net of current inputs, land, and capital costs) was estimated at ₱7,900-₱8,800/ha, which is 3-3.8 times that of the average of Laguna farmers.

- The farmer can minimize damage caused by typhoon or pest epidemics because the stage of growth is different in each plot. There is no evidence that the system encourages pest build-up differently from conventional intensive systems.

- The farmer gets a continuous flow of cash from weekly palay sales, enabling him to finance the farm operation himself and eliminating the need for nonfarm income. Another dimension of variation, however, is introduced because the price of rice has a seasonal variation.

The production system also has disadvantages or problems that need further investigation:

- The rice garden method may create a greater stress on the plants causing a quicker breakdown of pest resistance. Continued use of insecticides may bring about pest resurgences or pest resistance to insecticides faster than in other less intensive systems. This has not occurred, however, in the IRRI system where level of insecticide use is moderate,

or in any similar experiment at IRRI in which no pesticide was used.

- It is impossible for farmers without irrigation facilities that provide year-round water supply to use the system. Assuming that a 10-cm centrifugal pump had been installed at the IRRI rice garden, we estimated irrigation costs at about ₱1.66 to ₱2.38/10 m^3 water. This implies expenses of ₱5.25 to ₱7.51 to produce 50 kg rice. Laguna double-crop farmers with gravity irrigation paid an average of ₱2.31.

- It seems that the small plot size led to greater labor intensity at the rice garden. On a hectare basis, labor input for plowing and harrowing of 250-m^2 plots was 1.5 times that for a 1,000-m^2 plot. Labor requirement for levee making on the small plot was 3 times that for the large plots.

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